AN ILLUSTRATED GUIDE TO PRIMATE NECROPSY

by

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THESIS

Presented to the Faculty
of the Southwestern Graduate School of Biomedical Science
The University of Texas Health Science Center at Dallas
In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF ARTS
DEDICATION

To Gerry Wilson, husband, father, friend
Our dreams work true
Tightly hand in hand.
To Our Four, children, supporters, friends
Our dreams are shared
You believed in me.
To Lewis Sadler, Fred Clubb, the Primates
You guided and taught the dream
The thesis is for All of you.
ACKNOWLEDGEMENTS and CREDITS

This thesis represents the combined efforts of the Thesis Committee. Chairman, Lewis L. Sadler, M.S., Fred J. Clubb, Jr., D.V.M., Ph.D., Bonnie Raphael, D.V.M., Michael P. Schemb, M.S., Gaylord S. Throckmorton, Ph.D. I would like to thank them for their dedication, patience, and high standards. I would like to acknowledge Bonnie Mandro for her tireless typing, Mary Coffman and George Lawton, Dr. Clubb's lab assistants, for their teaching, help, and smiles. Special acknowledgement to Jeff Lane for his beautiful and accurate photography, and to Stephen Bland for his video taping. I would like to remember the faculty who prepared me for graduate school, Vince Perez, Ralph Borge, and Dr. Jim Benninger, Dr. Jim Goebel, Dr. Phil Goebel, Dr. Ervin Jindrich, Dr. Herbert Srebnik, Dr. Anne Williams, Pauline Velez and my fellow students. Most of all I would like to thank my husband, Gerry and our family of four, Karen, Becky, Anna, and David, who really made my Medical Illustration education a reality and believed in me.

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Publication No._____________

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The University of Texas Health Science Center at Dallas, 1985
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Department of Biomedical Communications.

The purpose of this thesis is to develop a basic, standardized illustrated guide for primate necropy. The subject of primate necropy is chosen because primates are used in biomedical research as an important resource in the study of surgical procedures, cancer and disease research, chemical studies, and other scientific and medical studies. Primates are a valuable animal resource. Some are so rare as to be considered an endangered species. Monkeys, specifically the primate family of Old World monkeys, Cercopithecidae, will be studied. One example from each of the two subfamilies, Cercopithecinae and Colobinae, are illustrated. Both Papio anubis and Colobus guereza have been observed, photographed, and drawn during six actual necropses. Sixty-eight illustrations are developed in pen and ink, and form the body of the thesis, along with explanatory text. The exact techniques used in this guide will enable the prossector to follow the general protocols on all nonhuman primates.
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I. PRIMATE NECROPSY

An Introduction

Because of their physical and emotional similarities to man, primates are invaluable substitutes in scientific research. Without them, many medical discoveries would never have been made... (Rimerl and DeVore, 1965, p. 159) (1)

The subject of primate necropsy is chosen for this thesis and guide because primates are a valuable animal resource. Some are so rare as to be considered as endangered species. Those that are not as yet endangered may become endangered if humans do not consider their value and act accordingly.

Primate, the name chosen by Linnaeus meaning first, is the animal order that contains prosimians, monkeys, apes, and humans. Non-human primates are an indispensable resource in biomedical research. Thus high standards of professionalism should govern their usage. The development of a basic necropsy guide supports controlled preservation of these animals. There appears to be a reasonable body of material and reports on the social nature of non-human primates, a smaller body on primate history and anatomy. History describes their use in ancient Egypt to do domestic chores such as sweeping and waiting on tables. Medical history notes that Pythagoras did practice non-human primate dissection. There are quite a few studies of the non-human primate such as the estrus cycle of their reproductive system.

Other research includes studies of the simian lines of their hands and genetic problems.

One need not be a follower of a spiritualistic cult to appreciate the saying: "A necropsy is a message of wisdom from the dead to the living." Postmortem examination is a valuable diagnostic technique. We realize this the more as we use it intelligently. For the necropsy may be, in fact, the sole answer to the question: "Why did the animal die?" (Benbrook, 1954, Chap.1, p.1) (2)

These comments from an editorial monograph by E.A. Benbrook published in the Journal of American Veterinary Medical Association summarizes the value of the necropsy in veterinary medicine. Benbrook (1954) (3) states that he believes in the importance of the necropsy for diagnosing animal diseases. He believes that with the rapid expansion of knowledge about animal diseases, the necropsy should almost be made mandatory for the standardization of diagnostic procedures.

William H. Feldman in his introduction to Veterinary Necropsy Procedures, states the "Necropsy is indispensable to an intelligent and scientific understanding of disease process". (1954, p. iii) (4) He feels that the postmortem should be carried out with skill and for a definite purpose. Curiosity may be an initial part of the purpose, but only part. The larger purpose is "to provide material for subsequent studies that will yield precise fact". These facts, objectively interpreted, properly collected, and systematically recorded can extend knowledge.

The knowledge of the necropsy is of the utmost importance in discovering the complexities of pathogenesis, the rationale for prevention and treatment of disease, and the basic welfare of both animal and humans. The necropsy should be viewed as a beginning not as an end.
Statement of Objectives

The purpose of this thesis is to develop a basic, standardized illustrated guide for non-human primate necropsy. Monkeys, specifically the primate family of Old World monkeys, *Cercopithecidae*, will be studied with one example from each of the two subfamilies illustrated. Both the baboon, *Papio anubis*, and the Colobus monkey, *Colobus guereza*, have been observed, photographed, and roughly drawn during their actual necropsies. Six necropsies have been documented.

By narrowing the specimens to the specific and available species of the baboon and the Colobus monkey, an exact and manageable area of study was possible. Both of the non-human primates covered represent the fields of research and zoo preservation. The *Macaca* sp. are often used in medical research as well as preserved in the zoo. Though the macaque will not be observed or illustrated in this thesis, the necropsy technique illustrated in this guide will enable the user to follow the general procedures for comparative standards on other primates.

To aid the prospective, other comparative anatomical distinctions will be presented. For example, *Colobus* is an arboreal monkey, long-limbed, slender, and lithe. The baboon, in contrast, is essentially terrestrial, with a large, powerful, sturdy body. Baboons and Colobus monkeys have long canine teeth. Throughout this thesis some general references to New World monkeys and humans will also be included.

Many non-human primates, such as baboons, are being used for experimental surgery by staff, students, and researchers without adequate knowledge about their specific anatomy or the benefits of good necropsy procedures from which to learn. Thorough and consistent procedural methods are needed to gather reliable data that could benefit humans and animal alike. There are a few good comparative anatomy books available such as Swindler and Wood, *An Atlas of Primate Gross Anatomy, Baboon, Chimpanzee, and Man*, 1973, that could add greatly to the care of the animals, the success of the surgeries, and the knowledge obtained from the research. Good anatomical and necropsy references are listed in the bibliography.

Definition of Key Terms

There are two key terms or words in this guide. The words to be defined are primate and necropsy.

Primate may be classified as a particular species in the following way: (Alexander and Alexander, 1979, p.269) (5)

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<tr>
<th>Common name</th>
<th>Baboon...Monkey</th>
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<tr>
<td>Scientific name</td>
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<td>Chordata</td>
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<td>Vertebrata</td>
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<tr>
<td>Class</td>
<td>Mammalia</td>
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<tr>
<td>Order</td>
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<td>Genus</td>
<td><em>Papio, Colobus</em></td>
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<tr>
<td>Specific name</td>
<td><em>Papio anubis, Colobus guereza</em></td>
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In *The Monkey Kingdom An Introduction to the Primates* by Ivan T. Sanderson, (1963) (6), the problem of how to define the primates is
explore. There is no single external feature that primates all have in common. Primates vary in size and structure as well (6), however, it can be shown they are genetically related. There are approximately seven hundred and fifty kinds of living primates, composed of two hundred and forty four species, grouped into eighty genera which fall into twelve families. This list includes: 1) Tupaioidea, 2) Lorisoida, 3) Lemuroida, 4) Tarsioida, 5) Hapalidae, 6) Pithecoida, 7) Cebidae 8) Copithecoida, 9) Cynomiteidae, 10) Colobidae, 11) Simiidea, 12) Hominidea. The scientific classification used here is that of Sanderson, 1963. This thesis will illustrate the subfamilies Ceropithecinae and Colobinae, using the species Papio anubis and Colobus guereza kibungensis, respectively.

In Saunders Dictionary and Encyclopedia of Laboratory Medicine and Technology, 1984, "necropsy" is defined on page 1044 as follows:

necropsy (nek'rops-e) n. Gr. 'necrosis view the gross and microscopic examination of the body and viscera after death and the interpretation of these findings. Generally performed by a pathologist, this examination is a mechanism for instructing physicians on anatomy, disease processes, and effects of therapy; a means for correcting misdiagnosis; a source of material for investigation and epidemiologic studies; and an instrument for medical-legal examination. Also called autopsy and postmortem examination.

According to Durand's Illustrated Medical Dictionary, Twenty-fifth Edition, 1974, W.B. Saunders, page 1021:

necropsy (nek'rops-e) Gr. 'necrosis view examination of a body after death; autopsy.

By scientific convention, necropsy is the term used when applied to animal postmorten. In Atlas of Small Animal Necropsy in the introduction, the following paragraph states:

Common usage of the term "necropsy" in veterinary medicine refers to the gross examination of the cadaver. A complete necropsy refers, however, to all postmortem examinations including microscopic, microscopic, toxicologic, and microbiological examinations. The term "autopsy" used synonymously with necropsy in human medicine has been avoided in veterinary medicine because of the prefix "auto" meaning self, implying self-examination. (Alden, 1968, p.1)
The amount of written material on non-human primate necropsy is limited. The articles and books found through Melville and Catline library and computer searches refer to primate anatomy, disease, care, and dissection. Some of these, especially the anatomy, are illustrated. No illustrated guide to primate necropsy appears to be available in contrast to the many illustrated guides to human autopsy. Illustrated material on proper primate necropsy procedure could add to the care of the primate, the success of the research, and basic knowledge. The little information that has been found is incorporated into this thesis.

There are twelve or thirteen living families composed of five main groups, Prosimian, New World monkeys, Old World monkeys, Apes and Humans. This thesis and guide will illustrate necropsy procedures on Old World monkeys, with some comparative reference to the other three groups.

All living primates share the ability to climb by grasping, except the tree shrew (Eimerl and DeVore, 1965) (8). The evolution of the primate grasp is related to the development of the prononsile thumb and the prononsile tail in New World species. The tree shrew has been alternately classified as a primate or as an insectivore. Prosimians are a transitional stage between insectivores and other primates. For millions of years prosimians dominated the arboreal environment but eventually were replaced by the monkeys.

Natural selection in an arboreal environment favored better grasp and also better vision with loss of a need for the sense of smell. This shift from smell to vision is reflected in the position of the eyes in the other three groups. As an adaptation to the arboreal life, the primate eyes moved closer together toward a frontal plane on the face. The field of sight now overlapped and created a depth of vision. As locomotion and grasp developed, primates acquired highly movable digits, most usually equipped with inside pads.

Scientists believe that the monkey evolved directly from "common prosimian ancestors some twenty-five to thirty-five million years ago" (Eimerl and DeVore, 1965, p. 13) (9). In monkeys and apes the emphasis of one sense over another and the areas of the brain for reception, show development away from the prosimian type and toward that of humans. Like humans, monkeys and apes see stereoscopically and in color. A large part of their brains are designated to the reception and interpretation of visual stimuli. We know that they have lost some of their sense of smell because the area of the brain used for interpreting smell is greatly decreased. The nasal mucosa surface area is also decreased.

There are four main genera of apes, all quite different from monkeys anatomically. All apes, except for gibbons, are much larger than tree-dwelling monkeys. Brachiation, arm-swinging, is accompanied by changes in primate anatomy. Apes wrists are more mobile than monkey or human wrists.
The Old World monkeys are divided into two subfamilies, Cercopithecinae and Colobinae, by the structure of their digestive systems. Papiro represents the species with a single stomach, and Colobus represents leaf eaters with a succulated stomach.

All Old World monkeys have incipient canines. Slanted nostrils, which are close together and comma-shaped, further classify Old World monkeys as Catarrhini or downward nosed. New World monkeys are the only primate species with proboscis tails. New World monkeys have round nostrils separated by a broad nasal septum, and are called Platyrrhini, which means broad-nosed. The Old World monkeys, illustrated in this guide, represent both the areas of zoo preservation and medical experimentation.

Limitations of the Study

This study was limited to observing and recording five necropsies of Papiro and one necropsy of Colobus between October, 1984 and March, 1985. In order to compensate for the small number of specimens, documentation of each primate necropsy was carried out by photography, video taping, and rough drawings made during the procedure. This information, along with the gross and histopathologic reports, were used to obtain an overview of the necropsy protocol as well as to illustrate particular aspects.

Nature and Order of Presentation

The format of the thesis is organized to reach a broad base of professionals who are involved in primate care and study, such as veterinarians, physicians, researchers, medical students, zoo technicians, and medical and scientific illustrators. The order of presentation follows the order of necropsy protocol as practiced at the University of Texas Health and Science Center at Dallas. It is hoped that this guide will form an accurate, basic guide to primate necropsy, which will be useful to the medical research and teaching community.

Review of Existing Literature

Literature on primate necropsy is limited. The subject, primate necropsy, was researched through computer and library searches (Medline and Catline), the Dallas Zoo Library, Animal Resource Center Library, private veterinary libraries, and suggestions by my committee. A few references to primate necropsy were found. Of the forty-six books and articles reviewed in total, fourteen books and articles were helpful and are briefly reviewed here. Four human autopsy books are listed for comparison.

In Veterinary Autopsy Procedures, Herbert J. Kruebingen (1971), describes a veterinary necropsy technique taught at the Pathology Department of New York State Veterinary College in the 1960's from the method originated with Dr. Peter Olafson. The article has two pages of photographs of dog brain slices but no drawings.
In an editorial, "Descriptions in Pathology Avoiding Pathological Descriptions", Robert W. Frichard (1971) describes how to write and record pathological material observed at autopsies. There are no illustrations and the editorial is four pages in length.

The Atlas of Small Animal Necropsy (Alden, 1981) is an excellent photographic guide for animals but primates are not included. This book offers an excellent presentation of small animal necropsy. The information is applicable to several necropsies procedures.

In Veterinary Necropsy Procedures (Jones and Gleiser, 1954), is the only primate necropsy procedure found. There are no illustrations and the brief text is written in a narrative format. The abdomen is opened first and the thoracic cavity second followed by examination and removal of the organs. The removal of the brain is not mentioned.

In Veterinary Necropsy Protocol for Military Working Dogs, (Department of the Air Force, 1973), the procedure is described, and four photographs of specimen bottles are included.

In "A Review of 105 Necropsies in Captive Baboons (Papio cynocephalus)" (Kim and Kalter, 1975), the pathological findings are reported and compared but no details of how the necropsies were performed is given.

In "Causes of death of infant rhesus and squirrel monkeys" (Padovan and Cantrell, 1983), the materials and methods and the results are presented. No necropsy details or illustrations are presented.

There are several illustrated anatomical references in An Atlas of Primate Gross Anatomy, Baboon, Chimpanzee, and Man (Swindler and Wood, 1982). First published in 1973 and revised in 1992, it is the best illustrated, comparative source.

Primate brains have been extensively studied. Swindler and Wood (1982, p. 60) mention nine classic works representative of the field of study.

The Monkey Kingdom: An Introduction to the Primates (Saunderson, 1957) has both illustrations and photographs and is a good resource on living primates.

Human autopsy books have much guide material, good illustrations, and good photography. The subject is well covered. The books researched are listed in the bibliography and described briefly below for comparative information and resources:

Current Methods of Autopsy Practice (Ladwig, 1972).


Examination of the Brain (Necropsy Technique) (Earle, undated). This booklet is full of illustrations and photographs.

Forensic Pathology: A Handbook for Pathologists (Fisher and Petty, 1977). This is an excellent, non-illustrated book.
In conclusion, since this Illustrated Guide for Primate Necropsy is just that, an illustrated, step-step guide and not an in-depth presentation of all aspects of pathology, toxicology, or anatomy, the literature review gives reference areas of study for more detailed work.

The necropsy books and the human anatomy books have been carefully chosen so as to form a basic resource of reference material for the reader. Each book has a different approach and different areas of emphasis. All the books together give a well rounded introduction to necropsy and autopsy procedures on primates and will serve the researcher well.

Since the necropsy reference material is no limited, much basic knowledge pertaining to the actual necropsy procedure of old world monkeys must be gathered from human autopsy procedures. Books on this subject are numerous, more complete in essential detail, and offer the best parallel reference to primate necropsy procedures. The external differences of size, weight, age, coat, scars, and any distinguishing marks must be carefully noted. The internal examination of viscera, organs, and tissues is carried out step-by-step by the Sokitsansky method in this illustrated guide, are very similar to the human autopsy procedure. The gathering of gross tissue samples for microscopic studies is basic, essential, and similar to human autopsy.

Although toxicology and cytology procedures are not illustrated in this guide, references to these specialized area of microscopic study can be found in the autopsia book list. Studies of experimental surgical procedures and equipment or zoological, anatomical comparisons are not a part of this guide because so little information is available about non human primates.

The literature review is a summation of the basic reference books available to aid the persecor to obtain, through death and necropsy of the primate, a beginning to the understanding of how the primate lived.

Methodology

The methodology is composed of three parts: 1) the specimen, 2) the necropsy procedure, and 3) the recording methods.

All specimens were obtained from the Animal Resource Center at the University of Texas Health Science Center at Dallas and from the Dallas Zoo. Five specimens of Papio anubis and one specimen of Colobus guereza were observed, studied, drawn, and photographed.

Six necropsy procedures were attended, observed, and reports collected. Other sources of necropsy protocols were obtained from library searches, written articles, books, and reports. Discussions with veterinarians, zoo personnel and faculty members were held and these personal communications included. The necropsy procedure presented, as
practiced by Fred J. Clubb, Jr., D.V.M., Ph.D., Pathology Department, the University of Texas Health Science Center at Dallas and Dr. Bonnie Raphael. Veterinarian of the Dallas Zoo, is the modified Rokitansky procedure, the removal of viscera en bloc for examination outside of the body, organ by organ.

Karl Rokitansky lived from 1804-1876, and was head of the Department of Pathology, University of Vienna. His methods are still applicable and still taught in veterinary schools.

The recording methods included: 253 color photographs, videotaping two and one half hours of complete necropsies as well as detailed specific drawings of the baboons and Colobus monkey from the specimens. Hand and footprints were also taken of the baboons.

Color slides were taken in sequential order throughout the necropsies. (The prosector posed each shot for accuracy and clarity.) A narrated slide-tape of seventy-seven of these slides was made. A video-tape, two and one half hours with narration, also was made. Rough pencil sketches of detailed areas of specimens and instruments were made. Pencil sketches of slides were drawn.

From all these resources, sixty-eight pen and ink plates form the necropsy guide. The purpose of these plates is to show the techniques, the structures, the instruments, the specimens and the sequences of procedure.

II. THE NECROPSY ROOM AND EQUIPMENT

The necropsy room should contain a stainless steel table with drain and hose. The room should have proper lighting and electrical outlets for recording devices and equipment. Cabinets and counter spaces for supplies should be provided. The room should be easy to maintain and clean. Masks, gloves, gowns, and specimen jars should be supplied.

The following list of medical supplies gives a standard itemization of Necropsy equipment. (AFM 163-10-TE, 1973 p.1) (10)

<table>
<thead>
<tr>
<th>Description</th>
<th>Federal Stock Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knife, Cartilage, Curved, 7 inch</td>
<td>6515-343-7100</td>
</tr>
<tr>
<td>Forceps, Tissue, Russian, 6 inch</td>
<td>6515-296-8323</td>
</tr>
<tr>
<td>Forceps, Bone Cutting, Straight, Liston, 8 3/4 inch</td>
<td>6515-331-1800</td>
</tr>
<tr>
<td>Reamer, Curved, Hartmann, 7 1/4 inch</td>
<td>6515-331-4600</td>
</tr>
<tr>
<td>Forceps, Dressing, Straight, 5 1/2 inch</td>
<td>6515-333-3600</td>
</tr>
<tr>
<td>Forceps, Hemostatic, Straight, Hemostat, 6 1/4 inch</td>
<td>6515-334-7100</td>
</tr>
<tr>
<td>Forceps, Ear, Raymond Shepard, Lucas, 5 1/2 inch</td>
<td>6515-333-6600</td>
</tr>
<tr>
<td>Mallet, Autopsy, Metal, with Hook</td>
<td>6515-340-0600</td>
</tr>
<tr>
<td>Blade, Surgical Knife, Detachable, Sterile, No. 15, 6s</td>
<td>6515-660-0008</td>
</tr>
<tr>
<td>Handle, Surgical Knife, Detachable Blade #3</td>
<td>6515-346-7800</td>
</tr>
<tr>
<td>Probe, General Operating, 10 inch</td>
<td>6515-356-9500</td>
</tr>
<tr>
<td>Saw Amputating, Satterlee, 8 inch</td>
<td>6515-363-1100</td>
</tr>
<tr>
<td>Scissors, General Surgical, Straight, Mayo, 6 2/4 inch</td>
<td>6515-364-0900</td>
</tr>
<tr>
<td>Scissors, Entotomy, 8 inch</td>
<td>6515-364-2100</td>
</tr>
<tr>
<td>Scissors, Iris, Angular, 4 1/2 inch</td>
<td>6515-364-4200</td>
</tr>
<tr>
<td>Scissors, General Surgical, Straight, 7 inch</td>
<td>6515-365-0600</td>
</tr>
<tr>
<td>Scale, Dial Indicating, Commercial, Autopsy</td>
<td>6670-439-1100</td>
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<tr>
<td>Rule, Measuring, Ophthalmological, Rhinological, Plastic, 17 cm</td>
<td>6515-362-6200</td>
</tr>
<tr>
<td>Saw, Bone-Cutting, Autopsy, Stryker, 110 volt, AC-DC</td>
<td>6515-296-8717</td>
</tr>
<tr>
<td>Field Post-mortem Kit, Veterinary</td>
<td>0545-145-0094</td>
</tr>
<tr>
<td>Bone Cutting Forceps, for Rib Removal</td>
<td></td>
</tr>
</tbody>
</table>
III. EXTERNAL OBSERVATION AND EXAMINATION

Methods for necropsy may vary because of anatomical differences. The basic approach illustrated in this guide should provide an efficient procedure regardless of these differences.

NOTE: Primates and humans can share such diseases as tuberculosis and polio. The passing of disease from animal to humans is called ZOONOSES. Mask, glove, and gown are always worn for protection by all attending personnel.

First read and review the clinical history and consider differential diagnoses before beginning. Place the animal in a dorsal to ventral recumbency. Examine the primate for external lesions and parasites. Examine all the body openings. Examine the eyes, the ears, the nose, the mouth, and genitalia. Take notice of the general health of the animal. Notice any scars or identification marks.
Review of Clinical History

The following clinical history is an example of a written report of baboon necropsy. Such a report should be obtained and a general diagnosis should be considered before beginning the necropsy.

ANIMAL RESOURCES CENTER DIAGNOSTIC LABORATORY
C.T.H.A.C.D.
Pathology Report

Date: 84/10/30

CLINICAL SUMMARY:
Upon arrival, routine surveillance and quarantine procedures were observed with no signs of illness. On 5/9/84 and 5/10/84 he was dewormed for Trichuris spp. and Balantidium coli with Dichlorovos.

On 10/8/84 he was tranquillized with Ketamine HCl, intubated, and maintained on Halothane and oxygen as anesthetic. The baboon was placed on cardiopulmonary bypass and a coronary arterial prosthesis was placed. During anesthesia, the animal was maintained with a Fentanyl drip. Surgery was without complications. Recovery was slow and 0.4 mg Narcan was given twice without significant change, but the animal was able to sit up and was breathing good by the end of the day (10/8/84). The animal experienced some post-op lohgarphy and was anorexic but the last 10 days was eating fruit and biscuits along with drinking water and Tang. On October 28 and 29 there was some loose stool. Approximately 8:45 A.M. on October 30, the animal was found in right lateral recumbency in the cage, exhibiting apnoeal breathing. At 8:55 A.M. was pronounced dead. (Clubb, 1984, p. 1) (11)

The necropsy begins with an external examination of the body of the Colobus monkey. The monkey is laid in a dorsal recumbency. The external part of the exam begins. The integument, the hair, and the markings of the animal are observed from the ventral position. The head is at the top of the table on the prospector's left.
Furia mangia, baboon, is illustrated in dorsal recumbency, with identifying marks.

The Colobus head is externally examined for pathological findings, such as swelling, infections, or injuries. Note the shape of the flat, comma shaped nostrils which are one of the determining features of Old World monkeys. They are called Catarhini. New World monkeys have rounded nostrils and are classified Platyrhini.
This is the head of a baboon with the eyes open, and the pupils dilated and fixed.

The teeth and gingiva of Colobus and Papio are carefully examined. The canine teeth of Papio were previously removed for laboratory purposes. The gums reflect the primate's health. The gums can show general diseases such as anemia (pale gums) and renal disease (oral ulcers), or local infections such as periodontal disease. The dental formula for the permanent teeth of the Cercopithecidae and Hominidae is: 2/2, 1/1, 2/2, 3/3, = 32.
The hands of *Cebus* and *Papio* are examined for injuries and anomalies.

The simian lines are illustrated here. The small bud of the thumb is shown. The scalpel is used to spread the hand and to give a sense of size. In the baboon, the opposable thumb is more developed. The development of the thumb is complete in the human. Swindler and Wood give the basic phalangeal formula for the primitive hand as: 3 4 2 5 1. (1982, p. 156) (12)

The dermatoglyphics of the plantar surface of the baboon foot shows the alternating ridges and sulci which is more pronounced in Old World monkeys than in other primates. Swindler and Wood give the general "primitive phalangeal formula is: 3 4 2 5 1". (1982, p. 272) (13)
IV. INTERNAL OBSERVATION AND EXAMINATION

The body is opened regionally and the entire organ system within each region is removed using the Rokitansky method.

The system of internal examination of the cavities and their organs follows the procedural order: 1) the oral cavity and contents, 2) the thoracic cavity and contents, 3) the abdominal cavity and contents, 4) the perineal cavity and genitalia, 5) calvarium and brain. Tissue is taken for microbiology, toxologic and histologic evaluations. In this guide, the abdominal cavities of *Colobus* and *Papio* were superficially opened before the thoracic cavity for clinical reasons. The prossector may use either order that applies to his particular needs.

After the external examination, an incision is made from the submandibular to pelvic or pelvic to submandibular region. The incision should be made with one long, clean stroke through the integument layer only.
The integument of Colobus is opened by transcutaneous incision. The Musculoskeletal System is examined. The amount of adipose tissue, fat deposit, is observed and recorded. These observations indicate the nutritional state.

This plate shows the abdominal cavity and contents of Colobus. The spleen lies to the monkey’s far left and is barely visible. The jejunum and ileum share a common free mesentry with the ascending colon in baboons. In comparison, apes and humans have a secondary support mesentery. The sacculated stomach is shown just behind a lobe of the liver.
The diaphragm separates the abdominal cavity and viscera from the thoracic cavity. The diaphragm of *Colobus* is shown here to be normal and complete. No tears or scarring are present; the negative pressure of the thoracic cavity is preserved. Here the sacculated stomach lies superiorly. The liver is reflected showing the ascending and transverse colon behind the liver. The small intestines fill the abdominal cavity.

An incision releases the diaphragm and thoracic negative pressure.
The tissue of the diaphragm is removed by soft dissection which is using the finger or blunt instrument for gentle, non-cutting dissection of delicate tissue.

The prosecutor now begins the opening of the thoracic cavity of *Cebus*. The ribs and intercostal muscles have been cut on the right side in order to reflect the costals in one place and not harm the thoracic contents. This approach is preferred since the pericardial sac and the heart can be evaluated before cutting the pericardial attachments from the thoracic wall. The vena cava is shown in *situ*. 
The left intercostals are clipped with bone cutters and the sternal plate is removed whole. In the baboon, the bony thorax is more elongated than in the human. There are 12 pairs of ribs in Papiol Colobus, and humans. Ribs one through nine are directly attached to the sternum in the nonhumans. In contrast, ribs one through seven are attached to the sternum in humans.

The prosector enters the oropharynx ventrally through the floor of the oral cavity. With the tongue reflected the oral cavity can be examined.
The bone cutters are used to clip the hyoid bones (not shown) of *Colobus*. This enables the prossector to remove this tissue and the thoracic contents (i.e., heart and lungs) en bloc and provides easy dissection of the esophagus and the trachea.

Tissue dissection of the glands and organs begins with the tongue. The proper procedure for dissecting the muscular tongue of *Colobus* is called book-slicing, or bread-leaving. Thin cross-sections are sliced from one end to the other. This is a useful technique to examine for parasitic cysts, abscesses, granulomata and structural anomalies.
The trachea, esophagus, lungs and heart are removed en bloc and then examined as shown in this anterior view of *Colobus*.

This is posterior view of the en bloc dissection of the trachea, esophagus, lungs and heart of *Colobus*. 
The lung parenchyma is examined and sections are obtained for fixation and later histological evaluation.

The pleural surface of a piece of lung tissue of *Colobus* is examined for pathological information, i.e., petechial hemorrhage or other indications of tissue damage or abnormalities.
The trachea is examined by cutting the ventral aspect from the epiglottis to the tracheal bifurcation. The bronchus can then be followed to the periphery.

The heart of the Colobus monkey is examined. In this plate, a postmortem clot is removed from the superior vena cava.
The size and shape of the *Colobus* heart is shown here in a left anterior view with the hand giving a comparison of size. The long axis of the heart is oriented more in a crano-caudal direction in *Papio*. The same orientation is found in most groups of Old World monkeys.

The posterior aspect of the *Colobus* monkey heart is shown.
This is a dorsal view, looking down into the opened right atrium of the *Callophilus* heart. The superior vena cava has been removed.

This is an example of one technique for examining the heart. The heart is opened along the "lines of flow" (i.e., posterior r. atrium ventrally, through to the A-V valves to the apex, and then proceed along the anterior surface through the pulmonary valves). The intraventricular septum is the landmark which the prosector follows. The same procedure is followed in the left ventricle.
In this view of the right ventricle, the internal structure of the *Colobus* heart is shown with the numerous myocardial ridges, the trabeculae carneae and the septomarginal ridge. This structure is well developed in the baboon and *Colobus*, but can be very variable, thus suggesting some degree of interspecific variability as discussed by Swindler and Wood (1982, p. 194) (14).

The anterior view of the baboon heart is illustrated here for comparative purposes. This view show the heart from the same anterior view as the *Colobus* heart on page 45 but with the long axis of the heart shown to lie in a more cranio-caudal direction in *Papio*. 
After examining the heart, remove the entire length of the thoracic aorta and examine for disease or anomalies.

The tissue between the two tightly tied knots is cut. The upper end of the gut is now free for removal.
The distal colon of *Colobus* is tied with string in two adjoining places, and cut between the ties. The entire digestive system is put aside for later evaluation.

In this posterior view, the entire abdominal viscera of *Colobus* have been removed for examination by the Rokitansky procedure. This modified human procedure consists of the removal of all visceral contents from their cavities, in one piece, to be examined outside the body as a unit.
Next, the prossector locates and squeezes the gallbladder. The bile expelled will mark the hepatopancreatic ampulla, Ampulla of Vater, and confirm the patency of the bile duct.

This plate shows the pancreas of Colobus being removed and examined from the dorsal aspect of the abdominal viscera.
The liver is cut free and the capsule examined. In the baboon, the liver extends farther than in the *Colobus* or humans, due to a developed left lobe. The liver morphology of *Papio*, *Colobus*, and humans is much the same. The small scissors shown in this illustration give a comparison for the total size of the *Colobus* liver.

The *Colobus* liver is cut into sections or "bread-loafed" and examined.
Inferior view of the liver of the baboon shows all four primitive lobes: central or medial, right lateral, left lateral, and Spigelian or quadrate. The central lobe is the largest of the four and the left is the smallest.

The spleen of Colobus is removed and examined. The spleen lies to the left side of the stomach and is larger and more elongated in the baboon, compared to Colobus. As in humans, the spleen is connected to the kidney by the lienorenal ligament which is well developed in Papio.
The spleen of *Colobus* is sectioned and pieces taken for histologic evaluation.

The adrenal glands and kidneys are removed and examined by cutting the ureter and leaving a small section for examination of these organs. The kidneys are located posteriorly, immediately dorsal to the peritoneum. In *Papio* and *Colobus*, the left kidney is more caudal than the right. In humans, it is the opposite. (Swindler and Wood, 1982, p. 222) (15)
A *Colobus* kidney is cut open along its midline and internal structures are examined. Both kidneys are examined.

The *Simmale Colobus* illustrated here has two ovaries and one uterus. The ovaries are small, globular bodies, attached to the broad ligament by short mesovarium and ovarian ligaments, as in humans. In *Papio*, the uterus is piriform and muscular and lies in a slightly ventral inclination. In humans, a marked ventral inclination is noted.
The genitalia of a young male baboon are shown for comparative purposes.

Shown is the entire digestive system of one *Colobus* monkey. The *Colobus* stomach with sacculations beneath the stomach is illustrated. As the *Colobus* is primarily a leaf eater, these sacculations are necessary for storage and digestion. The baboon’s digestive system, in comparison, would look similar but without sacculations as baboons eat fruit and small insects as well.
The stomach of *Colobus* is opened and examined.

The *Colobus* monkey is a leaf eater with a sacculated stomach. In this view, the extra sacculations are shown below the larger stomach. This enables the monkey to eat an enormous amount of leaves for later digestion. The baboon stomach is similar to humans. The scissors show the comparative size. The structure of the stomach divides the family *Cercopithecidae* into the two subfamilies *Cercopithecinae* (represented by Papio) and *Colobinae* (represented by *Colobus*).
The layers of stomach mucosa of *Colobus* are examined.

All mesentery is trimmed from the intestine to facilitate opening the gut. The superior and inferior mesenteric arteries carry blood to the gut, duodenum and rectum. In the baboon and Colobus monkey, there is a large right colic branch, but no middle colic branch as found in humans.
The intestinal mucosa and contents of the small intestines of the Colobus monkey are evaluated.

This plate shows an area of intestinal mucosa of the small intestine being examined. The small intestine begins with the duodenum and ends at the ileocecal junction. The large intestine begins at the cecum and ends at the anus. The baboon has large haustra. Both subspecies have vermiform appendixes. In baboons and Colobus there are no true sigmoid colons. No sigmoid arteries are present as they are in humans.
V. REMOVAL AND EXAMINATION OF THE BRAIN

Returning to the head, for the last part of the necropsy, the eyes are enucleated. The brain is left until last because of the possibility of an infectious disease, i.e. tuberculosis. The skull is opened, the brain examined and specimens are taken.

The right eye of Colobus is prepared for enucleation. The eyelids have been removed for easy access to the eyes. The orientation of the head is with the nose superior and the occipital part of the skull inferior on the table. The prosector stands above the inferior aspect of the orbits.
The four eye muscles, the medial and lateral rectus muscles and the superior and inferior rectus muscles, are located. A clamp holds the medial rectus muscle and the eyeball while the other three muscles are cut. The optic nerve is then probed and severed, thus freeing the eyeball from its orbit. The medial rectus muscle is cut last and the eyeball is lifted out and placed in a specimen jar for further study.

To begin the removal of the brain, in this dorsal view, the hair and scalp of Colobus are incised transversely. The flap of the scalp created is reflected back to reveal the layer of occipital muscles covering the skull.
The temporal fascia of Colobus is split by parasagittal cuts to remove the temporal muscles from the skull in order to reach the bone.

The temporal muscle layers over the skull have been cut and the Stryker saw can now be used on the skull. These muscles are thicker in the monkeys than in humans.
This illustration shows a left anterior view of the exposed skull of *Colobus*, with the scalp reflected over the face. The rotating, oscillating Stryker Saw is used to cut the skull.

A circle or cap of skull bone is carefully and completely cut in this right frontal view. Though the Stryker Saw is supposed to cut hard material only, care must be taken not to cut the brain. This illustration shows the right anterior aspect of the exposed skull. The temporal muscles are cut, but not removed, and the scalp is reflected down over the face.
In this right anterior view of the exposed skull, the temporal muscles are severed, the skull is completely cut around, and the calvarium is now pried up in order to enter and examine the skull contents, the tissues, the vessels, and the brain.

In this right side view, the calvarium and dura mater are carefully removed from the anterior to the posterior of the Colobus skull.
The inside of the calvarium of *Colobus* with the imprint of the dural sinuses is removed and examined. The dura mater is carefully checked as it is removed anteriorly to posteriorly with forceps.

The whole brain of *Colobus* is now examined *in situ* from a right anterior view. The cut temporal muscles are on both lateral sides of the skull. The scalp is shown reflected anteriorly over the face.
The brain stem of *Colobus* is removed while still connected to the brain. The advantages of such careful and non-destructive techniques are important for information and specimen preservation.

The pituitary stalk of a *Colobus* monkey is shown next to the forceps. The pituitary gland is dissected loose and examined. The contents of the exposed posterior cranial fossa have been removed.
VI. GENERAL CONCLUSIONS

Primate necropsy is the complete gross and microscopic examination of the primate at death. The necropsy is a mechanism for obtaining pathological information on the life and the death of the primate and is an invaluable scientific control.

The two primates in this illustrated guide are both examples of the family Cercopithecidae or Old World monkeys. This family contains two subfamilies, each represented here by the Colobus monkey, Colobinae, Colobus guereza and Cercopithecinae, Papio anubis. Followed page by page, this guide should be applicable to all primate necropsies and be as complete as the human autopsy protocols.

In conclusion, the quality necropsy acts as a control for the care, use, and preservation of these primates, and is an essential beginning to the foundation of knowledge of pathology.

The Colobus brain is carefully suspended in gauze to maintain its shape while being preserved in formalin. If not suspended, soft tissue will take on the shape of the container that holds it.
APPENDIX

1. The Preparation of Necropsy Protocols

Outline of Necropsy Protocols

A. Necropsy protocol should be prepared in an objective and descriptive way to give a precise word picture of all the observations made during the postmortem. An abstract of the original medical history, clinical observations, and the clinical laboratory data should always be included.

B. The value of these records of necropsy are as follows:

1. Education is continued
2. Basis for professional papers
3. Accurate record of facts for legal protection
4. Histology findings and interpretation
5. Confirming or refuting clinical diagnoses
6. Teaching devices

C. "The teaching value of a well observed clinical case and/or necropsy diagnosis on the case cannot be underestimated", Auburn University.

D. The necropsy record should follow the systematic procedure of the examination itself.

E. The descriptive writing of the record

1. Give a clear description of what is observed and an interpretation of what the prosector observes
   a. Position
   b. Size - use the metric system
   c. Weight - use the metric system
   d. Color - the tone, shade, and distribution
   e. Consistency and texture
   f. Odor
   g. Cut surface (ex. "nutmeg" liver)
   h. Shape
   i. Contents
   j. Lumen of tubular organs (Auburn University, 1974) (17)

2. Descriptive Terminology for Necropsy Reports

Descriptive Terminology is an art rather than a science. In pathology and anatomy certain patterns appear again and again and so do the phrases to describe them. The following list of phrases are from Auburn University and illustrate the point:

- Consistency and texture: Hard, tough, firm, pits on pressure, friable, soft, gelatinous, mucoid, dry, inspissated, caseous, crepitant, turgid, stringy, adhesive, gritty, granular, pliable.
- Shape: Ovoid, spherical, conical, elliptical, triangular, flattened, nodular, lobulated, tortuous, discoid, punctate, crateriform, bulbous, wedge-shaped, spindle-shaped, filiform, lacelike, whorled, interwoven, fungoid, mushroom-shaped, dome-shaped.
- Color: Use precise words in designating color, indicate degree, distribution and quality as dark, brilliant, light, pale, mottled, streaked, stippled.
- Surface: Hairy, ulcerated, covered with (specific) exudate, smooth, irregular, eroded, rough, pitted, elevated, depressed, glistening, dull, rugose, undulant, scaly, membranous.
- Tubular structures: Patent, dilated, obstructed, obliterated, narrowed, diverticulate, branched, communication, tortuous.
- Size: Always record measurements by the metric system even if only estimated or approximate dimensions can be obtained. One inch equals 2.5 cm. (Auburn University, 1974) (18)
3. Sample Pathology Report

This Pathology Report should serve as a check list for a quality necropsy procedure.

ANIMAL RESOURCES CENTER DIAGNOSTIC LABORATORY

U.T.H.S.C.D.

Pathology Report

Date: 04/10/30

Investigator: Department: Surgery

Species: Papio

Supplier:

Strain: E. anubis

Age: Adult Sex: M

Location:

Clinician:

Final Diagnosis:

Myocardial Infarction

SUMMARY:

CLINICAL SUMMARY:

Upon arrival, routine surveillance and quarantine procedures were observed with no signs of illness. On 5/9/84 and 5/10/84 he was dewormed for Trichuris spp. and Balantidium coli with Niclosamide.

On 10/8/84 he was tranquilized with Ketamines IM, intubated, and maintained on Halothane and oxygen as anesthetics. The baboon was placed on cardiopulmonary bypass and a coronary arterial prosthesis was placed. During anesthetics, the animal was maintained with a Pentamyl drip. Surgery was without complications. Recovery was slow and 0.4 mg Narcan was given twice without significant change, but the animal was able to sit up and was breathing good by the end of the day (10/8/84).

The animal experienced some post-op lethargy and was anorectic but the last 10 days was eating fruit and biscuits along with drinking water and Taps.

On October 28 and 29 there was some loose stool. Approximately 8:45 A.M., on October 30, the animal was found in right lateral recumbency in the cage exhibiting apneal breathing. At 8:55 A.M. was pronounced dead.

NECROPSY:

1) INTESTINAL:

On external evaluation, the animal is that of a well nourished male baboon. In the mid thoracic area there is a tattoo; an "A" and below that the number "3106". In the lower ventral abdominal area is the tattoo "8126". There is a thoracotomy incision in the left mid thorax. The incision measures 26 cm. The incision site is healing; however, there are several focal areas in which there is reaction to the suture. The skin in these areas is erythematous and moist. This area extends approximately 4 cm. Seven cm distal to the thoracotomy incision is a 4 cm wound dehiscence. This lesion does not extend beyond the superficial muscular layer. The deeper dermis, and extending into the superficial muscular layer at the thoracotomy site, is healed and shows no signs of inflammation. In the left inguinal area there is a 4 cm surgical incision. The suture is still present; however, this site is dry and healing. Both corneas are clear. The mucous membranes have a normal pinkish coloration. In the oral cavity, the dentition shows a moderate degree of periodontal disease.

2) THORACIC CAVITY:

There were multiple adhesions on the left side of the thorax. This was noted to be most severe around the bypass graft. It is interesting to note that a groove was formed by the graft on the parietal pleural surface of the left thorax. There is a grayish discoloration of the bypass in this area. There are multiple fibrous adhesions from the parietal pleura to the epicardial surface.

a) Lungs - The left lung is adhered to the parietal pleura. This is a very firm adhesion and suggests early fibrous organization. The left lung, in the apex region, is adherent to the heart. There are focal areas of consolidation in this particular lobe. The right lung, although having a slight darkish red discoloration, does not have any palpable areas of consolidation.

b) Heart - There are numerous firm adhesions of the pericardium to the epicardial surface. This is primarily along the coronary groove of the right ventricle extending posteriorly to the posterior crux. These attachments are undergoing very early fibrous organization. The entire epicardial surface is covered by fibrin and focal areas of hemorrhage.

The heart is cut in 1 cm broadleaf slices. The distal segment (apex) consists of the left ventricle and this entire slice is infarcted. The second cm slice contains a portion of the right ventricle and the left ventricle. The left ventricle is completely infarcted. The third cm contains infarcted myocardium, primarily in the anterior half of the left free wall. The infarct involves the entire intraventricular septum and half of the adjacent posterior. The fourth cm portion contains infarcted myocardium extending from the anterior portion of the left ventricular free wall into the anterior half of the intraventricular septum. The fifth cm section (which contains the LAD graft anastomotic site), contains infarct in the immediate anterior left ventricular free wall immediately distal to the anastomotic site. Proximal to the anastomotic site is a stainless steel surgical clip. This clip has completely occluded the left anterior descending artery. The remaining sections of the myocardium were unremarkable.
At the anatomic site at the aorta, there are areas of recent hemorrhage. This is at the anatomic site and around the coronary grooves.

At the ostia of the aortic anatomic site, a white strand of tissue extends into the lumen. Distal to this area, the lumen is occluded by a thrombus. This thrombus extends approximately 2 cm distal. The endocardium contains a large mural thrombus at the apex and this occludes the lumen of left ventricle. The mural thrombus extends anteriorly approximately 2 cm.

3) ABDOMINAL CAVITY: There is no ascitic fluid present.
   a) Liver - The liver is markedly swollen with rounded margins. There is an accentuation of the central venous areas (acute passive congestion). The right anterior-ventral portion of the liver, the serosal surface, has a whitish discoloration.
   b) Omentum - The omentum is within normal limits. It is interesting to note that this animal is free of parasitic cysts on the omentum.
   c) GI Track - Small intestines have a reddish discoloration along the serosal surface. The lymph nodes in these areas also have a darkish red discoloration. These segments are also watery and gas filled. The colon does not show the serosal changes noted in the small intestines; however, they are gas filled and the contents are watery. This extends distally to the rectum.
   d) Kidney - Left kidney is congested. The medullary area has a very dark reddish appearance and there is also some dark red streakings in the cortex. In addition, there is a 0.75 cm, pleated, whitish lesion extending from the subcortical area down to the cortico-medullary junction. A section of this tissue will be taken for histopathologic evaluation. The right kidney is markedly congested. This is most prominent in the medullary area. The capsule strips readily.
   e) Adrenal - The right adrenal gland had a marked area of dark reddish discoloration in the cortical area. The medullary areas have an off white color.
   f) Spleen - The spleen measures 12 cm along the long axis. Toward the dorsal portion of the spleen there is an area of cleavage possibly due to trauma at a much earlier date.

HISTOPATHOLOGY: pending
   1) Tissue evaluated -
   2) Histopathologic lesions -

CASE INTERPRETATION:
The death in this animal is associated with acute heart failure due to a myocardial infarction. The events which led to the myocardial infarction can be focused around the anatomic site of the graft and aorta. It appears that the graft became adherent to the thoracic wall in the region of the thoracotomy incision. The adherent graft could have put stress on the sutures at the aortic anatomic site. This then resulted in the hemorrhage around the anatomic site and could have possibly initiated the intravascular thrombosis. This resulted in a myocardial infarction of the tissue supplied by the bypass graft. Since this was a transmural infarction, a mural thrombus did develop in the apex portion of the left ventricular lumen. The thrombosis observed in the kidney and at the bifurcation of the aorta probably originated from the mural thrombus.

(Clubb, 1984, p. 1-4) (19)
REFERENCES


(3) Ibid. Pages 1-7.


(13) Ibid. Page 272.

(14) Ibid. Page 194.

(15) Ibid. Page 222.

(16) Ibid. Page 90.


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BIBLIOGRAPHY


Biographical Sketch

Genevieve Molloy Wilson was born in Lexington, Kentucky, on January 6, 1935, the daughter of Elizabeth Haggin Molloy and James Mulligan Molloy. After completing her secondary schooling at The Madeira School, Greenway, Virginia in 1953, she entered Sarah Lawrence College in Bronxville, New York. She finished her junior year and married Gerald David Wilson in 1956. In 1977, she returned to the California College of Arts and Crafts and graduated with a double degree in Fine Arts and Illustration with distinction, in May, 1979. During these two years she also obtained a minor in Pre-Med from Dominican College and the College of Marin. In 1979, she became a deputy coroner in Marin County as well as an eye enucleator for Marin County, Lions Eye Bank after being trained at the University of California, San Francisco. In 1980, she entered the science department at the University of California at Berkeley where she studied anatomy and embryology and drew for the department. In 1983, she entered the Graduate School of Biomedical Communications at the University of Texas Health Science Center at Dallas. She and her husband will be married for 30 years this June, and they have four children, Karen, Becky, Anne, and David. She is a medical and veterinary illustrator for Children's Hospital, San Francisco and the University of California at Davis, School of Veterinary Medicine. She also works as a free lance book illustrator and does medical, legal and police illustration in Marin County.

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Personal Protective Equipment (PPE) for NHP Necropsies

Recommended Personal Protective Equipment (PPE) to conduct NHP necropsies

- Surgical, N95 mask or respirator
- Eye protection: face shield or goggles
- Disposable head cover
- Double surgical gloves
- Disposable Tyvek® coveralls or gown over scrub suit
- Rubber boots or disposable waterproof shoe covers

In case of exposure to NHP body fluids

1. Stop work immediately
2. Apply first aid or follow instructions in B-virus exposure (bite/scratch) kit
3. Notify supervisor or vet
4. Proceed to institution’s occupational health clinic or emergency room with copy of B-virus exposure sheet if applicable

Emergency contacts

- Unit director or veterinarian
- Supervisor
- Occupational health clinic
- Local emergency room
- CDC Atlanta*
- B-virus hotline*

*if applicable