VII. BATS*

A. INTRODUCTION

1. General Characteristics

Bats comprise the second largest order of mammals, with almost 850 species distributed throughout the world today (see Appendix). It is probable that flying, bat-like mammals have existed for well over fifty million years.

Bats are extremely diverse in their feeding habits, diets, patterns of flight, echolocation, vision, temperature regulation, reproduction and size. All bats indigenous to Canada belong to the Family Vespertilionidae, insectivorous bats with a tail that is enclosed by the uropatagium (membrane between legs).

2. Biology of Brown Bats

The most abundant species of bats found in Canada are the little brown bat (*Myotis lucifugus*), and the big brown bat (*Eptesicus fuscus*). Characteristics for the identification of brown bats have been described, along with those of the other species of living bats, by Barbour and Davis (1969) and may be summarized as follows:

a. Big Brown Bat

Colour: light through reddish to dark brown. Wingspread: 325 to 350 mm. Length of forearm: 42 to 51 mm. Dentition: the upper canine and the first tooth lateral to it are in contact at the base; the latter tooth is half as high as the former. Other features: broad nose, broad rounded tragus (fleshy projection arising from the base of the ear), keeled calcar (a ridge-like projection extending from calcaneus into outer border of interfemoral membrane; aerodynamic function). The female is larger than the male.

b. Little Brown Bat

Colour: tan through reddish brown to dark brown; hairs darker at the base than at the tips; sleek glossy fur. Wingspread: 222 to 269 mm. Length of forearm: 34 to 41 mm. Length of ear: 14 to 16 mm. Dentition: the first tooth lateral to the upper canine is usually one-third as high as the canine. Other features: skull without sagittal crest, pointed, straight tragus, usually no keel on calcar.

Meaningful generalizations applicable to all bat species cannot, in most instances, be made. Consequently, the data presented in this chapter deal with the insectivorous brown bats of Canada and the U.S., unless otherwise stated.

Banding experiments indicate that bats have a long lifespan as compared to other mammals of similar size. Recoveries have been made 15 to 20 years and even as late as 24 years, after banding.

The annual life cycle of the brown bat includes a winter hibernation phase which frequently takes place in caves and mine shafts where the temperature will remain well above the freezing point. In the spring, with increasingly favourable climatic conditions and food availability, bats will return to their summer residence which may be in the vicinity of the hibernaculum or several hundred miles distant from it.

It is the female only (and later her offspring) that colonizes the attics of old houses and deserted buildings. Under normal conditions these female bats will be pregnant and give birth to one or two young in later spring or early summer. The young, after being nursed for three to four weeks, will commence to forage in flight. Juveniles grow almost to adult size during their first summer, but probably do not become sexually mature until the following year.

Bats usually disappear from their summer localities shortly after the young have been weaned and do not reappear until the following spring. It is not known exactly what their activities are after they leave, although casual observations suggest that brown bats usually migrate to another locality for the winter. In a few instances a colony of brown bats has been reported to remain in human dwellings throughout the year.

Autumn is the season when bats must accumulate a sufficient amount of body fat to meet their energy requirement for the following five to six months of hibernation. It is also the season when mating normally occurs.

B. **USE IN EXPERIMENTATION**

1. **Bats as Research Models**

Bats make very useful experimental animals. They are closely related to primates and hence to man. Their longevity allows for repeated testing of individuals.

Nonpainful manipulations may be readily performed while these animals are in hypothermia, precluding the need for chemical restraint or anesthesia.

An orderly sequence of structurally and functionally different organ systems has evolved among the various species of bats. As a result, comparative studies on these species provide an unparalleled source of information on interrelationships between the anatomy and physiology of organ systems, and on changes that have occurred as a consequence of adaptation to greatly different environments.

Mechanisms underlying echolocation, aerodynamics, and adaptive hypothermia (hibernation and torpor) can readily be studied in these animals in the laboratory. Information on organ function and enzyme activity at different body temperatures is obtainable from studies conducted during the arousal of the animal from hibernation, when the body temperature of a bat may change by as much as 35^{o}C.

Bats that hibernate make useful models for studies on the effects of low host temperatures on the development and activity of mammalian parasites, pathogens, and other microorganisms.

Long-term sperm storage is yet another area in which useful information may be gathered from studies on delayed fertilization in bats.

2. Bats as Laboratory Animals

The previous section has emphasized the fact that bat research is most useful and should be encouraged. It would, however, be unrealistic to suggest that either large numbers of insectivorous bats should be kept in the laboratory, or that breeding colonies should be established, for the following reasons:

a. Bat care is exceptionally time-consuming. Extreme patience and a rather exceptional sensitivity are required of the investigator and animal technician who would work with bats, if they are to adjust to the changing needs of these animals in captivity.

b. A majority of bats forage in flight and have to be individually trained to feed from a dish in captivity. The initial training feeding sessions may take from 20 to 30 minutes per bat. Some bats acquire the new feeding habit in two or three days; others may take up to four weeks before they can be counted on to feed properly on their own. Bats retain their nocturnal feeding habit when kept in the laboratory and, as a result, training should not occur during the day when normally they would be sleeping.

c. Individual big brown bats will consume up to 60 mealyworms (*Tenebrio* sp.) per night each, depending on the time of the year. As a consequence, large mealyworm cultures are required to maintain relatively few bats.

3. Planning Projects with Bats

The above listed requirements and difficulties associated with the maintenance of captive bats emphasize the necessity for careful advance planning of the bat research project in order to minimize the number of animals and amount of time required. Long-term studies such as those on echolocation and aerodynamics, in which the same individuals may be tested repeatedly, will usually involve relatively small numbers that will be readily manageable under laboratory conditions.

Laboratory experiments that must utilize large numbers of bats should, as a general rule, fit into one of the following three categories:

a. Terminal Experiments that will be performed within a day of collecting the animals.

b. Single Test Experiments that may be performed within a day of collecting the animals, and are of a nature that will permit the subsequent release of the animals.

c. Studies Associated with Hibernation in which the bats are collected after fat accumulation, in late autumn or early winter, and held in a controlled environmental chamber at a low ambient temperature. Under these circumstances, feeding will usually not be necessary and the animals may either be euthanized at the end of the experiment or released on arousal from hibernation in the spring.

C. ACQUISITION AND TRANSPORTATION

1. Capture Procedures

Bats are obtainable in the summer from their roosts and in the winter from hibernacula. In roosting places they are frequently found during the day hanging on beams or sitting between the cross-boards in an attic. Depending on the size of the colony, the required number of bats may be obtained by removing them with leather gloved hands. This type of collection requires speed, as the readily alarmed bats quickly disappear behind boards.

Speedy work is possible by having a one or two gallon, wide mouth, plastic bottle hanging over one arm during the collection. A dozen bats can safely be put into this jar for a brief period. To prevent suffocation or injury, bats placed in plastic bottles during collection must be transferred immediately after to appropriate cages for transportation.

A better collecting device consists of a wire-mesh cylinder with a smooth, fairly wide metal rim at the upper border (Barbour and Davis, 1969).

The procedures for physical restraint in the capture and handling of the nonhibernating bat are detailed in the section on Handling and Restraint.

Collecting from an attic inhabited by bats may be done by first establishing the location of the exit hole or holes. The majority of bats will leave through one or two spaces under the roof, more or less together, at foraging time. The wide end of a fine wire mesh funnel is mounted over the exit hole, and two or three sticks (1-2 m long) are fixed horizontally at the sides of the funnel. They serve to suspend a large cotton bag, the open end of which is tied firmly over the funnel. Bats will fly into the bag, being pushed from behind by other bats anxious to fly and forage.

Hibernating bats may be collected from caves and mine shafts where they may hang low enough on the walls to be removed by hand.

2. Precautions

Hibernating bats can be collected at any time during the winter; however, a given cave should not be visited more often than once or twice. The majority of bats hibernate in clusters of up to several hundred individuals, and there might be several thousand bats in a cave. Disturbing a member or members of a hibernating group causes others to arouse from hibernation, which is an energy-requiring process. Frequent disturbance may cause depletion of energy reserves at a time when no food is available. As a result, large numbers of bats may then fail to survive the winter. Unless required for

reproductive studies, adult female bats should be collected only during autumn and winter. If collecting is done in the summer, accidentally caught lactating females must be released immediately to prevent death by starvation of the young left in the nurseries. Lactating females can be identified by enlarged mammary glands and bare skin around the nipples.

3. **Transportation**

Bats can be placed in any suitable wire mesh cage for short distance transport by motor vehicle. However, it is preferable to use a narrow carrying case with a handle on a sliding lid that can be securely locked. The wire mesh walls of the cage should have a smooth upper metal rim, wide enough to prevent escape when the lid is removed.

When bats are to be shipped by commercial carrier, a wire mesh shipping cage is firmly fixed inside a wooden box provided with slits to allow air to circulate freely. The cage can be similar to the one described above, with the floor of the cage consisting of a metal x-ray. The tray should hold a foam rubber sheet that can be soaked with water; thirsty bats will lick it during transportation. The cage should be filled with crumpled paper towels to prevent injury in case bats fall off the wire mesh during transport.

D. QUARANTINE

Bats should be kept in a room by themselves for a minimum of three months, the approximate time of their incubation period for rabies. During this time, they should be caged in pairs to facilitate inspection and minimize the risk of spread should contagious disease develop. Brown bats should not be caged individually as they often become extremely nervous and exhaust themselves by continually attempting to escape.

It is essential that the person maintaining the bats should be acquainted with the symptoms of rabies. Rabies is a reportable disease under Canadian law and any animal suspected of being rabid must immediately be reported to the nearest veterinary representative of the Health of Animals Directorate of Agriculture Canada. Bats in quarantine must not be handled without wearing leather gloves.

Bats when brought in from the wild will invariably be heavily infested with ectoparasites (mites, ticks, fleas and lice). Treatment for ectoparasites is best accomplished by placing a small strip of vapona (dichlorvos) in the cage or room for a three day period; repeat at two week intervals, two or three times.

Bats that are being kept at room temperature should be checked daily and weighed twice a week during the initial months in quarantine.

Bats placed into a cold room for hibernation should not be disturbed until their scheduled time of arousal, following which they should be held under quarantine observation for at least a week in order to ascertain their health status.

E. CAGING AND HOUSING

1. General Considerations

Rooms in which bats are to be held must be free of gaps that lead to the outside. Small bats can squeeze themselves through spaces of about 1 cm, an order of magnitude often found between a door and the floor, or around the screens of ventilation shafts and drainage systems. Such openings should be closed off with fine wire mesh screens, while rubber or flexible plastic sheets should be mounted on the under side of doors.

Bats held in captivity on a long-term basis require different housing conditions during the hibernation season (from late October to late March) than during the other months of the year.

2. Nonhibernating Bats

During this period bats may be accommodated in a standard room similar to the one used during quarantine. If no new animals are to be added, the same room may be used.

Day and night time temperatures should be adjusted bi-weekly to simulate average outdoor conditions. Humidity does not seem to be critical during the nonhibernating season.

Photoperiod should be adjusted to outdoor conditions. Light intensity should be kept low. The room need not be illuminated if it has a window.

3. Bat Cages

The ideal bat cage is a walk-in, wire mesh chamber, large enough (3 x 1 x 2 m) to allow for short flights, and with a door that can be securely closed. The chamber requires one or more hiding places. A wire mesh bird cage (38 x 23 x 23 cm) without a door, if placed on a shelf and covered with a dark plastic sheet or towel is adequate. A layer of coarse paper towels should be placed firmly against the bottom of the bat cage and loosely crumpled paper on top. Bats will hide underneath this. Additional information on cages for bats under laboratory conditions may be found in the literature (Rasweiler, 1977; Pye, 1969).

If it is not feasible to hold the captive bats in flying chambers, they can be kept in bird cages as described above, but with a door that can be securely closed. In this case, they must be allowed to fly in the holding room for at least half an hour before feeding each day.

Under the conditions described, non-hibernating bats will deposit feces and urine, mainly on the paper towels. These should be removed at least once a week and the litter should be incinerated. Cages should be washed regularly at least once a month, and more frequently if feces are deposited on the wire mesh. It will not be necessary to clean the plastic cages (see below) while bats are hibernating.

4. **Hibernating Bats**

In winter, bats should be placed in a temperature controlled environmental chamber (cold room) for hibernation. Under appropriate conditions, bats will accumulate fat in late autumn in amounts of up to 50% of their body weight, in preparation for hibernation. The length of time bats remain in hibernation depends on the amount of body fat, the rate of metabolism of the individual, and the conditions of the environment.

Generally, bats which accumulate large amounts of fat in a relatively short time utilize their fat at a faster rate than do bats which accumulate fat at a comparatively slower rate. Under the conditions subsequently described, the average amount of fat utilized in hibernation is 1 g per animal per month. The approximate amount of fat available can be estimated from the difference in body weight in the summer, when bats are normally lean, and after fat accumulation in late autumn. From this, the period bats may be left in the cold room can be predetermined.

Plastic mouse cages (28 x 20 x 15 cm) with wire mesh lids should be used for bats placed in the cold room. To maintain a high humidity in the cage, a stack of about 25 folded paper towels is soaked in water and put into the cage. An underpad (Johnson and Johnson Ltd., Montreal and Toronto), composed of a plastic sheet and several layers of cotton, is extended loosely over the inner sides of the cage such that the plastic side of the pad makes contact with the water soaked paper towels in the bottom. The pad is held in position by the lid. To prevent bats from hanging on the wire mesh lid, and thus, from getting foot lesions from the cold metal, it is advisable to place a coarse dish towel over the cage, beneath the lid, leaving a narrow space for air to circulate. A stack of water soaked paper towels is then placed on top of the lid and then covered with a plastic sheet, again leaving a narrow airspace.

A petri dish with water and one with mealyworms, are placed in the cage. Bats periodically arouse from hibernation, urinate, feed, drink, and re-enter hibernation.

No more than three animals should be housed per cage so as to minimize disturbances from numerous arousals. For experiments that require removal of individuals during hibernation, bats should be held individually.

The inhabited cages are put on shelves enclosed by wooden or styrofoam walls (to eliminate draught), in a dark cold room, at about 5^{o}C. The humidity should be as high as possible. It is desirable to check cages every six to eight weeks to replenish mealyworms and remoisten paper towels, as necessary.

F. **FEEDING**

The preferred food for insectivorous bats in captivity is mealyworm larvae. Once bats have been trained to feed in captivity, petri dishes with mealyworms can be placed in the cage in the evening. Escaping larvae may be a problem, as they crawl on top of each other and over the edge of the dish. To keep escapes to a minimum it is advisable to distribute the required number of worms among several petri dishes.

Bats can be trained to eat finely ground beef or pork placed in small batches in petri dishes. However, they will often only eat hand proffered meat. Meat should not be the sole component of the diet, but should be supplemented with mealyworm larvae. This requirement is presumably based on the need for roughage provided by the larval cuticles.

Bats do well when fed homogenized liver (supplemented with mealyworms); however, as is also the case with ground meat, this food dries quickly and should not be put out before the animal is ready to feed. Liver also has the disadvantage of being a messy food that bats tend to get into their fur.

The general classes of foods required by the different families of bats are listed in the Appendix.

Water should be supplied in a petri dish and changed daily. Three or four drops of a multivitamin mixture should be added to the water.

G. BREEDING

Breeding bats in captivity should, unless the research necessitates it, be discouraged. They are monestrous, require considerable care, and there has to date been little or no need for controlled matings, inbred strains, etc. Should pregnant females or newly born young be required for experimentation, it is more economical and probably more humane to collect adult females from their hibernacula late in the hibernation season. Most such females will bear one or two young approximately ten weeks later and nurse them for ten to twelve weeks, provided the female is supplied with large amounts of food and left undisturbed.

Females are mated in the fall and store the sperm in their genital tract until after hibernation, when ovulation and fertilization take place. After a gestation period of eight to ten weeks, birth is given to one or two young. Breech presentation is common amongst big brown bats.

H. DISEASES AND HEALTH CARE

1. Bats as Vectors of Disease

Bats are susceptible to a variety of organisms and viruses pathogenic to man and other animals; yet, with the notable exception of the transmission of rabies by the vampire bat (*Desmodus rotundus*), particularly among cattle, only sparse information is available on the role of bats in the transmission of pathogens.

Brown bats in Canada (and elsewhere) not only occupy human dwellings, but also come in close contact with silver-haired bats (*Lasionycteris noctivagans*) and hoary bats (*Lasiurus borealis*), which are long distance migratory bats. These, in turn, may come in contact with bats from Central and South America. In addition, the potential for the spread of pathogens is enhanced by the fact that mosquitoes may feed on bats and houseflies lays eggs in bat guano.

Care should be taken when visiting bat caves, as histoplasmosis may be contracted by inhalation of airborne spores of *Histoplasma capsulatum*, a fungus that can be found on bat guano.

A bat bite should be treated immediately by forcefully sucking the injured site for some time and spitting out the blood. The wound should be kept open and bleeding if possible, until it can be properly washed and treated with a suitable antiseptic. Competent medical advice should be sought.

2. Common Bat Pathogens

In general, a healthy bat has a fluffy fur. It rapidly increases its ventilation and heart rate when disturbed and will attempt to fly off.

Pathogens isolated from brown bats in Canada and/or the U.S. include the Eastern, Western, St. Louis, and Venezuelan equine encephalitis viruses, the Montana myotis leucoencephalitis virus, herpes simplex and rabies viruses. Detailed information on disease-causing organisms in bats can be found in several reviews (Barbour and Davis, 1969; Constantine, 1970; Sulkin and Allen, 1970; Yalden and Morris, 1975; Ubelaker, 1970).

In addition to treatment for ectoparasites during quarantine, animals held over long periods in captivity should periodically be rechecked for ectoparasites and treated as necessary.

I. HANDLING AND RESTRAINT

1. Manual Restraint

Bats can be readily picked up from their hanging or sitting positions by placing a thumb against one of the folded wings, the middle finger against the other, and the index finger over the caudal head region. The animal is then lightly pulled while sliding the fingers of the free hand in a forward direction under its belly. The jaw of the animal is kept extended and closed by gently pressing against it from below. When semi-immobilized in this manner, the animal cannot bite and will release its claws because of the pull, placing its legs on the operator's hand. The fingers of this hand are then bent to enfold the bat. The finger and thumb that were immobilizing the wings can then be removed. Bats will relax in this position provided they are not squeezed.

If required, a bat can be held in a fixed position on a table by immobilizing its head and wings between fingers, as previously described. A cotton towel should be placed under the bat to prevent it from sliding. In bright light, the head should be loosely covered to prevent the animal from becoming excited.

2. Hypothermia

To avoid the use of anesthetics and yet prevent struggling, bats may be placed overnight in a cold room at about 10^{o}C. As already noted, nonpainful manipulations such as vein puncture are facilitated on torpid animals;

however, painful surgical procedures must never be undertaken under hypothermia alone.

J. SPECIAL PROCEDURES

1. Blood Collection

The total blood volume of a brown bat is approximately 10% of its lean body weight. The method used for obtaining blood will, therefore, depend on the amount of blood required. Puncturing of blood vessels should be done with the aid of a stereoscopic microscope.

To obtain one or more drops of blood, the bat is put on a pad under the microscope and a gloved hand, with the fingers slightly bent, is placed over the animal. Bats quickly settle in this position and fall asleep. The thumb of the gloved hand is then moved laterally and the bare hand is used to carefully extend the wing from between the index finger and the pad. The wing is kept extended by placing the tip of the index finger and the thumb on it. A light shone on the wing will reveal the vessels and stimulate blood to circulate through them. Several drops of blood can now be obtained by puncturing a small vessel with a fine needle.

For the withdrawal of arterial or venous blood it is advisable to use a flexible cannula assembly (rather than a hypodermic needle attached to a syringe). Such an assembly consists of about 4 cm PE 10 polyethylene tubing, into one end of which is inserted a 30-gauge hypodermic needle without a luer lock hub. To the other end is attached a Tuohy-Borst Adapter for the accommodation of a hypodermic syringe.

Provided that there is no experimental reason against blood from a hypothermic animal being used, the bat may be rendered torpid by the procedure already outlined under Handling and Restraint. The torpid bat is placed on a pad under the microscope, the anterior body covered with a coarse cotton towel, and the hind legs extended and immobilized by taping the feet to the pad. The needle of the cannula assembly is then inserted into the interfemoral vein in the uropatagium and kept in position by placing a small piece of tape over the tubing. No more than about 10% of the total blood volume should be withdrawn if the animal is to be kept alive.

For large blood samples, the animal should be killed by cervical dislocation. The thoracic cavity is then rapidly opened, and the blood is withdrawn from the exposed heart.

2. Urine Samples

Bats normally urinate in the evening after arousal from sleep. To obtain maximum amounts of urine, collecting should, therefore, be done at that time. The bat is removed from the cage prior to arousal, enclosed by one hand, and held in an upright position. A small glass vial is held over the external urethral opening from the bladder. The vial should be surrounded by masking tape so that the bat can hang on to it and keep its hind legs.

3. **Fecal Samples**

Captive bats deposit feces on the paper towels in the cage from whence samples may be readily obtainable. If fresh feces are required, collecting should be done at the time of feeding, when bats will frequently defecate.

K. ANESTHESIA

Pentobarbital sodium injected intraperitoneally is required in doses of 40 to 60 mg per kg of body weight for light and deep anesthesia, respectively (Rauch and Beatty, 1977). The anesthetic becomes effective in 15 minutes provided no handling occurs and the room is kept free of noise. During this time, bats should be placed in plastic mouse cages provided with paper towels in the bottom. The animal should be loosely covered with a light cotton cloth. The anesthetic begins to lose its effect about one hour after injection. Recovery time is approximately one hour at an ambient temperature of 23^{o}C and 3 hours or more at 20^{o}C. A small amount of water in a petri dish should be provided subsequently; however, food should be withheld overnight to prevent vomiting.

L. EUTHANASIA

Bats are humanely killed by cervical dislocation, decapitation, stunning by a blow to the head, or by anesthetic overdose.

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APPENDIX

CLASSIFICATION, DISTRIBUTION AND DIET OF BATS

	Classification	Approximate No. of Species	Geographic Distribution	Natural Diet
Kingdom	Animalia			
Class	Mammalia			
Order	Chiroptera			
Suborder	Megachiroptera			
Family	Pteropodidae (fruit-eating bats bats)	150	Far East and Africa to Australia	Fruit, Flowers, Pollen, Nectar
Suborder	Microchiroptera			
Superfamily	Emballonuroidea			
Family	Rhinopomatidae (mouse-tailed bats)	2	Africa, Asia	Insects
Family	Emballonuridae (sheath-tailed bats)	44	Pan-tropical	Insects
Family	Noctilionidae (bulldog bats)	2	Central & South America	Fish and Insects
Superfamily	Rhinolophoidae			
Family	Nycteridae (hispid bats)	13	Africa and Far East	Insects
Family	Megadermatidae (yellow-winged bats)	5	Africa and Asia	Vertebrates and Insects
Family	Rhinolophidae (horseshoe bats)	75	Old World	Insects
Family	Hipposideridae (regarded by some authors as subfamily)	53	Africa, Asia	Insects
Superfamily	Phyllostomatoidea			
Family	Phyllostomatidae (leaf-nosed	131	Central and South	Insects, Vertebrates, Fruit,

	bats and vampire bats)		America	Nectar, Vertebrate Blood
Superfamily	Vespertilionoidea			
Family	Natalidae (funnel-eared bats)	4	Central America, Caribbean	Insects
Family	Furipteridae (smokey bats)	2	Central America	Insects
Family	Thyropteridae (disc-winged bats)	2	Central and South America	Insects
Family	Myzopodidae (sucker-footed bats)	1	Madagascar	Insects
Family	Vespertilionidae (common bats)	280	Worldwide	Insects (two species eat fish)
Family	Mystacinidae (short-tailed bats)	1	New Zealand	Insects
Family	Mollossidae (free-tailed bats)	82	Pan-tropical	Insects