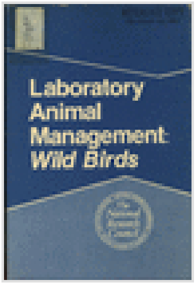

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Laboratory Animal Management: *Wild Birds*

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

Except for a few treatises in specialized areas and a few reports on husbandry of domesticated species—e.g., coturnix and chickens—there is little convenient information on the care and use of birds in captivity as research animals. This report is designed to fill this void, although the diversity of species that may be so used is so great that it is impossible to cover all contingencies in a single modest volume. Then, too, there is a paucity of available information on a number of aspects of the subject. Consequently, the report is designed to provide a generally sound basis for developing management programs that will be applicable to many species of wild birds that are utilized in the laboratory.

The Committee has intentionally eschewed the formulation of rigid standards or guidelines, lest the user be tempted to substitute them for good sense and a humane approach to his material. The report summarizes certain special problems associated with procurement and identification of wild species and with their maintenance in captivity and provides citations to relevant published literature.

As the title indicates, this report deals exclusively with the husbandry of wild-caught birds, as distinct from domesticated forms such as poultry. The term *birds* in the text, then, is to be construed in this more restrictive sense as applying to wild birds only.

COMMITTEE ON BIRDS

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INTRODUCTION

Wild birds have been used in biomedical and ecological investigations for a very long time. They tend to be active during the day and are relatively easy to observe. Many species are small enough to be kept in captivity in quantity yet large enough for convenience in experimentation; they have diversified into nearly all habitats and patterns of living. Because they offer the investigator an array of advantages and options, their use in research is increasing steadily.

The literature of avian biology of the past 25 years shows that the number of species used for experimental purposes in captivity has increased severalfold, paralleling the growth of avian ethology and comparative physiology during this period. Although any of the approximately 8,700 species of birds may be kept in captivity as research animals, only a few hundred are now so used. Within this group of species, however, there are great differences in body size, nutrition, behavior, and environmental requirements.

Each species, at some state of its use in the laboratory, may well have to be treated as a biological system having unique environmental or trophic requirements, or both. Long-established habits and practices in the care of domesticated birds cannot be transposed intact to wild species without the risk of serious difficulties. There is no substitute for a thorough knowledge of the species under consideration in its natural environment, for good sense, or for a humane respect for wild animals. Those who manage captive birds must have these basic attributes to be effective.

I PROCUREMENT AND IDENTIFICATION

The major initial problems in using wild species of birds as research animals include legal procurement and possession, receipt and correct identification of species, and adaption to laboratory conditions.

PROCUREMENT AND POSSESSION

Statutory Restrictions

The procurement, transportation, possession, and treatment of wild species of birds and their eggs are governed by several state and federal statutes, the provisions of which must be strictly observed. Illegal acts, intentional or inadvertent, may jeopardize the privilege of a research organization to use wild species of birds. An informational bulletin, "Migratory Birds Are Protected by Federal Law" (U.S. Department of the Interior, 1974), can be obtained from the appropriate Special Agent in Charge, Division of Law Enforcement, U.S. Fish and Wildlife Service (see Appendix A). This list includes some, but not all, of the species protected by the "Convention between the Government of the United States and the Government of Japan for the Protection of Migratory Birds and Birds in Danger of Extinction, and Their Environment" (March 4, 1972). Certain species that are not afforded federal protection may be protected by state laws. Investigators contemplating the use of species not included in the federal list should consult their cognizant state conservation agency (Appendix A). A summary of federal statutes affecting the use of wild birds, parts thereof, or eggs is provided in Table 1, with references to sources of published codes and regulations. Investigators contemplating the capture or use of birds in Canada should first obtain the advice of the Director, Canadian Wildlife Service, and of the appropriate provincial wildlife agency (Appendix A).

The capture and possession in the United States and its territories of federally protected species, or of foreign species defined as harmful or endangered, are restricted to holders of special permits issued by state and federal law-enforcement agencies. Typically, parallel permits are

TABLE 1 Federal Statutes Affecting the Use of Birds as Laboratory Animals

Legislation	Main Provisions	Codification and Regulations[a]
Migratory Bird Treaty Act	Protects wild species of birds, their nests, and eggs	40 Stat. 755; 16 USC 703–711; Title 50 CFR Parts 20 and 21
Eagle Act	Protects bald eagles and golden eagles, their parts, nests, and eggs	50 Stat. 250; 16 USC 668 as amended; Title 50 CFR, Part 22
Endangered Species Act of 1973	Specifically protects native and foreign endangered and threatened species	16 USC 1531–1543; 50 CFR, Part 17
Lacey Act	Forbids interstate or international transportation of wildlife taken, transported, or sold in violation of any state or foreign law	18 USC 43; Title 50 CFR Part 14
	Regulates the importation of wildlife defined as harmful	18 USC 42; Title 50 CFR Part 16
Animal Welfare Act	Regulates the sale, transportation, and treatment of laboratory animals	Title 9, CFR; 36 RF 248
Airborne Hunting Act	Forbids the use of aircraft in taking wildlife	16 USC 742j-1; Title 50 CFR Part 19

[a]Abbreviations: Stat. = U.S. Statutes; USC = United States Code; CFR = Code of Federal Regulations; FR = Federal Register.

required by both agencies. Advice on this subject can be obtained from the cognizant Special Agent in Charge, U.S. Fish and Wildlife Service, and from appropriate state wildlife agencies (Appendix A).

A federal Bird Marking and Salvage Permit is also required when research involves the capture of protected species of birds by mist nets or drugs; the banding of such birds with federal bands; or the artificial color-marking of free-living birds or of captives that could escape. Researchers planning to use any of these procedures should first consult the Chief, Bird Banding Laboratory, Office of Migratory Bird Management, Laurel, MD 20810.

Special permits are not required to possess foreign species of birds or their eggs obtained from licensed commercial sources, or of native species of birds or their eggs obtained from authorized game-bird propagation facilities in the United States, unless such birds are to be banded with federal bands and/or color-marked and if there is a chance of their being released from captivity intentionally or otherwise. *The release of foreign species of birds in the United States or its territories is prohibited.* Persons knowingly receiving birds or their eggs obtained or transported illegally, or imported by unlicensed dealers, are subject to the penalties provided by the statutes summarized in Table 1.

The importation of all domesticated or wild species of birds (including their eggs, carcasses, parts, or products) is subject to U.S. Department of Agriculture regulations and quarantine. Information on current regulations and quarantine requirements can be obtained from the Animal and Plant Health Inspection Service, Federal Center Building, Hyattsville, MD 20782. In addition, the importation and possession of species designated as harmful by the Secretary of the Interior are restricted to the holders of special permits. Avian species included in this category are: the Rose-colored Starling *(Sturnus roseus)*, Red-billed Quelea *(Quelea quelea)*, Java Sparrow *(Padda oryzivora)*, and Red-whiskered Bulbul (*Pycnonotus jocosus*). Information concerning the importation and use of such harmful species can be obtained from the Special Agent in Charge, U.S. Fish and Wildlife Service (Appendix A).

Methods of Procurement

Subject to the statutory restrictions summarized above, birds may be obtained for research purposes from domestic or foreign commercial dealers, from private or governmental game-bird propagation farms, or by capture from free-living populations.

Commercial sources of domesticated as well as wild species of birds are listed in the National Academy of Sciences publication *Animals for Research*, 9th edition (Institute of Laboratory Animal Resources, 1975). Certain game-bird species may also be obtained from state or federal facilities. Inquiries should be directed to the sources identified in Appendix A.

Investigators requiring species that are not available from commercial or governmental sources must rely on capture from free-living populations. Capture techniques are too many and varied to be dealt with in detail here. A summary of common apparatus and methods is supplied by Taber and Cowan (1969), and Appendix D lists selected general and special methods, with references to the technical literature. Methods of capture must minimize the likelihood of injury to the birds. They must also offer protection from predators, debilitation, weather, and shortages of food and water. Traps, nets, and temporary holding cages or bags must be serviced frequently enough to assure that captive birds are not exposed to any avoidable distress.

Transportation of Captives

The Animal Welfare Act of 1970 stipulates conditions for the transportation of certain warm-blooded vertebrates (Table 1). Generally, it requires that shipping containers must be strong enough to protect the occupants from injury and large enough for them to assume a normal posture without crowding.

Large or fractious birds should be individually restrained by humane methods, as they are otherwise apt to injure themselves. The shipping containers must permit adequate ventilation and should be placed only where ventilation is assured and where the birds are protected from the physiological distresses from heat, cold, altitude, and exhaust gases. The container and its sanitary floor material, if any, must be clean at the beginning of transportation. When shipment is by common carrier, the container must be externally labeled with the names and addresses of the shipper and consignee and with the number and species of birds contained therein. Prior arrangements should be made to assure that the shipment is met by a laboratory representative as soon as it reaches its destination, thereby minimizing delay in delivering the birds to regular housing facilities.

RECEIVING PROCEDURES IN THE LABORATORY

A definite routine should be established for the reception of new stocks of birds and for their introduction into the research activities of the laboratory. The initial reception procedures should include the following:

- The shipment should be inspected immediately, and injured or sick birds isolated. Dead birds should be necropsied immediately or frozen for later necropsy.
- The birds should be immediately banded, tagged, tattooed, or identified to ensure individual recognition. General methods and information as to the proper sizes of bands and tags are provided by Taber and Cowan (1969) and by the North American Bird Banding Manual (U.S. Department of the Interior, 1972). Special care must be taken when affixing bands or tags to young birds. The beak, wings, or legs may be mutilated by identification devices that do not allow sufficiently for growth. In some species, allowances must be made for the effects of molt (Jarvis, 1970).
- Care should be taken to assist newly received birds to adjust to cage conditions. Since each species or group of similar species presents individual problems, the only safe general guideline is that newly arrived birds should be watched carefully until any difficulties of accommodation are understood and solved. The most common problems involve injury sustained while attempting to escape from small cages; failure to find food and water or to adapt to artificial or strange foods; and injury or displacement from food and water by aggressive birds in the same cages. Injury can be minimized by temporarily covering the cage with cloth. With certain species, merely covering the top of the cage with a sheet of newspaper sharply reduces attempts to escape. The search for food and water can be aided by scattering a mixture of laboratory food and, if possible, natural or seminatural food on the floor of the cage and supplying water in open dishes, then replacing them gradually with laboratory food and water delivered from standard cage appliances. The effects of aggression in aviary flocks can be reduced by providing several feeding and watering stations or, if necessary, by isolating particularly aggressive individuals.
- A new shipment, if not previously quarantined, should be isolated for an appropriate period of time in an aviary or other facility apart from the general laboratory stocks (see pp. 37–42). Shipping containers should be treated to prevent the transmission of infectious diseases.
- An individual record should be kept for each bird including data as to origin, species, sex, age, tag or band number, records of health, therapy, immunization, experimental history, and ultimate disposition. These records are necessary not only for effective laboratory management, but also to facilitate preparation of reports to state and federal

regulatory agencies. It is so important that information on species, sex, and age be accurate that the methods for obtaining it are dealt with in the next section.

DETERMINATION OF SPECIES, SEX, AND AGE

Species designations such as "gull," "quail," "duck," and "wild canary" are not uncommon in the technical literature, but are too vague to be useful in comparative biology. A research animal must be defined as fully as possible, not only in connection with immediate investigation, but also for the unforseeable requirements of future investigators. An adequate preliminary characterization of a research animal must include at the least a record of species, sex, age, body weight, and genetic strain or geographic origin.

Identification of Species

Because the diversity of species imported into the United States is increasing rapidly (Banks and Clapp, 1972; Clapp and Banks, 1973), the correct identification of research animals has become both more difficult and more important. Compared to other wild animals, the species of birds are undoubtedly the best defined and the easiest to identify. There are many good identification aids to assist even the ornithologically unskilled to identify most wild species correctly. A report of species identification must include in every instance the Latin name and may include the vernacular name; the vernacular name alone is inadequate. Investigators using wild birds should be aware that the scientific nomenclature may be changed from time to time in response to shifting taxonomic opinion and the rules of nomenclaturial priority. For example, the Zebra Finch, which is commonly used in the laboratory, was designated in the recent past as *Taeniopygia castanotis*, but is now named *Poephila guttata*. This case illustrates the point that whenever Latin synonyms are known they should be reported. In this instance, it would be written *Poephila guttata* (=*Taeniopygia castanotis*). Otherwise, much confusion can result.

Species identifications reported by commercial dealers and collectors are not always reliable. Indeed, it sometimes occurs that species in shipments including two or more similar species are represented as one.

Whenever there is doubt concerning correct species identification, the ornithological novice should obtain the aid of a skilled colleague or the advice of the curator of a major ornithological museum; in the latter case preserved specimens should be provided for inspection (Chapin, 1946; Mosby *et al.*, 1969).

Identification of Sex and Age

The sex of birds can be ascertained in all cases either by postmortem examination or by surgical inspection of the gonads (see p. 82). There are no reliable general guides for ascertaining sex by external inspection. Sex in some day-old galliformes and waterfowl can be ascertained by inspection of the cloaca. In many species the sexes differ obviously in size, coloration, feathering, integumentary appendages, or other attributes; in others, there may be no reliable external clues except during the breeding season, when the condition of the cloaca (Wolfson, 1954) or the presence of a defeathered brood patch (provided only one sex engages in incubation) are adequate indicators of sex.

Because the age of adult birds can be ascertained from external characteristics in some species but not in others, no adequate general guidelines can be provided. Characteristics of age (as well as sex) are summarized by Taber (1969) for some North American game birds and by Wood (1969) for other wild species. A reasonably accurate method for estimating age in young songbirds (Oscines), either at necropsy or by simple surgery (Miller, 1946), is to examine the extent of pneumatization of the cranium (e.g., Serventy *et al.*, 1967). Incomplete pneumatization usually indicates that the bird is less than 7–8 months old.

Genetic Lines or Geographic Origin

Because of the strong, but frequently ignored, likelihood of functional differentiation among genetic lines or varieties of domesticated birds and among distinct geographic populations of wild species, it is important to specify as fully as possible the genetic history or geographic origin of birds used in the laboratory. For wild species this information may be augmented by reporting subspecific identity, if any, when such subspecies can be ascertained by an expert.

II HOUSING (HOLDING, BREEDING, AND EXPERIMENTAL)

Although, conceivably, any species might be kept, and even bred, in captivity, only those persons or institutions prepared to make a major commitment should attempt to keep any but the most commonly utilized forms.

Housing is frequently the most demanding and expensive aspect of a captive-bird program. The New York Zoological Park began exhibiting stilts (*Himantopus* sp.) in 1899 but did not successfully breed them until 1965. The most significant change during this 66-year period occurred in 1964, when more appropriate housing was provided. In the absence of satisfactory housing, all other improvements in care during those years were insufficient to induce breeding. Similar experiences with other species have occurred frequently. Although impressive longevities are often achieved in minimal facilities, birds so housed are seldom fully representative of their species either physiologically or behaviorally, whether for propagation or as subjects for investigation.

In the simplest terms, housing must protect and reliably confine the birds. Although the diversity of species requirements makes species-specific housing instructions impractical, there are both theoretical and practical guidelines that facilitate planning. Obviously, the goal of each specific research program will strongly influence the selection of housing.

Bird housing includes both open and covered enclosures and, where the weather is inclement, indoor and outdoor enclosures. Basic facilities are: paddocks, cages, bird rooms, aviaries, ponds, lakes, and water pens. Because Kasparhauser facilities, navigation cages, wind tunnels, activity cages, and the like are primarily investigative aids rather than basic housing, they will not be discussed here.

After ascertaining which species are to be kept, the investigator should first visit installations where the species, or related forms, are already maintained within a similar climatic zone. The curators of several major U.S. collections (see Appendix B), which house representatives of nearly one-eighth of all the species, are excellent sources of up-to-date information on bird care. Zoos frequently have enclosures whose designs can be adapted for specific purposes.

GENERAL CONSIDERATIONS

The first step in the design of bird housing is the identification of the requirements that must be met. For the most part, research using species that are not commonly maintained and bred should be avoided by all but the most experienced individuals, because information is scant and the likelihood of running into difficulty is substantial. The literature concerning each species to be housed must be examined to identify the factors that may influence housing: i.e., photoperiod, temperature and humidity preferences or requirements, vegetational and substrate associations, social and behavioral patterns, and avicultural history. Housing should be adapted to the bird, not the bird to the housing.

When research objectives permit, wild-caught birds should be housed in ways to minimize stress (change). The individual bird's performance of regular maintenance activities—eating, drinking, preening, and defecating—must be a principal concern, since the period of adjustment to captivity is directly proportional to the degree of adjustment imposed. During this period, little normal behavior will be evident. For example, even the most spacious aviary, if it lacks adequate cover, will not satisfy the needs of skulking towhees; woodpeckers will not nest in bushes, nor thrushes in hollow trees.

The success of bird housing depends on the sources and histories of its specimens, as well as physical provisions. Birds reared in captivity are usually to be preferred, because their previous care and housing may be easily imitated and little time is lost during their acclimatization to new quarters.

As in nature, captive immature birds tend to be more susceptible to inclement weather, so that the age of specimens is a factor to consider in drawing up housing plans. Species with a history of successful reproduction in captivity usually breed more readily than others in comparable housing. Care should be taken to avoid breaking up pairs of birds, such as geese, that establish long-lasting pair bonds (see Chapter V).

SPECIFIC GUIDELINES

Location of Enclosures

Whether considering laboratory cages designed for physiological studies of canaries or spacious paddocks in which to propagate cranes, freedom from disturbance should be a primary consideration in choosing a bird housing site. Zoo birds soon learn to ignore the constant presence of visitors as long as they are prevented from encroaching on the birds' enclosures. Captive birds that are seldom visited often remain highly sensitive to disturbance and sudden noises.

Obviously, it is important to segregate quarantine areas (see pp. 37–38) as well as food delivery and waste disposal areas, which are often serviced by nonprogram personnel.

Design of Enclosures

The living space within a bird enclosure must conform not only to the requirements of the research but also to species' needs. Simple box cages may suffice for temporary holding or quarantine, but many programs demand a fuller behavioral spectrum and even reproduction (see pp. 55–57). The design and quality of housing will determine the degree of normal behavior that may be expressed and even how much area in absolute terms will be needed to carry out the work. Many living space factors should be considered in designing enclosures for reproduction or behavioral studies.

- The practical effectiveness, size, and conformation of a bird enclosure is influenced by its interior design. A relatively small, heavily planted aviary can house more birds successfully than a larger, but comparatively bare, enclosure. Height and shape are also important, since many species of flying birds are excessively stressed when confined in low-roofed aviaries. Aviaries should be high enough to permit their inhabitants to fly above their keeper's head. Recently, aviculturists have experimented with aviaries of unusual configuration, such as C-shapes and L-shapes, in an attempt to provide natural barriers for the establishment of territories. Interconnecting aviaries or enclosures should be considered wherever intensive management is expected. It is better to shift a bird from one enclosure to another by "herding" it than by risking the trauma of netting or trapping.

• The interior equipment of a bird paddock or aviary should meet the needs of the proposed research. Imitation of nature will help ensure success. For example, a bird that in the wild requires vertical sticks approximately 1 cm in diameter and 1 m high as the platform for its courtship displays must be provided with something very like this in captivity if normal display is to occur. Again, a grebe that requires emergent aquatic vegetation upon which to rest its floating nest may never adapt to substantially different circumstances. In zoos, natural cage substrates have proven highly significant in inducing breeding in wild-caught ground-nesting birds.

—Daily behavior patterns must be considered when planning cage equipment. For example, a species that customarily roosts in tree cavities should be provided with comparable retreats. Roosting perches and cavities, as compared to other perches within an aviary, should be high and well sheltered. At night, birds may select a high perch in an unsheltered spot in preference to a sheltered perch that is lower.

—Perches should be of wood and of a diameter comfortable for the bird's foot.

—Ponds and lakes should be constructed with gradually sloping sides (unless species with special adaptations are concerned) to facilitate egress from the water, especially for land birds that accidentally fall in. Bird ponds must constantly overflow to remove surface scum and oils. This is particularly important wherever fish or other food containing oils are fed. Otherwise, birds may become seriously oiled. Where underwater viewing is called for in the research, collaboration with a nearby zoo or aquarium is advisable. Enclosures that provide this capability are exceptionally expensive.

Not only are pool shape, position, and size often species-specific, but water depth must also be planned carefully. Factors to consider are water flow, character of bottom, ease of cleaning, and freedom from freezing. Air compressor systems developed for marinas are now used in waterfowl collections to maintain year-round open water even in very cold climates. Such systems are most effective in water 2 m deep or more.

• Exposure to wind, rain, snow, sun, and shade must be considered when planning outdoor enclosures and aviaries. A sunny southwest exposure would be desirable for aviaries housing tropical pigeons in a north temperate climate, whereas the cages should be open towards the cooler northeast if they were to be used for ptarmigan. Generally, however, aviaries should be situated so that their occupants are protected from prevailing winds. Shade is also important for most birds; if it cannot be provided by natural vegetation, two or more areas should be suitably covered. The need for shelter from rain and snow is species-specific (see "Construction of Enclosures," pp. 17–21).

• Duplicate life-support facilities are essential in bird housing. Dominance behavior may prevent confined birds not only from sharing feeding areas but also from obtaining adequate shelter and roosting sites. Therefore, aviaries should be designed with several separated feeding places. The number of separate life-support facilities depends upon the social patterns, species, and number of birds involved. Conflict is usually most severe between conspecifics.

Temperature, humidity, ventilation, and air-filtering must be carefully managed in indoor enclosures. Because ventilation is related to heat loss, air movement should be increased whenever temperature is increased. Successful zoo exhibits, housing a wide variety of species, have from 3 to 15 air changes per hour. Drafts, pockets of dead air in the enclosures, and sudden temperature changes should be avoided. Although many temperate and tropical birds seem comfortable at 22°C, temperature requirements may be crucial so far as high-latitude and some high-altitude species are concerned. Northern alcids, such as *Lunda cirrhata* and *Uria aalge*, have been successfully maintained at the New York Zoological Park at a year-round temperature of 1°C. Although deep-polar penguins, such as *Pygoscelis adeliae*, have been maintained at the same temperature, the birds attained better condition and bred consistently when the temperature was lowered to 4°C and appropriate photoperiods were instituted.

Little information is available on species-specific humidity factors in aviculture. As a general rule, most aviculturists seek to maintain conditions comfortable for man, between 45 and 70 percent relative humidity. High-latitude birds, such as penguins, alcids, and even gyrfalcons, are especially susceptible to airborne diseases. Successful housing for these species usually includes spore filters. A positive air pressure should be maintained within their enclosures to reduce influx of unfiltered air.

Aviary size, both indoors and outdoors, significantly affects cage climate. Large enclosures tend to provide a considerable variety of microclimates, which allows the birds an opportunity for some selection; climates in small cages must be more carefully controlled.

• Although flooring in outdoor aviaries and paddocks is usually earth, sand is to be preferred whenever frequent cleaning is necessary. Indoor aviaries may be floored with sand, gravel, earth, cement, outdoor carpeting, or various commonly used litters. Dust levels, cleanability, and the likelihood of its causing digestive upsets are factors to be considered in choosing litter.

• Day length is known to be important in bird reproduction (see "Photocycle," pp. 58–59). Advancing day length with artificial light has been successfully used to bring cranes into reproductive condition. It is less commonly recognized that diurnal equatorial species kept at high latitudes may lack sufficient feeding time when winter days grow short. Provision should be made for extending day length with artificial light and time clocks when handling small tropical species, which have rapid metabolism. These measures may be employed in outdoor paddocks as well as within aviaries and bird rooms. When photoperiod is adjusted to aid feeding it may, at the same time, either induce or suppress cycles of reproduction and molt, depending on the species and the photoperiodic regime. Because the photoperiodic control processes in birds are very diverse, guidelines on this subject are lacking. An expert avian photobiologist should be consulted before tampering with the natural photoperiod.

Captive birds tolerate a wide range of light intensities. Even sunbirds (Nectariniidae) have been bred in cages whose floor-level lighting rarely exceeded 10 footcandles. Under crowded conditions, reduced light intensity may be employed to control cannibalism.

The effects of the spectral quality of light cannot be predicted for a particular species, but colored skylights are not to be recommended. Artificial lights for bird rooms and aviaries that lack substantial sources of natural light should produce a spectrum resembling that of natural light. The spectrum produced by white incandescent lamps approximates that of natural light more closely than does fluorescent light. Special wide-spectrum fluorescent lamps are now commercially available that approximate daylight more closely than do the more familiar "cool-white" or "warm-white" fluorescent lamps.

• Protection from other birds, especially conspecifics, must be considered at an early stage in planning housing for many species. Visual barriers between adjacent aviaries or cages are usually sufficient, but acoustic isolation may also be needed to avoid stress or to meet the needs of a particular experimental design.

• Predators, from rats to raccoons, are a challenge to anyone designing enclosures (see "Construction of Enclosures," pp. 17–21).

Service and Features

A daily management routine should be carefully planned before housing design is completed. While the care of laboratory-type cages is straightforward and designs are usually conventional, large aviaries, bird paddocks, and ponds may well be complex.

- Access doors in large enclosures should be placed to assure service with a minimum of disturbance to the birds. For example, food may be introduced on shelves through special feeding doors at heights best suited to the species housed in the enclosure. Waterers may be serviced in the same way. Sliding doors should be used rather than the hinged ones.
- Often, aviaries can be designed so that most cleaning can be accomplished by hosing from the outside. In any event, the location of drains and the surface grading, whether the aviary has a washable floor, utilizes deep litter, or has a planted earthen substrate, are difficult to change later and should be planned with maintenance uppermost in mind.
- Whenever regular keeper service inside the enclosure will be necessary, a well-defined service route that avoids nesting and roosting areas should be planned.
- Comfortable observation points should be incorporated in the design and so arranged that no part of the enclosure is hidden from the observer. In addition, each bird enclosure should have holders for record sheets and cards near the keeper's service door.
- Whether cages are large or small, bird management is enhanced when provisions have been made for shifting birds without capture. As regards laboratory-type cages, this may require only a sliding partition. In aviaries and paddocks, interconnecting doors are necessary.
- Government regulations should be consulted when it is proposed to house potential pest species, with special regard to double doors and other escape-resistant features. Aviaries and bird rooms should be kept locked and access carefully restricted. Windows and ventilators must be carefully screened.
- Protrusions such as faucets, pipes, lock hasps, doorknobs, light fixtures, or ventilating fans are potential hazards. A protruding wire or nail may seriously injure a large bird, even in an open paddock, if it extends into the bird's living space. Birds have been known to be injured by perching upon hot water or steam lines. Where such objects cannot be recessed, they should be shielded.

Construction of Enclosures

• The structural materials used in bird enclosures and aviaries are simple. Unprotected wood must not be used in enclosures for woodpeckers, or any but the smallest psittacines, unless there is provision for frequent replacement. Materials that exude toxic substances, or living plants that contain them, must be avoided. Treated woods must be used with caution, if at all, where birds like psittacines or woodpeckers are to be housed. Clear glass or plastic should be soaped when new birds are introduced to prevent their flying into it. The soap may be gradually removed as the birds become familiar with their confines.

• Open paddocks, ponds, lakes, water pens, or other enclosures without tops are commonly used for normally flightless birds, such as ratites, and for birds that have been rendered flightless (i.e., pinioned). Because open-topped enclosures do not involve roofing, it is possible to provide large spaces and appropriate environments for pinioned pelicans, flamingos, screamers, ducks, geese, swans, cranes, and coots. However, such restraint is not advisable for species that do not normally spend most of their time on the ground.

Fences surrounding enclosures of this kind may need to be as high as 2.5 m to restrain such large species as cranes; a 1.5-m fence will confine most waterfowl. Fences often extend from the shore out into lakes to create water pens. If wind and topography are favorable, pinioned cranes and even tree ducks (Dendrocygninae) may occasionally clear a high fence.

Fencing may be of hexagonal, square, or cyclone-type mesh, sufficiently fine to confine chicks if the enclosure is to be used for breeding. Mesh can be as large as 5 cm if the lowest 45 cm of the fence is covered with a fine mesh wire. Vinyl-coated steel fencing and galvanized fencing are usually employed for bird enclosures. Near saltwater, vinyl-covered fabrics should be used. Inexpensive plastic netting has now become available and may prove useful for temporary enclosures.

Fencing should extend 50 cm below the substrate level and then turned out an additional 30 cm if there is any danger from digging predators. Raccoons and cats may be dissuaded from entering open-topped enclosures by a double row of electric cow guards mounted according to the manufacturer's instructions, set about 60 cm and 120 cm, respectively, above ground level on the outside of the fence. Birds susceptible to the attacks of raptors should not be kept in open-topped enclosures.

Few birds regularly held in open-topped enclosures will voluntarily seek shelters in inclement weather. Where climate makes it necessary to provide a heated shelter in certain seasons, it should be so positioned that its doors open along a fence line. It will then be relatively easy to herd the birds into the shelter. Commonly birds are fed in the shelter as winter approaches so that they become accustomed to it and enter it readily.

Shelter buildings should be sited so that they open away from prevailing winds. Their design is dependent on species-specific considerations. Captive birds in open-topped enclosures are especially subject to competition from flocks of wild birds.

Open paddocks must include water sources, feeding areas, service entrances, and, where areas are large, a truck entrance. They should be low-density enclosures, requiring minimal cleaning (see "Sanitation," pp. 42–44).

• Outdoor wire-mesh aviaries, attached to indoor aviaries, which permit the birds to select either, are ideal for housing many species. The basic design is more than 300 years old and can be adapted to provide facilities for the vast majority of small or medium-sized birds. Commonly, they are designed to provide an indoor aviary space serviced from a keeper's passage. Small sliding doors giving access to the outside aviary are placed at a height appropriate to the species and operable by pulleys from the keeper's passage and sometimes from the outside aviary. Food and water, indoors and out, can be introduced through special doors in order to reduce the frequency with which the keeper must enter the enclosure. Both outdoor and indoor aviaries must also provide the essential life-support facilities. The outdoor aviary usually is thought of as the "breeding" area.

Partitions between indoor aviaries may be solid or of wire mesh. Translucent fiberglass partitions help maintain light levels and prevent fighting but make it more difficult to heat the shelter area. Outdoor aviaries, which are usually more spacious, need not have solid partitions except where ground-nesting birds are housed. In that case partitions should be solid and high enough to prevent the birds from seeing each other.

Where solid partitions are used, heating is usually provided by hot water radiation. Perimeter and radiant heating may be used, as well as forced hot air. The birds must be carefully shielded from heating elements. Where open-mesh partitions permit free circulation of air, inexpensive unit heaters are frequently practicable. The keeper's passage should be well drained and easily cleaned. The bird enclosures should be adequately lighted to permit observation of the birds through the wire mesh.

Outdoor aviaries must be planned with pests and predators in mind.

Wire mesh 1.5 cm or smaller is necessary to keep out mice, which are especially troublesome in aviaries, particularly where seed-eating birds are kept. Good sanitation is one of the best defenses. Rats are capable of killing birds their own size and frightening even larger birds. Aviaries without solid concrete floors can be protected from rats by excavating the entire bottom and securely covering it with 1.5-cm galvanized heavy gauge hardware cloth firmly affixed to the sidewalls, then refilling with soil or litter. Outdoor aviary structures must be strong enough to withstand the weight of accumulated leaves and, in cold areas, of snow.

In northern regions, aviaries strong enough to resist snow loads can be winterized by covering them with sheets of clear or translucent plastic. Although the resulting greenhouse effect provides a substantial amount of solar heat, artificial heat is also needed. Ventilation must be provided; a winterized aviary can quickly become an oven on a sunny day.

Aviaries in warm parts of the country usually do not require an elaborate indoor structure. A simple shed providing shade and shelter from rain and wind is usually sufficient.

• Holding cages can be used to keep birds under closely controlled conditions, or for limited periods. A variety of styles are available, the most popular design of which is the box cage. Closed on three sides, top, and bottom, it has a barred front with one or more sliding doors, a removable metal waste tray at bottom, and a number of perches, depending upon the size and species housed. Some box cages have special feeding doors on which to hang cups to hold food and water. (Larger water containers must be introduced for bathing.)

An enclosed box cage seems to afford the occupant more security and protection from drafts than does the typical pet-shop canary cage, which is open on all sides. However, needs differ; some species are seriously stressed by confinement within small spaces, whatever the design. Woodpeckers (Picidae), woodcreepers (Dendrocolaptidae), kingfishers (Alcedinidae), and trogons (Trogonidae) are often thus stressed. Birds of moderate size that should not be kept in box cages include the rails (Rallidae) and the Charadriiformes.

It is often helpful to provide a cloth or paper drape over the front of a box cage when settling a new bird within it. When a small bird must be transferred from a holding cage and it cannot be done through a shift door, covering the entire cage with a black cloth, to which a lightproof sleeve has been affixed, enables the keeper to reach in and gently remove the bird from the darkened cage without a struggle.

The box cage should be tall enough to permit the bird to perch well above the floor, yet have substantial headroom. While the proportions of box cages may vary, their design should provide maximum distance from the perch or perches on one side of the cage to the other to permit space for exercise. If hanger-type feeding cups are used, perch support should not impede access to the feeders and waterers. A ledge, smoothly beveled into the side of the box, should overhang the lip of the metal waste tray to prevent feces from getting into the area around the edge of the tray,which is difficult to clean. The tray may be covered with litter or folded newspaper. Plastic outdoor carpeting or artificial turf, which may be hosed off, is often practical. The entire cage front should be easily removable for occasional but thorough cage scouring and disinfection.

Box cages are usually made of wood, with metal fronts, but fiberglass construction is more durable.

• Bird rooms usually contain holding or box cages, although they may contain sizable aviaries. These rooms provide controlled conditions of light, heat, and ventilation for individuals or groups of birds in a series of segregated enclosures. In this type of facility, the usual veterinary hospital procedures for sanitation and pest control should be made. Where holding cages are frequently used, adjustable racks or shelves are advantageous.

Bird-room layouts should provide for separation of bird areas from food preparation or other maintenance activities. A keeper should make his or her presence known before entering the cage so as to avoid startling the birds. Where breeding is planned in bird-room aviaries and space is restricted, it may be wise to cover the fronts of the aviaries with opaque material to provide more seclusion. Small special feeding and watering access doors are useful under such conditions. Where box cages are kept on racks, the open sides should not face each other. The cages should be placed at heights convenient for observation and servicing. Bird rooms should have a dim night-light on at all times. Other essentials include a slop sink, a burner, worktable, hose petcocks, and good drainage.

• Food preparation, heating equipment, and storage and service areas should be isolated from bird housing. The checklist below includes items to be considered in planning. Storage capacity should accommodate the amount of food and other materials needed for at least 1 month.

—Kitchens, including sink, hot and cold water, refrigeration, food storage cabinets and bins, provision for food utensil sterilization, food preparation area

—Storage for cages, litter, construction materials
—Delivery area, easily accessible and well removed from bird areas
—Waste disposal area, well away from bird areas
—Utility room, furnace, hot water heater, tool storage, isolated from birds
—Personnel area, with lockers and a rest facility, record-keeping facilities
—Live food colony area, where mealworms or other live food can be reared for bird food
—Quarantine area, for isolation of new birds (see pp. 37–42).

III NUTRITION

Information on nutrition and feeding practices related to commercial poultry production has not been fully exploited by those handling other avian species. At the beginning of this century, it was thought that grains alone were adequate for poultry. Later a mixture containing about 20 percent meat meal and 80 percent grains was routinely used as feed. Around 1920, 5 or 10 percent dried milk was added to the grain and meat meal mixture to supply needed vitamins. Later (1930–1940), requirements for minerals and other vitamins were determined. A parallel occurred in the late 1940's with regard to feeding of pigeons. At one time it was believed that pigeons could subsist largely on grain supplemented by Canada peas (*Vicia cracca*), but later it proved better to supplement the diets with protein, minerals, and vitamins.

Unlike poultry, for most birds reared in aviaries there is no economic incentive for rapid growth and a quick turnover of stock. Rather, because the main goal is longevity and sustained breeding, the philosophy of feeding is very different (Kratzer, 1971).

DIVERSITY OF FEEDING ORGANS

The diversity of avian feeding organs constitutes a unique management problem. The beaks of birds have evolved to accommodate a number of foods. For example, the cockatoo (*Cactua* sp.), a seed eater, has a hooked beak that acts as a powerful and efficient nutcracker, yet the bird's tongue is supple enough to extract the kernel from a cracked nutshell. Certain birds have beaks adapted to breaking open oyster shells, while other species have beaks more capable of spearing prey. Flamingos feed on organic matter found in mud; their curved bills are lined with hairlike laminae that filter out and retain minute plants and animals. Insect gleaners characteristically have short, thin beaks. The broad flat bills of swallows and flycatchers facilitate the capture of insects in the air. Predators such as hawks and owls have strong, hooked beaks adapted to tearing flesh into pieces small enough to swallow; some species are capable of swallowing whole mice and other small rodents. The bills of hummingbirds are adapted to plucking arthropods from cracks in bark, and their tongues are long and tubular, suitable for extracting nectar from flowers. The woodpecker's tongue is very flexible, enabling it to penetrate deep into holes to retrieve invertebrates.

Basic information on digestion and the avian digestive system is helpful in planning a feeding program (see Farner, 1960, and Ziswiler and Farner, 1972, for excellent reviews). A major feature distinguishing avian from mammalian digestive systems is the reduction of the anterior parts to the minimum required to procure food. A light horny beak replaces teeth; the jaw has a relatively lightweight, fragile skeleton and correspondingly less bulky musculature. The long esophagus is large in diameter and may have a storage as well as transfer function. A gizzard is usually present. Beyond the gastric area the avian digestive system does not differ greatly from that of other vertebrates.

REQUIREMENTS FOR SPECIFIC DIETARY COMPONENTS

Water

The three main sources of water available to the birds are free water, water contained in ingested food, and water produced during oxidative steps of intermediary metabolism. Requirements for free (not metabolic) water vary greatly, even for land birds (see Bartholomew and Cade, 1963). The weight of water consumed per day may vary from zero, in the case of some xerophilous birds, to two or three times that of the feed consumed, as in the case of gallinaceous birds fed commercially prepared feeds. Bartholomew and Cade (1963) point out that the water requirement of a given species is related to such physical factors as ambient temperature and humidity, salinity of drinking water, and composition of food. The impact of these factors is affected by physiological capacities as related to pulmocutaneous water loss, water loss in feces and urine, capacity for osmoregulation and electrolyte excretion, and capacity for tolerating dehydration and/or high blood viscosity.

Water should be available at all times. It should be fresh, clean, and free from excessive minerals. Large-capacity automatic waterers are suggested as a way of economizing on labor.

Some seabirds are subject to salt depletion in captivity. These birds have large supranasal salt glands that supplement renal salt excretion. When stressed, birds involuntarily overexcrete salt from the supranasal glands. If they do not replenish the salt through water or food intake, their condition rapidly deteriorates. On the other hand, after ingestion of oil (e.g., after being caught in an oil slick), the supranasal glands may not function properly. Birds in this condition should not be given saltwater until the glands return to normal.

Energy

The energy requirements of birds are customarily met by providing carbohydrates, fat, and proteins in proportions approximating the natural diet. The amount of feed consumed by birds is influenced by its energy content and the ambient temperature. During colder weather, birds require a much higher percentage of their feed as carbohydrates. If given a choice of individual feedstuffs, a number of bird species may not voluntarily select adequate diets, because they are greatly influenced by their previous experience and training.

Protein and Amino Acids

In a mixed ration most of the proteins are derived from oil-bearing seeds or from meat meal or fish meal. As to amino acid balance, that of grain may be inadequate. For example, corn, while a good source of carbohydrates, is low in tryptophan and lysine. To insure amino acid balance, a variety of protein sources may be used. An outright deficiency may well result in lower reproduction and poorer feathering. The protein content of a ration must be higher for very young birds and for females during the breeding season. Many species that live largely on fruits, nectar, and low-protein diets as adults customarily feed their young on animal matter, e.g., annelids and arthropods that are rich in protein. The protein content of rations given to growing birds of a long-legged or heavy variety should not be too high, otherwise rapid growth caused by the extra protein may result in leg weakness.

Nutritionists commonly express the nutritional requirements of birds in terms of energy, protein (amino acids), minerals, and vitamins. In general, the amino acid requirement of birds decreases as the growth rate slows with age.

Requirements for certain domestic species have been exhaustively studied. Those for chickens (Subcommittee on Poultry Nutrition, 1971) include 11 amino acids, 13 vitamins, and 11 minerals. The amino acid requirement for other species, where known, is very similar. A number of commercial species require 25–30 percent protein for rapid growth. The duck, which has a lower protein requirement, is an exception; protein requirements of 17 and 15 percent are typical for young and adult ducks, respectively (Coles, 1960). The vitamin and mineral requirements are minimal in adult birds that are in a nonreproducing state. It is, therefore, important to avoid overfeeding.

Because ingredients contributing protein are usually the most costly part of a diet, it is desirable to provide an adequate, but not superfluous, amount. The protein requirements of the domestic coturnix (*Coturnix* sp.) illustrate differences often encountered: young, 25 percent; adult maintenance, 16 percent; and adult breeding, 20 percent (Vohra, 1971). Representative feeds used in the diets of selected species are summarized in Appendix C.

Minerals and Vitamins

Minerals have many functions; they are necessary for skeletal bones, regulation of osmotic activity and pH, transport of oxygen, and activation of enzyme systems. The young have more exacting requirements than adults. Mineral deficiencies may be manifested by leg weakness, loss of feathers, and other symptoms.

The calcium requirement varies with the sex, age, and state of reproduction. For example, in chickens (*Gallus* sp.) the requirement for calcium is lowest in the male and highest in the laying female; 0.035 percent and 4 percent of the weight of the ration, respectively (Kratzer, 1971). The metabolism of calcium is linked with that of phosphorus, vitamin D_3, manganese, and zinc.

Phosphorus, as well as calcium, is a constituent of bone and is also important in the protein of the cell nucleus. It is associated with the transfer and release of energy and is involved in the metabolism of carbohydrates and fats. For poultry, the phosphorus requirement is approximately 0.75 percent of the ration weight.

Sodium chloride is usually added to commercial rations in the form of iodized salt, which also fulfills iodine requirements. The need for both phosphorus and sodium is presumed to be greatest in omnivorous birds.

Other minerals required by some species are: magnesium, potassium, manganese, zinc, iron, copper, and selenium. Both mineral and vitamin supplements should be supplied regularly.

Seedeaters should be given grit for their gizzards. A hard insoluble grit with sharp edges is recommended; the size should be selected in relating to the size of the bird. It is more sanitary to provide grit in containers than to scatter it on the floor.

Vitamins other than ascorbic acid, as an integral part of enzyme systems, are required as a protection against metabolic disturbances. Vitamins can either be added to feed, or water-soluble varieties can be mixed in the drinking water. Commercial liquid vitamins are suitable for general use and therapy. The form of vitamin D required by birds is vitamin D_3.

FEED ACCEPTANCE

Sensory Detection

Ingestion is a very complex event involving not only the sensory organs, but many other physiological processes. Hunger and recognition of food are important to food acceptance, along with such factors as: color, odor, flavor, form, time of feeding, social factors, methods of presentation, and quantity and frequency of feeding.

The color of a diet may enhance its acceptance. For example, young ducks, swans, geese, and gallinaceous birds, as well as rheas (*Rhea* sp.), are attracted by green foods. Chickens drink more from blue water containers than from clear ones (Knoblock and Siegel, 1970). Gull and tern chicks will peck at red and orange patches on their parents' beaks.

Food odor is not usually important. Although some vultures (*Cathartes aura*), oilbirds (e.g., *Steatornis caripensis*), and kiwis (*Apteryx* sp.) are believed to locate food by its odor, most species do not seem to have a strongly developed sense of smell.

Food taste appears to have little to do with preference (with the possible exception of raptors), as most birds have few taste buds. In coturnix the taste buds are associated with the ducts of the salivary glands, which may account for their preference for a mild sugar solution over distilled water (Harriman and Milner, 1969). The ability to discriminate may be more important in feeding behavior when commercial diets are fed. Birds also rely on vision for food recognition.

Feeding Habits

The shape, size, and form of the food given to the bird are important. As yet, pelleted or compressed rations have not been widely used in feeding aviary birds. This approach should be considered where the composition of the feed and the size of the bird permit, since it prevents the birds from picking over the feed and eating the choice particles first.

Certain feeding drives must be met if conditions are to approximate the natural state. For example, the tearing beak of eagles, seed-cracking beak of parrots, and bill strainer of a flamingo must be kept in use, lest these structures overgrow. Again, food should be supplied to those species that tend in nature to eat frequently during the day in such a way as to occupy a substantial amount of time. The daily cycle of the species in question is important as it relates to the time of presenting food. Such nocturnal birds as owls will not eat until dark. Many birds feed in nature only on live, moving food. Highly insectivorous birds may be gleaners (e.g., warblers and vireos); others may be aerial feeders (e.g., swifts and swallows), pursuers (e.g., flycatchers), or probers (e.g., woodpeckers). It is difficult for the aviculturist to deal successfully with such a variety of feeding habits.

Social factors influence the feeding habits of birds. For example, chickens in groups eat more and gain more weight than when fed in isolation. Newly captured birds are more readily induced to feed when placed with others of their kind. When birds are kept in groups, competition and territoriality must be considered in the dietary program. Feeding areas must be numerous and widely spaced. They must be so placed at different levels in the aviary as to simulate conditions encountered in nature by birds that dwell either on the forest floor or in tree tops. Specialized feeders can often be induced to change their feeding habits while in captivity, e.g., birds that normally feed in the air may be taught to feed on the ground. Swallows, initially fed mealworms with forceps, will later eat live prey placed in a dish. Probers may be taught dish feeding. Live prey placed in a dish of dog food, chopped whole egg, etc., will often stimulate woodpeckers to feed.

Precocial chicks such as pheasants, quail, and ducks are relatively easy to feed in captivity. Semiprecocial chicks (e.g., gulls and flamingos) require some parental care. The greater flamingos (*Phoenicop-*

terus sp.) produce an esophageal fluid that is initially the sole source of nutrition for the chicks (Fisher, 1972).

The newly hatched young of altricial species, which include pigeons, parrots, owls, hawks, and all passerines, rely on their parents to deliver food to the nest. Substitutes for the predigested foods and crop secretions supplied by doves and pigeons range from infant formulas to slurries of chicken mash (Fisher, 1972). Young birds hand-reared in captivity require frequent feeding to ensure adequate growth. This may be once or more each hour depending on the species. The time required for the crop to empty can be determined by palpating it every 5 or 10 minutes, then averaging the crop-emptying time to determine a desirable frequency of feeding.

Techniques

Great care should be taken to ensure that feed is clean, fresh, free from contaminants, palatable, and nutritionally adequate. Unless husbandry conditions make it necessary, it is inadvisable to use coccidiostats, growth-stimulating levels of other similar materials, such as antibiotics and arsenicals, or drugs for the removal of helminth infestation (Fowler, 1972).

Moldy food should not be used since some fungi produce compounds that are toxic. Feed should be stored above the floor in a cool, dry place away from vermin and pests. The cage food holder should be of metal or glass, suspended, and detachable.

The quantity of feed presented at one time varies greatly with the species. Such species as the Blue Tit (*Parus caeruleus*) will eat up to 30 percent of its body weight in 1 day. The large food intake of hummingbirds is related to the dilute nature of their food and their high energy requirement. Some small birds feed without interruption during the daylight hours and may suffer during short-day seasons unless additional lighting is provided. On the other hand, a number of species can survive fasting for a remarkably long time. Some marine and gallinaceous species can fast for a week or more while incubating their brood and during the molt cycle.

Weighing the birds at regular intervals will show if feed intake is sufficient. Some birds need their feed restricted. In poultry, feeding may be omitted 1 day per week without decreasing egg production significantly (Abplanalp, 1958). The Honolulu Zoo adopted this practice for birds of prey with the result that the birds seem to have better appetites and to be healthier.

Frequent presentation of food appears to stimulate feeding activity, particularly in insectivorous birds. Mechanical feeders can be used to facilitate this effort.

Various procedures are effective in persuading certain species to eat. For example, most diurnally active birds tend to move from dark areas toward the light, where the food areas should be located. Such fish-eaters as grebes and loons can be taught to eat by first providing deep crocks full of water and a few live mosquito fish. Then, when they begin to stab at the live fish, dead mackerel, white bait, etc., can be dropped in, which the birds will eat in the excitement. Within a couple of days the birds will be weaned over to the dead food. Some raptors that refuse dead food will accept live baby rats. Accipiters, primarily bird-eaters, will often accept rodents if the animal has been slit open, exposing red meat. Often, small birds can be induced to eat by masking their cages so the only available light filters through the feed container. Many insectivorous birds gradually accept moist food when meal-worms, crickets, maggots, wax moths, and other live insects are added to the mixture of feed and water. Most birds will drink even when they will not eat, so it is possible to supply nutrients in liquid form. As a last resort, forced feeding may be necessary.

Special difficulties may arise in dealing with species that have fixed feeding habits or with birds captured as adults. If, for example, the natural food is a particular genus of mollusk or insect, it may be necessary to force feed the bird for a long time before it learns to pick up food itself. On occasion, problem feeders can be induced to accept a substitute diet, thereby avoiding forced feeding. For example, grebes can be tricked into eating small bits of fish by fluttering one's finger in front of a bright light directed on the dish, such that shadows flicker about. Apparently, the grebes perceive this as swimming fish, where-upon they stab at and eat the pieces. Other special problems should be solved in like manner, where possible, since forced feeding brings about appreciable stress.

Although the digestive systems of birds of prey can manage such roughage as fur, chitin, and bones, the desirability of adding roughage to their ration in captivity is questionable.

To cut costs, zoo birds are often fed commercially prepared dried dog food supplemented occasionally with such natural foods as greens and mealworms.

Captive hummingbirds do not thrive if fed only an artificial nectar; however, the addition of a water-soluble protein concentrate in quantities similar to those found in natural nectar (e.g., Super Hydramin® or Kalamino®) increases life expectancy (Fowler, 1972).

FEEDSTUFFS AND MIXTURES

Artificial Feedstuffs

The food habits of birds are most often discovered by observing them in their natural habitats and examining the contents of their crops. Their food frequently depends on the seasonal availability. The Ruffed Grouse (*Bonasa umbellus*), for instance, eats substantial amounts of fruits and insects in the summer, but subsists primarily on buds and twigs in the winter and early spring. Leaves constitute about 10–15 percent of the crop contents throughout all seasons (Bump *et al.*, 1947). Aviculturists should take advantage of seasonal variability in food habits to substitute commercially prepared foods.

In the following discussion, food for birds is primarily treated as the mixed ration rather than as individual ingredients. Space limitations preclude extensive detail. Tollefson (1969) and Fisher (1972) should be consulted for a more comprehensive account of bird nutrition.

Poultry starter rations are entirely suitable for growing pheasants, quail, and partridges. Some zoos do not mix their bird feed, but purchase it from commercial suppliers. These feeds are usually formulated for a specific purpose and are available as mash, crumbles, or pellets. Because mash feeds are dusty, they are less acceptable. Although pellets cost more, they reduce waste by birds and loss from wind.

The nutrition of commercially raised pheasants and Bobwhite Quail (*Colinus virginianus*) has been reviewed by Howes and Beane (1966) and Scott (1966). The nutritive requirements of mallards (*Anas platyrhynchos*) are summarized by Ewing (1963). Pellets are especially economical in feeding ducks, saving up to 3 percent over the feeding of dry mash (Orr, 1969).

Natural Feedstuffs

Natural and seminatural feedstuffs that may be accepted by birds include such seeds or grains as sunflower and millet, given either individually or in a mixture. Cereal grains are also extensively used.

Fruit-eating birds are ordinarily given fruits that are seasonally available locally—apples, oranges, and papaya are examples. Meat-eaters are usually given either live or freshly killed rodents or chickens. Some meat-eaters, especially scavengers, prefer the meat ground or cut into chunks.

Invertebrates that may be offered in limited amounts to birds in aviaries include fruit flies, mealworms, bee larvae, termite larvae, and earthworms. Fishing crickets, wax worm larvae, and fly maggots are also suitable for feeding certain bird species. Information on rearing of mealworms has been provided by Ficken and Dilger (1961) and Bates and Busenbark (1970). A technique for harvesting honey bee larvae for bird food can be found in Gary *et al.* (1971). During most of the year, night-flying insects may be trapped with blue-light insect traps and fed on the following day.

The pigment content of feed is important to those species wherein the pigments or their derivatives are transferred to the bird's feathers, beak, shanks, and flesh. Such birds as flamingos, ibises, tanagers, and woodpeckers become pale if their feed does not contain the red, orange, or yellow carotenoid pigments. Many diets used in U.S. zoos include foods containing pigment, i.e., carrots, alfalfa, dried brine shrimp, and red pepper. Certain synthetic pigments, such as canthaxanthin or commercial xanthophylls, may also be used. In some species that have melanin pigment, a deficiency of lysine may result in the bleaching of normally dark wing feathers.

Choices of Diets

The form and composition of food are important considerations. No one diet is best for a single species. Commercial poultry rations, especially those for turkeys, or canned balanced dog foods are suitable for raising birds of many species. Some zoos are using commercially prepared dry dog foods supplemented with such natural food as greens and mealworms. These feeds have obvious advantages: reduced likelihood of error in preparation, uniform composition, moisture stability, choice of diet appropriate for particular ages and reproductive states, and minimal need for inventory and mixing facilities. Thus, many prefer to use commercial rations. Two diets extensively used in U.S. zoos are Zu/Preem raptor diet* and Purina Trout Chow.† Doubtless, other commercial rations may be used successfully.

Newly caught raptors often refuse to accept prepared food. In addition to the suggested diets for carnivores, Zu/Preem fresh-frozen diet for birds of prey has been used for Golden Eagles (*Aquila chrysaetos*), Prairie Falcons (*Falco mexicanus*), owls, and other

*Hill's Division, Riviana Foods, Inc., P.O. Box 148, Topeka, Kansas.
†Ralston Purina Company, St. Louis, Missouri.

TABLE 2 Typical Diets Including Supplements Fed Representative Birds

	Omnivores Diet O1, O2, or O3	Supplemented Diet S1, S2, or S3	Carnivores Diet C1, C2, or C3	Vitamin Capsule[a]	Supplements						
					Greens	Prey	Fish	Seeds	Fruit	Pigment	Nectar
Tinamous	x				x						
Rheas	x				x						
Ostrich	x				x						
Cassowaries	1/2		1/2		x						
Penguins				x			x				
Cormorants				x			x				
Pelicans				x			x				
Waterfowl	x				x						
Flamingos		x		x	x		x			x	
Herons				x			x				
Storks				x			x				
Vultures[b]			x			x					
Hawks, eagles[b]			x			x					
Falcons			x			x	x				
Mound builders		x			x				x		

Guinea fowls	x				x					
Pheasants	x				x					
Coots	x				x					
Button quail	x				x					
Cranes	x	x		x		x	x			
Plovers			x							
Woodcocks		x							x	
Gulls, terns		x		x			x			
Doves	x							x	x	
Parrots, lories		2/3	1/3					x	x	
Barn owls[b]			x			x				
Owls[b]			x			x				
Swifts		x								
Hummingbirds										x
Kingfishers				x			x			
Woodpeckers		x								
Shrikes			x			x				
Wrens		x								
Crows, magpies		x	x			x			x	
Starlings		x				x			x	
Zebra finches		x			x			x		
Finches, canaries		x						x	x	
Sparrows		x							x	

[a]Such as multiple vitamins.
[b]Skip feeding for 1 day per week.

species in zoos, including the Fort Worth Zoo, Woodland Park Zoo in Seattle, and Cologne and Frankfurt zoos in Germany. Caution should be exercised when using commercial products to feed young birds of prey if their nutritional requirements are largely unknown and because the soft consistency causes difficulties. Purina Gamebird Breeders Layena,* mixed with equal parts of ground meat, is recommended for owls, hawks, and eagles. One should be very careful to adjust the amount of feed to the needs of the bird.

Although Purina Trout Chow,* 40 percent protein, is often used to supplement the feeding of anseriforms, which are difficult to maintain in captivity, the formulation of most diets is influenced by the cost and availability of the ingredients. Typical diets used in zoos have been published; mostly, they are either rations that have been tested in one or more zoos or that are judged on composition to be nutritionally adequate.

Three basic formulas have been used (see Appendix C): diets for omnivores, diets for carnivores, and supplemental or "enriched" diets for caged birds.

Special Diets

In addition to formulated diets, supplements are often necessary to keep many species healthy and productive, as noted above in connection with the nectar diets of hummingbirds and the pigments needed by several species. Although most birds like mealworms, impaction may occur in some species due to the chitinous material in the worms.

A summary of diets suitable for certain representative species appears in Table 2. The table lists supplements as follows:

- Multiple vitamin capsules
- Greens—lettuce, alfalfa, and cut grass
- Animal carcasses—mice, rats, rabbits, chicks, and pigeons should be provided birds of prey to stimulate their interest in ordinary feeds. (Pigeons and doves are carriers of *Trichomonas,* but if frozen seem to be safe.)
- Fish—smelt, herring, anchovies, mackerel, and such others as are available. Fish should be cut into manageable sizes for the species concerned and preferably supplemented with vitamins and minerals.
- Seeds—usually a mixture of seeds from millet, hemp, and certain

*Ralston Purina Company, St. Louis, Missouri.

grasses. One part birdseed mixed with three parts diet will often encourage birds to recognize and consume the food.

- Fruit—combinations of dried oranges, apples, bananas, lettuce, and other seasonal fruit, ordinarily in containers separate from that holding the main diet
- Pigment
- Nectar

IV HEALTH OF BIRDS AND PERSONNEL

Commonly regarded as rather delicate and fragile, birds are actually hardy creatures, remarkably resistant to most infectious agents and quick to heal if injured. Because they are also uricotelic and efficient in digestion of their foods, birds, except for a few frugivorous species, create few sanitary problems in confinement compared to most mammals. In short, if their nutritional, feeding, and housing requirements are fulfilled, most birds can be maintained indefinitely in confinement in good health and physical condition. This is one of the reasons that birds are good laboratory animals. Only when birds are stressed by experiment design, excessive crowding, undernourishment or malnutrition, exposure to extreme physical conditions, or improper caging, or during a particular experiment, are they likely to contract diseases or become debilitated by parasites.

Every investigator who keeps confined birds for study should strive to maintain them in the best possible condition consistent with his experimental design. Not only is there a moral obligation to do so, but research results can be seriously biased if the experimental animals are in poor health. While most investigators are not expert in the diagnosis and treatment of diseases or competent in small animal surgery, anyone who works regularly with captive birds should learn to recognize the common signs of sickness and weakened condition and know the rudiments of diagnosis, treatment, and surgery. The investigator should have some standard references on the subject. Two good ones are: *Diseases of Cage and Aviary Birds,* edited by Margaret Petrak

(1969) and *Infectious and Parasitic Diseases of Wild Birds*, by John W. Davis *et al.* (1971). Much of the following information has been taken from these two sources.

Any investigator who holds large numbers of birds should have veterinary advice and services readily on hand. If his institution does not have a veterinary college or a staff veterinarian, it is usually possible to find a private practitioner who will take an active interest in birds, often as a way to gain experience with this group of animals. Other sources of help are the special interest groups in which veterinarians take an active part. For example, the Raptor Research Foundation has a Pathology Committee consisting of several veterinarians who are experts in the diseases and ailments of raptorial birds. These committee members perform diagnoses, necropsies, surgery, and treatment of birds held by others in the foundation. Similar groups could no doubt be organized for other major taxa commonly held in captivity, e.g., parrots, doves and pigeons, waterfowl, gallinaceous game birds, finches, and sparrows.

PREVENTION AND CONTROL OF DISEASES

Davis *et al.* (1971) provide information on 27 avian diseases in five categories: viral diseases; bacterial, rickettsial, and mycotic diseases; parasitic infections; neoplasms; and toxins. Birds are also subject to nutritional and metabolic disorders, which have been summarized by Petrak (1969). It is impracticable to attempt here a detailed catalogue of the etiology, transmission, clinical signs, pathogenesis, pathology, diagnosis, and treatment of all these conditions, especially since these topics are well covered in the two cited references. Instead, certain general guidelines are provided, to be supplemented by basic sources of technical information on avian diseases and parasites as summarized in a short annotated list of references (see pp. 49–53).

Quarantine and Initial Examination

Before newly acquired birds are brought into contact with others already in confinement or before new birds are subjected to experimental conditions, they should be isolated and observed to determine whether any are diseased or otherwise incapacitated. The period of isolation depends on the specific requirements for quarantine (mandated by law in some instances). The quarantine room or area should be separated from the laboratory or main aviaries. If a separate building is not available, then a separate room or cage area may well suffice. Small birds can be effectively isolated from other birds in the same room by placing them in specially vented chambers in which the intake air is filtered and the excurrent air is exhausted to the outside of the building.

During quarantine each bird should be given a complete physical examination, especially if it is intended for long-term use in a permanent arrangement with other birds. The investigator may prefer to have a veterinarian do the examination on especially valuable birds, but if he is familiar with the normal anatomy and function of the species in hand, he should be able to detect any gross abnormality or malfunction, which can then be referred to a veterinarian for diagnosis and treatment. Chapter 9 by R. M. Stone in Petrak's (1969) book details the procedures. It is best to have a check-off sheet for each bird and to maintain a complete medical history from the time the bird is first acquired. A sample examination record is shown in Figure 1.

The key to successful, early detection of any disease or disorder is a thorough knowledge of the normal, healthy behavior; appearance; and anatomy of the species in question. Such familiarity comes only from repeated observations and daily contact with the subject, but when acquired, it allows recognition of deviations from the "healthy gestalt."

The keeper should check on the attitude and performance of all birds daily. Common and easily detected signs of disorder include: reduced food intake or less commonly, the reverse, hyperphagia; excessive drinking; inactivity, sitting with feathers fluffed out; sleeping during the day (diurnal birds); frequent bathing; excessive scratching or preening; excessive loss of feathers out of season; feather plucking; squinty or watery eyes; heavy breathing, gasping, smelly breath; shivering or shaking; droppings with abnormal color or consistency; nasal drips (not to be confused with normal salt secretion from the nasal glands); and disgorgement of food. There are many other indicators of malfunction—some are very subtle; others, such as the loss of equilibrium associated with thiamine deficiency, are obvious and need urgent attention. Table 3 lists some common lesions and diseases associated with them.

Any birds showing signs of sickness should be examined physically—in the hand—for lesions on the skin, in the mouth and throat, and around the eyes. If indicated, an oral specimen should be cultured for bacterial or other infectious agents, and another sample should be examined microscopically for trichomonads and other protozoa or microorganisms.

RECORD OF PHYSICAL EXAMINATION

Species ______________ Sex ______________ Name or No. ______________
Date ______________ Time start ______________ Time end ______________
Body Wt. ______________ Anesthesia, if any ______________

Head and Neck Region:
1. Feathers ______________
2. Skin ______________
3. Eyes and Lids ______________
4. Ears ______________
5. Nares and Cere ______________
6. Beak ______________
7. Mouth, Throat, Tongue ______________

Wings:
1. Primaries ______________
2. Secondaries ______________
3. Upper Coverts ______________
4. Under Coverts ______________
5. Other ______________

Back and Rump:
1. Feathers ______________
2. Skin ______________
3. Preen gland ______________
4. Tail ______________

Breast:
1. Feathers ______________
2. Skin ______________
3. Fat at rib cage ______________
4. Contour (Fleshiness) ______________

Belly:
1. Feathers ______________
2. Skin ______________
3. Palpation ______________
4. Cloaca ______________

Upper Legs:
1. Feathers ______________
2. Skin ______________
3. Muscles and Joints ______________

Tarsus and Feet:
1. Skin and Scales ______________
2. Talons ______________
3. Pads and Soles ______________

General Comments: ______________

Examined By: ______________

FIGURE 1

TABLE 3 Common Clinical Diagnoses of Birds[a]

Topographical Area	Symptom or Lesions	Possible Diagnoses
Head	Swelling	Trauma, pox, sinusitis, insect bite, stomatitis (granulomatous), abscess
	Ocular lesions	Conjunctivitis, vitamin A deficiency, trauma
	Abnormal nasal discharge	Rhinitis
	Nasal hemorrhage	Trauma or hypertensive rupture of blood vessels
	Mouth lesions	Trichomoniasis, capillariasis, stomatitis
	Fluid from mouth	Capillariasis or other mouth lesions
	Blood from mouth	Same as nasal hemorrhage
	Damp feathers on side of head	Otitis, trauma
	Head on one side	Otitis, trauma, encephalitis, or other nervous disease
	Blindness, complete or partial	Trauma, poisoning (especially chlorinated hydrocarbons), vitamin A deficiency
	Voice change	Syngamiasis, starvation, several other conditions
Wings	Wing hanging	Fracture; dislocation; "dropped wing"; tendonitis/arthritis; traumatic damage to joint, tendon, or ligament; osteodystrophy; irritant injection in pectoral muscle
	Blood on feathers	Compound fracture, skin wound, damaged young feathers
	Swellings	Fracture, abscess, bursitis
	Missing feathers	Molting, feather abnormalities
Legs	Porosis—swelling or displacement	Osteodystrophy, fracture, dislocation, bursitis, abscess including tuberculosis, edema
	Hemorrhage	Trauma or fracture
	Absence of feathers	Ectoparasites, feather abnormality
Feet	Swelling	Bumblefoot, arthritis
	Pale color	Low dietary xanthophylls (species with yellow or reddish feet)
	Localized lesions	Pox, bumblefoot, vitamin A deficiency

TABLE 3 Common Clinical Diagnoses of Birds[a] (Continued)

Topographical Area	Symptom or Lesions	Possible Diagnoses
Body	Swelling	Fracture, abscess, hematoma, neoplasia, impacted cloaca
	Soiling of cloaca	Enteritis
Feathers	Missing	Molt, trauma, nutritional deficiency, metabolic disorder, nonspecific factors
	Broken	Trauma, metabolic disturbance, nutritional deficiency
	Frayed	Ectoparasites, metabolic disorder
General	Dyspnea	Foreign body in upper alimentary or respiratory tract, syngamiasis, rhinitis, air sacculitis, aspergillosis, pneumonia
	Hyperpnea	Septicemia
	Anorexia	Overweight, several infectious diseases
	Dysphagia	Pellet not cast (predatory birds), foreign body, any condition affecting buccal cavity or causing dyspnea
	Regurgitation	Esophageal capillariasis or other crop lesion, gastritis, air sacculitis and certain other conditions
	Enteritis	Bacterial or parasitic infection, low-roughage diet, air sacculitis, unsuitable food, nonspecific factors
	Green feces	Low food intake
	Yellow feces	Previous administration of certain drugs (e.g., 2-amino 5-nitrothiazole)
	Dysentery and diarrhea	Coccidiosis, capillariasis, trauma, cloacal lesion (e.g., calculus)
	Nervous symptoms	Poisoning (especially insecticidal), vitamin B_1 deficiency, hypocalcemia, hypoglycemia, bacterial otitis or encephalitis, trauma

[a]Modified from J. E. Cooper, 1972

The same procedure should be applied to samples of excrement. These simple procedures will identify most of the infective ailments that afflict birds, excluding viruses. Analysis of blood samples for infective agents usually requires the assistance of a trained clinician. Nutritional diseases are also difficult to diagnose although they account for a large fraction of ailments in captive birds.

Prevention of Infectious Diseases

To minimize the incidence of disease in quarantine (isolation), an examination as outlined above must be routinely carried out, augmented by adequate sanitation and control of pests (vectors of disease or parasites). In general, the larger the colony of birds and the higher their density per unit of cage or aviary space, the more difficult it is to maintain adequate sanitation, pest control, and other disease prevention measures. Since most wild birds are not kept under extremely abnormal densities or spatial restriction, preventive measures are usually less demanding than is the case with small laboratory mammals or commercial poultry operations, where many thousands of individuals may be housed in one room.

Routine Examination In addition to daily inspection of the appearance and behavior of birds in confinement, each bird should receive a complete physical examination, in the hand, once or twice a year, following the same procedures used in the initial examination. Oral specimens and excrement should be examined microscopically and cultured if there is any indication of disease-causing agents. Whenever a bird shows symptoms of sickness or physical debility, it should be isolated from other birds and thoroughly examined. Isolation should continue until the condition is diagnosed and corrected, unless it is judged not to be exacerbated by contact with other individuals.

Sanitation Procedures for maintaining sanitary conditions vary greatly, depending on density; type of caging, whether indoors or outdoors; purpose for holding the birds; the species or types of birds involved; and turnover in the colony. Birds in small holding cages and birds held at high density in the same cage or aviary generally require a regular weekly schedule of sanitary maintenance. Floors of interior facilities should be washed and sanitized with a solution containing both a cleaning agent and a microbiocide; the floor or substrate surface of outdoor aviaries should be at least physically cleaned. Cages, other holding units, and auxiliary equipment should be washed with hot water containing a detergent and a microbiocide, as indicated by the accumulation of excrement and food remnants. All such equipment should be washed and disinfected after each experiment or changeover in bird population. Mechanical cage-washers are indicated when the cleaning burden is large.

Birds kept in large enclosures, or experimental rooms, at low density require less stringent sanitation procedures. Adequate substrates or litter may make it possible to reduce cleaning to once or twice a year. For example, if the floor is covered by several inches of coarse sand or fine gravel, a pair of hawks or falcons can be maintained under sanitary conditions in a room 3 × 6 m (10 × 20 ft) for up to 1 year simply by occasionally raking through the substrate to remove dried excrement and food scraps. Once or twice a year such rooms or large aviaries should be cleaned throughout, including walls, perches, nest boxes, etc., and thoroughly sprayed with a disinfectant such as a mild solution of formaldehyde. The area should be left vacant for at least 1 week after spraying.

Many large cages, aviaries, and laboratory rooms have concrete or tile floors and drains to facilitate washing; but most birds, especially large ones, develop foot problems on concrete or similar hard surfaces. It is, therefore, inadvisable to house birds for long periods in areas with bare concrete or tile floors.

Aviaries in which plants are allowed to grow under seminatural conditions can be maintained essentially as "balanced" self-cleaning systems, especially if they also have a flow-through watering system. An occasional physical removal of unused food and piles of excrement that accumulate under favored perches is all that is required.

The schedule and details of sanitation must be adapted to suit the needs of particular species. The important variables are the types of food and feeding regime required and the quantity and physical constitution of the excrement. Seed-eating birds require the least care and sanitation; because their food is dry, it does not spoil. Also, because the volume of their excrement is relatively small, it dries quickly to a hard consistency. At the other extreme are such frugivorous birds as mousebirds (Coliiformes), waxwings (Bombycillidae), and toucans (Ramphastidae), which consume large quantities of perishable food, have relatively inefficient digestion, and void large amounts of fluid and odorous excrement that quickly attracts pests. Omnivorous, insectivorous, carnivorous, and piscivorous birds fall between these extremes in regard to the sanitary problems associated with their foods and excrement.

Most birds require water for drinking and bathing (aquatic forms may have additional requirements). The watering trough or bath should be positioned so that excrement from perching birds does not fall into the water. The water should be kept fresh by frequent changes or by a flowing system.

Pest Control Cockroaches, flies, house mice, and rats are the usual pests that make sanitation and health for birds in indoor facilities difficult. Birds in outdoor aviaries may also be at risk from predatory mammals and birds and from such avian pests as house sparrows, starlings, and feral pigeons. Adequate sanitation will do much to counteract pests that are attracted to food or excrement. In addition, sealing off or eliminating potential breeding sites should reduce the likelihood of pest populations becoming established in the facility.

Feed, bedding, and litter should be stored in pest-proof containers that are opened only when necessary. These containers should be kept in a storage room apart from the bird room or aviary and from areas where refuse is accumulated before removal from the building. Spoiled food, dirty litter, and other refuse from cages or aviaries should be deposited in pest-proof containers until removed from the facility. All wastes, soiled litter, and carcasses should ultimately be incinerated. Where burning is not permitted, deep burial is an alternative solution, but only in sites that do not contaminate groundwater.

If a pest population does become established, it probably will have been because the guidelines for sanitation outlined above were not followed. All operations should be carefully reviewed to identify the cause of the infestation. Elimination of whatever conditions favor the pest population may well be all that is required to effect control.

If pests must be poisoned or trapped as a last resort, the following obvious precautions should be taken: (1) Do not place poisoned baits or traps where birds can come in contact with them—it may be necessary to remove the birds from the facility during the pest control program; (2) avoid sprays or other general application of chemicals that have toxic effects on birds; (3) exercise great caution when applying chlorinated hydrocarbons, as these chemicals can have residual, long-lasting, sublethal, as well as lethal, effects. Biological control may be a suitable alternative.

Outdoor aviaries should be so constructed as to prevent the entry of predators or other vermin (see pp. 18–19). If the aviary does not have a vermin-proof floor, a subterranean shield should be installed a foot or more deep around the periphery of the cage. Even when the aviary is impenetrable to predators, special problems may arise. For example, Great Horned Owls are notorious killers of pheasants caged under wire mesh. By causing the pheasant to flush against the wire top, the owl can seize it by the head through the wire and kill it.

Prophylaxis If adequate standards of nutrition, housing, and sanitation are practiced, the use of prophylactic drugs, immunization, and topical disinfectants can be minimized. In certain high-risk areas where a particular pathogen is endemic and especially virulent, it is advisable to immunize against the infective agent, provided an effective and safe method is available. Indiscriminate prophylaxis (e.g., routine use of microbiocides in food or water) is not recommended, as most of these drugs act quickly and need be used only after diagnosis of a specific infection. The same generalization applies to drugs for ectoparasites and endoparasites.

Care of Eggs

The developing embryo is subject to some diseases and disorders, although the interior of a freshly laid egg is usually free of microorganisms. While bacteria and fungi occur in profusion on the outer surface of the eggshell, the physical structure of the shell and its cuticle exclude most microorganisms under normal nesting conditions. If an infective agent does manage to penetrate this outer barrier, then proteolytic enzymes in the albumen provide an additional defense. Embryonic disease is likely only when physical barriers are breached or biochemical defenses are overwhelmed.

Infection of the egg sometimes occurs before the shell is laid. *Salmonella pullorum* and other bacteria from the maternal digestive tract may contaminate the yolk of a forming egg; contamination from the oviduct is also possible. Maintenance of health of the laying female is the only way to prevent congenital infections.

The preponderance of microorganisms on the outside of the eggshell are saprophytes. Most grow better at 20°C (i.e., before incubation) than at 37°C (Romanoff and Romanoff, 1949). The commonest forms of bacteria are bacilli and micrococci; the commonest fungi are *Penicillium* and *Mucor*. *Aspergillus fumigatus* is one of the most successful fungi in entering eggs, where it grows vigorously on the membranes adjacent to the air cell and kills the embryo.

Moisture on the shell promotes the invasion of microorganisms. A rapid change in ambient temperature resulting in condensation on the egg is, therefore, a frequent precursor to infection. For the same reason, washing eggs before incubation is unwise, as is mechanical abrasion, which may remove the protective cuticle and assist the entry of infective agents. Dirt is best removed by mechanical buffing. The most critical time for entry from the shell surface occurs during the cooling after laying as the air cell forms. The vacuum set up in the large end of the egg may draw in microorganisms through the shell pores.

Most poultry operations, in which large number of eggs are incubated, routinely fumigate the cabinets during incubation. This is probably advisable for wild birds' eggs too. A fumigant often used with good results in preventing *Aspergillus* infections in falcon eggs at Cornell University is a 1.1 mixture by volume of potassium permanganate and 37 percent formaldehyde (exact volumes depend on the size of incubators, whether air is forced or still; poultry operators should be consulted for advice before using these caustic chemicals). There is virtually no way to rid an infected egg of pathogens; therefore, prophylaxis is of paramount importance.

PERSONNEL AND PERSONAL HYGIENE

Few diseases and parasites are common to birds and men. Of the more than 150 zoonoses reported for man, less than one-fourth involve birds as alternate hosts, and only two or three can be considered serious in man (Herman, 1969). Birds and bird products may be the passive carriers of pathogens that infect man, and vice versa. High standards of hygiene among personnel working with birds are essential, not only to protect the health of the workers but also as an added protection for the birds themselves.

Procedures for Hygiene

Before personnel enter work areas where birds, their feeds, or other related items are kept, they should pass through a locker and washroom wherein they don lab clothing and wash their hands thoroughly with a germicidal soap. In passing to the work area, they should also step through a germicidal bath for footwear. On leaving the work area, the same procedures should be followed. If the worker has been engaged in especially dirty work, such as cleaning large cages or aviaries, a shower should also be required.

The above guidelines apply mainly to large clinical holdings where maximum precautions are required, usually because infectious agents are directly involved in experimentation. Whether deviations are acceptable depends upon the size, location, and function of particular holdings or collections of live birds. The project director must use his own discretion when deciding which procedures are to be required of his workers.

All those in regular contact with laboratory animals should have an active immunization for tetanus. In addition, those working in laboratories where zoonoses are under study should receive regular physical examinations, including diagnostic tests specific to those diseases; appropriate immunizing agents should be administered when available.

DISEASES AND PARASITES COMMON TO BIRDS AND MAN

Virus and Virus-like Infections

Bedsonial Infection One of the more serious zoonoses involving birds is ornithosis, or psittacosis, which can be fatal in man. Many species of birds other than parrots can be primary reservoirs of this disease. Ornithosis is systemic, and there are no clear-cut diagnostic symptoms. Special laboratory training and facilities are required for reliable serological examination; propagation of the bedsonial agent, which is an obligate intercellular organism; and confirmation of the diagnosis. Suspected cases in birds should be considered positive and treated with tetracycline, by which all known strains of avian bedsonias are readily inhibited. Prophylactic use of chlorotetracycline has also effectively eliminated both overt and latent psittacosis in large parrots prior to entry into the United States.

Arboviruses Birds are also hosts for a group of arboviruses that cause diseases classed as encephalomyelitis. Eastern and western equine encephalomyelitis are well-known examples. The greatest risk to handlers of infected birds is through the bite of infected mosquitoes that have come in contact with the birds. The disease can also be transferred mechanically from bird to man, or vice versa. In regions where arboviruses are endemic and mosquitoes prevalent, it may be a wise precaution to screen enclosures of captive birds to prevent entry of mosquitoes.

Rocky Mountain Spotted Fever Antibodies of Rocky Mountain spotted fever have been found in birds and bird ticks, but the significance to human health is uncertain. It is possible that birds and their ticks spread this disease to man. Obviously, ticks and other ectoparasites should be removed from birds at the time of their initial examination in quarantine.

Newcastle Disease Newcastle disease is a viral infection that occasionally occurs in investigators who handle infected birds or who work directly with the visus. The most common symptom in man is acute granular conjunctivitis, but the infection is not always confined to the eyes. One to two weeks are usually sufficient for complete and permanent recovery. A particularly virulent strain of Newcastle disease virus was identified in 1971 in parrots imported from countries where the disease is epizootic in poultry; and psittacines and other cage birds have been epidemiologically implicated as reservoirs of this virus. As a result, the U.S. Department of Agriculture has issued regulations severely restricting the importation of all birds.

Bacterial Diseases Several human bacterial diseases have been found in birds or have been induced in them experimentally: brucellosis, hemorrhagic septicemia, listerellosis, pseudotuberculosis, endemic relapsing fever, swine erysipelas, tularemia, and human tuberculosis. In none of these cases are the birds the primary source of infection. Avian tuberculosis has rarely been authenticated as infective in man, and any suspected human case should be carefully examined to confirm the presence of avian-type tubercle bacilli.

Salmonella sp. and the toxin from *Clostridium botulinum* cause food poisoning in man, and contaminated birds' eggs and flesh are primary sources. In fact, these bacteria probably represent the greatest health hazard to man stemming from birds. Fecal contamination is the usual mode of transmission. There is also a hazard to birds from human carriers of *Salmonella* and *Clostridium*.

Fungal Diseases Aspergillosis is a widespread and serious fungal disease in birds, mainly affecting the respiratory system. It occasionally appears as a secondary infection in man; however, birds are not known to be sources of infection for man. Aflatoxins may occur as contaminants in some feeds. Histoplasmosis is a serious human disease of fungal origin. The fungus grows well in bird droppings, and concentrations of bird excrement at roosts have been implicated in outbreaks, especially among children. Infection in aviaries or among cage birds is uncommon.

Parasites The metazoan parasites of birds are not much of a menace to humans. Most of these organisms are too host-specific to establish themselves in man. The free-swimming forms of avian schistosome blood flukes can penetrate the skin of man, but they are unable to complete their life cycle in man and die, thereby producing a condition called "swimmer's itch" or "clam digger's itch." Waterfowl kept under seminatural conditions could be a source of human infection.

Allergies

A number of people show severe allergic reactions to close contact with birds. Feathers may produce violent asthmatic attacks, and some bird keepers develop a pulmonary disease that resembles "farmer's lung," or "pigeon fancier's lung," a disease caused by inhalation of allergens from avian excreta. Cessation of contact with the allergy-producing materials usually alleviates the condition and may be the only permanent solution. More than one biologist who started out working with birds has had to turn his attention to another group of animals because of such allergies.

SOURCES OF INFORMATION ON AVIAN DISEASES AND PARASITES

Many thousands of research papers have been published on bird diseases and parasites; most pertain specifically to poultry, a situation that has been changing rapidly in the last few years. The references mentioned below have been chosen, in most cases, because they consider birds generally in addition to poultry. No attempt has been made to probe the vast poultry disease literature, but the "standard" reference work edited by Hofstad (1972) has been included.

General References, Bibliographies, and Compilations

- Beard, J. W., ed. 1964. *Proceedings: International Conference on Avian Tumor Viruses, Durham, N.C., 1964.* National Cancer Institute Monograph 17. xiv + 803 pp., illus.

Contributions from 150 participants under the following headings: leukosis and associated neoplasms, avian host response to Rous sarcoma virus, mammalian host response to Rous sarcoma virus, *in vitro* cell–virus interactions; immunologic and biologic virus properties, ultrastructure, and biochemistry.

• Bolton, G. R. 1971. Physical examination of pet birds. *Vet. Clin. North Am.* 1(1):141–152. illus.

Describes a three-step procedure: obtaining the history, examining the bird cage, and examining the bird. The latter contains detailed directions for a complete physical examination of all parts of the bird.

• Cooper J. E. 1972. *Veterinary Aspects of Captive Birds of Prey*. The Hawk Trust, Newent, Gloucestershire. 47 pp. + bibliography, 7 appendixes, 16 figures.

Work is based on 63 clinical and 101 postmortem cases of infectious diseases, 25 clinical and 20 postmortem cases of trauma, and 15 clinical and 39 postmortem cases or other conditions. Topics include respiratory conditions, trauma, anesthesia, foot conditions, ectoparasites, endoparasites, enteritis, septicemia and peritonitis, tuberculosis and sinusitis, virus infections, nervous conditions, cardiovascular conditions, urinogenital conditions, shock, and stress. Appendixes include data on clinical findings, postmortem findings, species examined, drugs used for treatment, major clinical diagnoses in birds of prey, major postmortem diagnoses, and parasites from birds of prey.

• Davis, J. W., R. C. Anderson, L. Karstad, and D. O. Trainer. 1971. *Infectious and Parasitic Diseases of Wild Birds*. Iowa State University Press, Ames. ix + 344 pp., illus.

A basic and extremely useful reference, containing contributions from 32 authors who have summarized and correlated the available information on infectious and parasitic diseases of wild birds. The book was prepared in response to inquiries from students, research workers in animal diseases, wildlife biologists, veterinarians, public health workers, aviculturists, and others who do not have ready access to the widely scattered primary sources of information. Part One—"Viral Diseases"—consists of chapters on Newcastle disease, arboviruses, duck plague, pox, quail bronchitis, and puffinosis. Part Two—"Bacterial, Rickettsial, and Mycotic Diseases"—has chapters on salmonellosis, avian cholera, pseudotuberculosis, tuberculosis, quail disease (ulcerative enteritis), botulism, chlamydiosis (ornithosis–psittacosis), erysipelothris, listeriosis, aspergillosis, candidiasis, and Q (query) fever. Part Three—"Parasitic Infections"—has chapters on fleas and lice, nematodes, coccidiosis, trichomoniasis, *Leucocytozoon* Danielewsky 1890, *Haemoproteus* Kruse 1890, *Lankesterella (Atoxoplasma),* and toxoplasmosis. There are chapters on tumors and the effects of toxic substances. Each chapter provides information under the following headings: history, distribution, etiology, transmission, signs, pathogenesis, pathology, diagnosis, immunity, treatment and control, and references.

- Halloran, P. O. 1955. A bibliography of references to diseases in wild mammals and birds. *Am. J. Vet. Res.* 16(61, Part 2): 1–465.

Arranged by taxonomic orders; citations on birds run from pages 306 to 465 and include more than 6,300 entries. A useful entry to the older literature.

- Hofstad, M. S., ed. 1972. *Diseases of Poultry,* 6th ed. Iowa State University Press, Ames. xiii + 1176 pp.

This book, a thorough revision of the earlier Biester and Schwarte compilation (1965) under the same title, contains contributions from 40 authors on the following topics: principles of disease prevention (diagnosis and control), nutritional deficiency diseases, avian salmonellosis, avian arizonosis, avian pasteurellosis, tuberculosis, infectious coryza, avian mycoplasmosis, avian vibrio infections, erysipelas, ulcerative enteritis, miscellaneous bacterial diseases, chlamydiosis (ornithosis), fungal infections, neoplastic diseases, avian infectious bronchitis, laryngotracheitis, Newcastle disease, avian encephalomyelitis, avian influenza, arbovirus infections, avian pox, duck virus hepatitis, duck plague, transmissible enteritis of turkeys, miscellaneous infections, external parasites, nematodes and acanthocephalans, cestodes, tremadodes, protozoa, miscellaneous diseases and vices, poisons, and toxins.

- Petrak, M. L., ed. 1969. *Diseases of Cage and Aviary Birds.* Lea & Febiger, Philadelphia. x + 528 pp. illus.

The most useful general reference for the laboratory investigator who wants to keep his birds in good health, this book contains contributions from 25 authors and was written for use by clinicians, students, research zoologists, and aviculturists. Part One—"Nonclinical Aspects"—consists of chapters on the following subjects: common types of cage birds, caging and environment, behavioral aspects, genetics; anatomy of the budgerigar; some physiological attributes of small birds; nutrition; and orphan birds. Part Two—"Clinical Considerations"—comprises the bulk of the book: clinical examination and methods of treatment; clinical laboratory examinations; surgical techniques and anesthesia; nutritional deficiencies; French molt; conditions involving the integumentary system; diseases of the skeletal system; diseases of the respiratory system, blood, and lymphatic system; diseases of the digestive system; diseases of the urinary system; diseases of the reproductive system; diseases of the nervous system; diseases of the endocrine system; diseases of the organs of special sense; infectious diseases—diseases of bacterial origin, viral diseases, psittacosis and ornithosis; parasitic diseases; mycoses; neoplasms; metabolic and miscellaneous conditions; gout; poisoning and other casualties; and birdborne diseases in man.

- Seneviratna, P. 1969. *Diseases of Poultry (including Cage Birds).* John Wright and Sons, Ltd., Bristol, England. viii + 229 pp., illus.

Written for the veterinary student and the field veterinarian, the book includes sections on the diseases of domestic fowl—turkeys, ducks, geese, and miscellaneous birds—and cage birds. The latter contains useful tabular information on the cause, clinical signs, diagnosis, postmortem lesions, and treatment of some common avian ailments. Bibliography of more than 295 titles.

- Subcommittee on Avian Diseases, Committee on Animal Health, Agricultural Board, National Research Council. 1971. *Methods for Examining Poultry Biologics and for Identifying and Quantifying Avian Pathogens*. National Academy of Sciences, Washington, D.C. 326 pp.

This 326 page volume reviews such topics as the design of experimental facilities; the maintenance of cultures and experimental animals; the isolation and identification of Newcastle disease, infectious bronchitis, laryngotracheitis, fowl pox, coccidiosis, and avian encephalomyelitis; the isolation and evaluation of bacterins; the use of diagnostic antigens for detecting mycoplasma, salmonella, and Arizona infections in flocks; and the identification and differentiation of avian viruses. A detailed subject index facilitates access to needed information.

Periodical Literature. There are now two journals devoted specifically to the diseases and pathology of birds:

- *Avian Diseases*, published at Ithaca, New York, by the American Association of Avian Pathologists; vol. 1 began in 1957. 4 issues per year.

Currently publishes more than 1,000 pages per year on all aspects of avian diseases, including special issues such as vol. 16, no. 1, 1972, 200 pages on the control of Marek's disease.

- *Avian Pathology*, vol. 1 published in 1972 by the World Veterinary Poultry Association. Lj. Hozic. Beograd, Bulevar JNA 18, P.O. Box 422, Yugoslavia.

A multilingual quarterly, mainly poultry-oriented, this journal publishes about 300 pages per year.

In addition to the above, many other journals publish original research and reviews pertinent to disease and health of birds in captivity. Those frequently cited in general works are: *American Journal of Veterinary Research, Auk, Australian Veterinary Journal, Bird-*

Banding, *British Poultry Science*, *British Veterinary Journal*, *Bulletin of the Wildlife Disease Association*, *Canadian Journal of Comparative Medicine*, *Condor*, *Ibis*, *Journal of the American Veterinary Medicine Association*, *Journal of Infectious Diseases*, *Journal of Parasitology*, *Journal of Wildlife Management*, *Poultry Science*, *Veterinary Bulletin*, *Veterinary Record*, and *Wilson Bulletin*.

V REPRODUCTION IN CONFINEMENT

Propagation of birds in confinement for laboratory use is often advantageous. At times induction of normal reproductive cycles, as desired by behavioral scientists studying reproductive behavior, is called for. At other times production of birds is undertaken for any of a wide array of scientific or educational purposes. Because of the tremendous diversity of reproductive modes among the thousands of species of birds, it is not possible to provide here specific information on reproduction in confinement. It is, however, possible to point out factors that must be considered when attempting to induce successful reproduction and to provide a few generalities as starting places for the proper breeding of captive birds. Although details of husbandry have been determined for a number of domesticated forms, these represent fewer than 1 percent of the world's 8,700 species of birds and only a few of the major groups (especially waterfowl, gallinaceous birds, and doves). Therefore, the comments that follow emphasize wild species.

Since it is impossible to provide exhaustive references for the many species that may be reared in confinement, the reader must search current literature for additional help, although many earlier references are summarized by Hediger (1965). *Avicultural Magazine* and *International Zoo Yearbook* contain useful information on many species. The *Journal of Wildlife Management* provides helpful articles on waterfowl and gallinaceous game birds. It may be necessary to search the numerous international, national, and local ornithological journals to find material pertaining to the propagation of wild species in captivity.

A few of the better-known journals are *Alauda, Ardea, Auk, Condor, Emu, Ibis, Journal für Ornithologie, Ostrich,* and *Wilson Bulletin,* but there are many others.

PARENTAL REARING

Few wild species nest successfully in confinement. Special inducements must be provided to facilitate pair-formation, copulation, nest-building, incubation, and feeding of the young. Nesting conditions and other requirements vary widely among avian species. Ornithological journals should be consulted for information on a species' natural breeding biology. The critical factors should be simulated in confinement.

Species Commonly Bred in Confinement

Table 4 lists species that commonly reproduce well in captivity and distinguishes those species that will reproduce successfully in small cages from those that breed only in relatively large aviaries. The *International Zoo Yearbook* (1972) lists 19 orders containing 592 species, omitting hybrids, that have reproduced in aviaries. Information is available as to special conditions required for breeding many of the species in Table 4, but is scattered in the literature. Goodwin (1965) summarizes useful information on a variety of domestic species. *Avicultural Magazine* should also be consulted.

Social and Physical Requirements

Although some species will reproduce under the usual conditions of maintenance, most species have additional or different requirements. Several of the factors that may require modification are elaborated upon below.

Most species must have an environment suitable for courtship, pair-formation, nest-building, egg-laying, incubation, and care of young. The young of some precocial species require little care; parents merely lead the young to feeding areas and warn them of danger. Almost all species incubate their eggs directly; notable exceptions are megapodes (mound builders) and nest parasites (such as the European Cuckoo [*Cuculus canorus*] and Brown-headed Cowbird [*Molothrus ater*]), which lay their eggs in the nests of other birds. The male megapode builds a compost pile in which the heat of fermentation

TABLE 4 Representative Avian Species Commonly Reproducing in Confinement

Order	Species	Type of Confinement
Tinamiformes		
Elegant-crested Tinamou	(*Eudromia elegans*)	aviary
Pelecaniformes		
Cormorants	(*Phalacrocorax* spp.)	aviary
Anseriforms (waterfowl)		
Mute Swan	(*Cygnus olor*)	aviary
Canada Goose	(*Branta canadensis*)	aviary
Domestic mallard (including white Pekin form)	(*Anas platyrhynchos*)	aviary
Muscovy Duck	(*Cairina moschata*)	aviary
Mandarin Duck	(*Aix galericulata*)	aviary
Falconiformes (birds of prey)		
American Kestrel	(*Falco sparverius*)	aviary
Galliformes (gallinaceous birds)		
Common turkey (including pigmented forms)	(*Meleagris gallopavo*)	aviary
Chukar	(*Alectors chukar*)	aviary
Tufted guinea fowl	(*Numida meleagris*)	aviary
Domestic fowl (including red Burmese jungle fowl)	(*Gallus* spp.)	cage
Common peafowl	(*Pavo cristatus*)	aviary
Ring-necked pheasant	(*Phasianus colchicus*)	aviary
Japanese quail	(*Coturnix coturnix japonica*)	cage
Bobwhite	(*Colinus virginianus*)	cage
Columbiformes (doves and pigeons)		
Rock dove (domestic and pigeon)	(*Columba livia*)	cage
Ringdove	(*Streptopelia* sp.)	cage
Diamond dove	(*Geopelia cuneata*)	cage
Psittaciformes (parrots)		
Budgerigar (domestic parakeet)	(*Melopsittacus undulatus*)	cage
Lovebirds	(*Agapornis* spp.)	aviary
Passeriformes (perching birds)		
Canary	(*Serinus canarius*)	cage
Zebra Finch	(*Poephila guttata*)	cage
Java Sparrow	(*Padda oryzivora*)	cage

NOTE: In most orders listed above, many other species have also been induced to reproduce successfully in confinement by simulating natural conditions similar to those provided for the species listed.

incubates the eggs. Megapodes can be induced to breed in confinement (Baltin, 1969).

Space Nesting-space requirements are important to the inducement of successful nesting for most avian species. Highly domesticated forms such as the Ringdove (*Streptopelia* sp.) will reproduce in small cages containing one adult male and female. Most wild species fail to breed in cages, but many will reproduce in aviaries that are sufficiently large and free from interference by other animals, including conspecifics. The sizes of the birds do not alone provide an accurate guide to their space requirements for reproduction. The nature of courtship display (particularly if the male performs aerial courtship flights), general activity of the species, and habitat-diversity requirements must also be considered. For instance, certain swans and geese that breed in confinement prefer to build their nests on small islands; therefore, they require substantial space.

In addition to the cage and enclosed aviary, the roofless pen is also used to confine birds. In these enclosures, birds must be prevented from flying away by either wing-clipping (cutting of light feathers to prevent flight until the next molt) or by "pinioning" (Petrak, 1969). Flight can be temporarily prevented by brailing, i.e., binding, which prevents the wing from being extended. Roofless pens are frequently used to contain waterfowl on estates and in zoological gardens. They have also been used to introduce wild breeding populations onto refuges (Collias and Jahn, 1959).

Nest Site To encourage successful reproduction, an acceptable nest site should be provided. Many domesticated species, such as the Ringdove and canary, may simply require an appropriately placed cup. Ringdoves will build a nest in a laboratory finger bowl placed on the floor of the cage, preferably in a back corner, whereas canaries will build in a cup attached to the cage 10 cm or more from the floor. Hole-nesting species may require an artificial hole; for example, an elevated nest box will be used by Wood Ducks (*Aix sponsa*). Still others may require a nest site among branches of a tree or bush. This is difficult to simulate except by placing trees, either growing or cut, in an aviary. The ornithological literature should be searched for information on the natural nesting sites of each species. The natural conditions should be copied as closely as practical in confinement. Davies (1961) induced the Magpie Goose (*Anseranas semipalmata*) to nest by simulating its marsh environment. He placed vertical fibers affixed to wooden bases throughout the aviary.

Design, Construction, and Materials The construction of cages or aviaries for reproduction is similar to that required for holding birds, as described on pp. 19–20. There are, however, many additional considerations concerning the design, construction, and use of materials. If wire mesh, such as chicken wire or hardware cloth, is used as the caging material, it must be fine enough to confine hatchlings as well as adults, especially for precocial species.

Special precautions in design must be taken to exclude nest predators from aviaries. Such predators as rodents and some snakes that pose a threat to adults also prey on eggs or young birds.

Outdoor aviaries must provide adequate shelter from the elements at the nesting sites of small species. This shelter may have to be arranged after the pair has built a nest. The choice of construction materials depends in part on the species and the geographic location of the outdoor aviary. Wild species confined within their geographic range may experience competition with wild birds outside the aviary. If the male within the aviary must spend much of its time defending its "territory" against a male outside, reproduction may fail. Or, if a male outside successfully courts the female within, she will fail to form a pair-bond with the enclosed male. It is, therefore, sometimes necessary to enclose an aviary with opaque materials, or move animals indoors, to facilitate successful reproduction. Neighboring confined conspecifics may interfere with reproduction in similar ways, although in social species an opposite phenomenon may occur. Ringdoves reproduce more successfully when sounds of conspecifics can be heard in the nesting cage. Therefore, complete isolation from conspecifics is not always best. Again, a literature search for information on conditions of reproduction in the wild provides valuable clues for successful propagation of confined birds.

Breeding enclosures, whatever their nature, should permit observation of the breeding pair without disturbing the birds. It is important to be able to follow the course of courtship, incubation, and rearing of the young so that intervention, if necessary, may be sufficiently prompt to promote success. Nef (1963) discusses observing birds in breeding cages, specific problems with different kinds of birds, and gives advice on materials, cleaning, maintenance, location, and control of predators.

Photocycle Except for highly domesticated, and perhaps near-equatorial species, many birds begin reproduction only when gonadal development is initiated by increasing day length. Conversely, gonadal involution in some species is associated with decreasing daylight. Indoors, therefore, the photocycle must be controlled by time clocks in the lighting circuits. Ordinary time clocks must be reset continually to simulate the changing light periods. A convenient alternative is an astronomical time clock that automatically mimics seasonal progression. Gradual increase in the day length is not necessary for some species; an abrupt increase is effective in photosensitive birds. Furthermore, by manipulating the photocycle, it may be possible to induce more frequent breeding than under natural conditions.

A few species are independent of the annual photocycle under natural conditions. For them, other environmental events, such as rainfall, may trigger the culminating phases of reproduction (for reviews, see Altman and Dittmer, 1966; Lofts and Murton, 1968; Farner and Lewis, 1971). Some birds become refractory to long days; to regain reproductive potential they require a series of short days before they will become responsive again to long days.

Age at Breeding and Pairing Behavior The age and length of time during which birds normally reproduce vary greatly among species. Generally, smaller birds reproduce earlier and have shorter reproductive and total age spans than do larger birds. Most songbirds and ducks breed during their first spring, gulls at 2–4 years of age, eagles after even longer periods, and albatrosses and condors may first breed at 9–12 years (Cody, 1971). (See the bibliographies in Wynne-Edwards, 1955; Amadon, 1964; and Lack, 1968.)

Quail of various species are often favored as laboratory animals because of their early reproductive age; Button quail (*Turnix sylvatica*) reproduce at 5 months (Hoesch, 1960) and Japanese quail (*Coturnix coturnix japonica*) at 6 weeks (Padgett and Ivey, 1959). Kirkpatrick (1964) found that Bobwhites (*Colinus virginianus*) matured sexually at only 5–7 months of age under artificial light, which is more rapidly than under natural lighting.

The male of many species must achieve dominance over the female before a pair-bond will form and normal reproduction will proceed. Because captive females may become aggressive, the breeder must observe carefully the developing relations in a pair newly placed together. At Cornell, female falcons were tethered such that the free-ranging male could establish sufficient dominance within a few weeks to make a pair-bond possible. Feeding schedules may also influence the progress of courtship (see the following section).

Nutritional Requirements and Feeding

Successful reproduction may depend upon meeting special nutritional requirements, about which little is known for most wild species. In particular, females may require special nutrients for formation of eggs, and the young of most species require foods other than those fed to adults in confinement.

Qualitative nutrition of birds is straightforward: about 40 different nutrients are required, including 13 essential amino acids, 13 inorganic elements, and 13 vitamins, in addition to adequate nitrogen, energy, and miscellaneous substances (Scott, 1973). Slightly different, but more explicit, requirements for poultry are given on p. 25. However, adequate nutrition depends upon the provision of nutrients in a form birds will eat and can assimilate in required amounts, both absolutely and in relation to one another. Scott (1973) reviewed recent experiments on the importance to avian reproduction of energy, protein and amino acids, linolenic acid, and vitamins and minerals. King (1973) also emphasized the importance of nutrition to reproduction.

Feeding During Courtship Both the placement and schedule of food distribution may influence the behavior of a courting pair. It is wise to provide two food dishes or feeding areas for an enclosed pair so that the male and female may feed simultaneously without competing. In many species of both carnivorous and granivorous birds, the male feeds the female as an aspect of courtship, usually by transferring food directly from his bill to hers. The pair-bond may be strengthened in these species by providing opportunities for courtship feeding throughout the day. This can be accomplished by introducing small portions of food frequently instead of large portions once or twice a day.

Special Diet for Egg Formation The formation of eggs places a strong physiological and nutritional stress on reproducing females of most species (King, 1973; Scott, 1973). The relation of nutrition to inducement and success of reproduction is not understood in detail, but adequate protein and calcium sources in foods appear to be important. During deposition of eggshells, calcium may be drawn from the bones of the female itself. Therefore, high-calcium sources should be made available. For example, cuttlebone is commonly placed in cages of small birds. Ground oystershell or limestone grit may also be provided *ad libitum* for supplemental calcium. These are preferred to mixing calcium sources with other feeds, since it is possible to get an imbalance in the calcium:phosphorus ratio.

Special Diet for Young Birds Parents may seek for their young food entirely different from that necessary for their own nutrition. As a consequence, if this need is not recognized and met, reproduction in confinement often fails in species that are otherwise healthy. Observations of wild birds indicate that parents distinguish their own food from that they feed to the young. For example, the seed-eating American Cardinal (*Cardinalis cardinalis*), which gathers insects for its young, has been observed to pause on its way to the nest, lay an insect larva aside, eat some seeds, then pick up the larva and fly to the nest with it.

In general, the natural feeding modes of avian species may be divided into four classes:

- precocial species in which the parent does not provide the food, but may lead their young to it;
- species in which the parents manufacture food internally and feed their young by regurgitation;
- species that gather food, partially digest it, and then regurgitate it for their young; and
- species that bring whole food to their young.

The first category includes most waterfowl, in which the female leads the young from the nest to aquatic feeding areas. When such species are bred in captivity, the conditions of confinement may have to be adjusted to provide not only adequate nutritional resources for the young, but also the proper environmental stimuli that induce the female to lead their young and the young to feed.

Species that manufacture their own food include doves and pigeons. They develop "crop-milk" from epithelial cells sloughed off from the crop to form a high-protein soup that they feed to their young by regurgitation. After the first few days, partially digested food is combined with the crop-milk. The composition of pigeon crop-milk closely resembles that of some types of mammalian milk. The American Flamingo (*Phoenicopterus ruber*) and male Emperor Penguin (*Aptenodytes forsteri*) also produce fluids to feed their young, but the role of fluids produced by Procellariiformes is uncertain (Fisher, 1972).

Species that gather and partially digest food include gulls, some passerines, and other species that can be bred in captivity. Terns, as well as many birds of prey, also fall into this category. The appropriate food varies tremendously among species. Terns may require whole fish or other aquatic organisms; hawks and owls, small mammals and other prey; small passerines, insects and other arthropods, especially in larval or pupal stages. In the last case, it may be particularly difficult to provide suitable food in the laboratory for the parents to deliver to the young. Although commonly used laboratory insect larvae, such as mealworms, may induce the parents to feed, they are too chitinous for the young to digest properly. Ivor (1944) succeeded by giving captive passerine parents access to the natural environment during the day, after their young had hatched. This scheme allowed the parents to gather suitable natural foods, while the presence of the nestlings assured the return of the parents to the captive environment.

The basic nutritional requirements of young birds are similar in most species. These include adequate sources of energy, protein, and micronutrients needed for growth and development. The primary difficulties lie in providing these nutritional components in a manner that induces successful feeding.

Other Considerations

While social, physical, and nutritional requirements are paramount to inducing successful reproduction in captivity, there are other factors that also require attention in some species. These include certain behavioral abnormalities that may result from conditions of confinement.

Egg-eating Loss of eggs comes about in several ways. One of the most common is predation by individuals other than the parents, from the same or a different species, when reproductive pairs are not isolated. This may be due either to natural predilections for nest-robbing (e.g., by corvids such as crows and jays) or to unnatural feeding induced by captivity.

Parents may destroy their own eggs, due to various factors not well understood. The roles of the sexes during incubation vary widely among avian species: from the female being the sole incubator, through various patterns of shared duties, to complete incubation by the male (as in phalaropes). Under natural conditions, when only one sex incubates, the other parent often plays no further role in rearing of the young, and may even leave the vicinity of the nest. In confinement, when the nonincubating parent is forced to remain near the nest, abnormal disruptive behavior may occur. With prior knowledge of these roles, it may be well to sequester the nonincubating sex to avoid destruction of the eggs and other disruptions.

Eating of the Young Hatchlings may be eaten or injured by birds other than the parents, by the parents, or by siblings. In the first instance, the danger can be avoided by isolating the reproducing pair.

The eating of young by their parents may result from factors similar to those causing egg-eating by parents. For instance, in Button quail, the male builds the nest, incubates the eggs, and feeds the young; the female of the pair may kill the chicks unless she is removed from the aviary (Hoesch, 1959). In some species the presence of the female may not be necessary or even desirable once the eggs have been laid. The parents of some species may kill or eat their youngest offspring as a means to regulate brood size when the food supply is unpredictable (Cody, 1971). This phenomenon, called "chronism" (or "kronism"), may be diminished in aviaries by providing an adequate food that is suitable for feeding to the young.

Cannibalism by siblings, called "cainism," occurs especially when the siblings are of different sizes. In some birds of prey this phenomenon occurs under natural conditions. In some species it is thought to be an adaptation to unpredictable food supplies (Cody, 1971). Incubation may begin with the laying of the first egg, so that hatching of the brood is asynchronous, and the young greatly differ in age and size. When the parental supply of food is low, the older and larger nestlings may eat the smaller ones, thus preventing the parentally gathered food from being distributed too thinly among several young and at the same time conserving the nutritional resources that went into production of the entire clutch. In other species "kronism" and "cainism" occur regardless of the feeding conditions, and their adaptive significance under natural conditions is not fully understood. Therefore, "kronism" and "cainism" in captive birds of prey are not necessarily unnatural behavior induced by abnormalities of captivity. Since either phenomenon could indicate inadequate food resources, proper feeding at this stage is important.

Weaning and Separation The behavioral mechanisms by which parents rear their young and the age at which self-feeding occurs vary among species. In precocial species the young may be independent as soon as they can fly. The parents may then simply leave their young, since weaning is not necessary. In other species, such as Canada Geese (*Branta canadensis*), the young may stay with their parents for the first year, even though they are not fed by their parents. Social attachments may be advantageous in the wild to bring the young safely through their first migration or because of factors unrelated to feeding. Therefore, the dependence of the young on the parents is often more complex than mere feeding requirements. To the aviculturalist these factors demonstrate that the time of weaning is not necessarily the time at which young can be removed from their parents without detrimental effects.

A minimum of three conditions should be met before sequestering young: they should be able to feed, they should be able to thermoregulate, and some should be able to fly.

Marking Birds Individual marking of birds is described on p. 7. It should be added here that certain kinds of marking may cause rejection and thereby possibly disrupt reproduction. Goforth and Baskett (1965) found that marking a female Mourning Dove's (*Zenaidura macroura*) head with yellow plastic tape aborted a pair's first attempt at reproduction. Already-established mated pairs were not behaviorally affected by such yellow tape, and other colors did not seem to have such disruptive effects.

FOSTERING AND ARTIFICIAL METHODS

It may be neither possible nor desirable to induce the complete reproductive cycle of a species in captivity. Alternatively, propagation may be accomplished by artificial incubation of eggs obtained elsewhere; young may be reared by fostering; and other procedures may be invoked to bypass certain steps in natural reproduction.

Artificial Insemination

While artificial insemination techniques are used in some poultry species, notably the turkey, the method has not yet been developed for most other birds. Modified techniques were successful for the Blue Grouse (*Dendragapus obscurus*) (Stirling and Roberts, 1967) and Japanese quail (Marks and Lepore, 1965), but were less effective than natural matings. Recently, the artificial insemination of some birds of prey has been moderately successful (Berry, 1972; Temple, 1972; Grier, 1974).

Artificial insemination is described by Ernst *et al.* (1970) in a volume that, although concerning specifically the turkey, contains much general information on techniques and equipment.

Preincubation Holding of Eggs

The procurement of eggs for artificial incubation was discussed on p. 5. The timing of removal of these eggs from the nest may be important. In captivity, eggs may be deposited at random rather than always in the nest. Those not in the nest are usually suitable for artificial incubation, although eggs that are incubated naturally for at least a few days generally have much higher hatchability. However, if it is intended that the breeding pair recycle, early removal of the eggs will hasten the process. It may, therefore, be necessary to strike a compromise as to the best timing for removing the eggs, based on experience with the particular species being propagated.

If so desired, incubation of fertilized eggs may be delayed either to assure a particular hatching date or because incubation facilities are not immediately available. Freshly laid, unwashed eggs can often be held for a week or two in temperatures of 14 ± 3°C and at 70 percent relative humidity. Household refrigerators are generally too cool for this purpose. If held at room temperatures (above 20°C), embryos will begin development that can be abnormal or lethal. Failure to rotate held eggs, incorrect humidity, length of time held since laying, and other factors may reduce hatching abilities of eggs.

Eggs should not be washed. Washing allows bacteria to penetrate the eggs and promotes the spread of bacteria from contaminated eggs to others (see p. 45). Since cracked eggs spoil easily and seldom hatch, they should be culled when detected, either before or during incubation. Short-term cooling below room temperature has proved beneficial for the eggs of some species. Eggs obtained at later stages of incubation, in which embryo development has already begun, should generally continue to be incubated. Interrupting incubation may kill embryos or cause abnormalities of development, particularly if the interruption is long and the temperature low.

Incubation of Eggs

Eggs of many poultry, game, and a few other species are routinely incubated artificially; but the eggs of most other species are often difficult to handle successfully in this way. Such eggs of wild species as have been successfully hatched artificially are often those taken from the nest only after the natural parents have provided most of the care. This procedure is especially recommended for small passerines (Lanyon and Lanyon, 1969) and probably applies to most wild species. Factors to be considered in artificial incubation include temperature, humidity, egg-turning, and length of incubation.

Hatching success under artificial incubation may not be high. Even with such domesticated species as the Japanese quail only about 60–70 percent of the fertile eggs hatch (Padgett and Ivey, 1959). The figure may be considerably lower for many species of wild birds, for which 50 percent is considered good. However, with proper conditions of storage and lack of inbreeding, a 70–80 percent hatching success is common for domestic species.

A valuable reference on artificial incubation is Romanoff and Romanoff (1949). This compendium discusses the formation, laying, structure, and other characteristics of eggs and provides information on egg abnormalities. Rol'nik (1970) summarizes part of the material covered by Romanoff and Romanoff, but also includes many practical tips on storing and handling eggs for artificial incubation, detailed information on embryonic development of all the organ systems, and a review of the effects of environmental conditions on development. Drent (1973) has reviewed much of the basic literature concerning natural incubation and identifies four factors as critical to successful incubation: turning of the eggs, temperature, humidity, and gas-exchange levels. His bibliography lists valuable relevant literature.

Most artificial incubation is accomplished in incubators, although at times foster parents are used. Incubators vary considerably in size and egg-capacity, type of heating elements (electrical coils, circulating hot water), provisions for controlling humidity, mechanisms for turning or rotating eggs, supply (electricity, kerosene), capacity for circulating air, size range of eggs accepted, and so on. Complete specifications should be obtained on incubators before purchasing one. Before placing eggs in an incubator, it should be thoroughly cleaned inside, tested for dependability for at least 48 hours, and stabilized at desired incubation temperature.

Temperature Most avian eggs will develop normally within some optimum range of temperatures (Rol'nik 1970). The proper incubating temperature is closely related to the factors involved in heat exchange, i.e., ambient temperature, air movement, and humidity. For example, in a still-air incubator, a 39°C temperature reading above the egg indicates an internal temperature of the egg comparable to that found in a forced draft incubator where the reading is 37°C.

Incubation temperatures are apt to be slightly lower than the body temperature of the incubating parent, since in most temperate-zone species there is no way to provide the egg with temperatures higher than this throughout the daily cycle. Most avian body temperatures exceed 38°C; incubation patches may be as high as 40°C in fairly large birds such as owls (Howell, 1964), and small birds may have even higher temperatures.

A mean egg temperature of 34.0 ± 2.4°C for 37 species representing 11 orders of birds under natural conditions has been reported by Huggins (1941). Other authorities have indicated egg temperatures in the range of 33.5 to 38.0°C for various species in nature (Drent, 1973). In forced-draft incubators the egg temperatures will approach that of the incubator after an equilibration period. High temperatures are lethal; for chicken eggs this occurs at about 39.5°C in forced-draft incubators and from 41.5 to 43.5°C in gravity-vented still-air incubators.

The best way to determine the optimum incubation temperature is to measure the rate of egg development; the temperature at which artificially incubated eggs hatch after a period closest to the normal incubation period for wild birds is probably close to the optimum temperature. Within a narrow range, lower temperatures will result in longer incubation periods, higher temperatures in shorter periods.

The temperature in an incubator may be sensed by tray-thermometers placed among the eggs, or by thermistor leads to an external readout. Tray thermometers should be positioned so they can be read through a window, thus avoiding unnecessary opening of the incubator. In general, forced-draft incubators produce better hatches because of better temperature control, but the control of humidity is conversely often difficult.

Incubator temperatures should be checked regularly, at least twice daily, even in tested, reliable incubators. The temperature in an incubator already stabilized may change after the eggs are inserted because of altered airflow, among other factors. Therefore, incubator temperatures should be checked frequently at the beginning of incubation without opening the incubator door or, if the thermometer cannot be read from the outside, immediately after opening the door.

Humidity Moisture must be added to the incubator during incubation, especially during the hatching period. Relative humidity must be controlled to prevent abnormal water loss from eggs (see Rahn and Ar, 1974). Control of relative humidity is difficult because isolation from ambient conditions is usually poor. Eggs of waterfowl, gulls, and some other species that nest in naturally humid environments hatch best in incubators with high humidity (80 percent), whereas those of terrestrial species hatch best in moderate humidities (50–75 percent). A relative humidity of 60 percent is satisfactory for incubation of domestic fowl until hatching, when it should be raised to about 70 percent.

Relative humidity is measured in forced-draft incubators by taking temperatures simultaneously on a dry-bulb thermometer and a wet-bulb thermometer.

For many other species it suffices to place shallow pans or trays of water in the bottom of the incubator, whereby evaporation of the water will sufficiently humidify the chamber. For ducks, geese, and other birds, the customary practice is to spray the chamber or even the eggs with an atomizer each time the incubator is opened for checking or egg-turning.

Light Until recently, it was generally believed that lighting conditions do not strongly affect the hatchability of eggs in incubators; therefore, most incubators are kept dark. However, recent evidence suggests that light may have a pronounced effect on embryonic growth (Coleman *et al.*, 1974) and may help to trigger hatching (Adam and Dimond, 1971). Investigators may wish to experiment with incubator illumination of their own material until more information on this subject becomes available.

Egg-turning Most incubating parents turn the eggs during incubation (Drent, 1973), particularly in the early phases. This can be mimicked during artificial incubation in several ways.

One common method, for small numbers of eggs, is to mark one side and then rotate the egg 180° around the long axis once, twice, or more times each day. Another method involves incubator trays with sliding floors that may be gently jostled back and forth to rotate all eggs on the tray. A third method, used in some large incubators, is an electrically rotated unit into which all egg trays are inserted. The unit is controlled by an external time clock that may be set to rotate the trays at any interval desired. In this last case, the eggs are packed with large ends up and secured in the trays to prevent shifting during rotation. Eggs that are too small for conventional trays may be protected from damage by packing in paper towels or hardware cloth supports, as suggested for Japanese quail (*C. coturnix japonica*) by Wilson *et al.* (1961).

Rotation early in the incubation period is necessary. Chicken eggs are ordinarily turned for the first 15 days of incubation. Incubating hens may turn their eggs several times each hour. Eggs are more likely to hatch in incubators if turned three to nine times per day. Eggs should be turned at odd intervals and in various directions. Turning is usually discontinued late in incubation, when embryonic rotation within the egg brings the embryo into proper position in relation to the air sac at the blund end of the egg and orients the bird for proper hatching. Although the optimum time to cease rotation during artificial incubation has not been ascertained, it appears that eggs should not be rotated after two-thirds of the species' normal incubation period has passed.

Incubation Periods Temperature, humidity, and perhaps other factors may strongly influence the interval from onset of incubation until hatching. Nevertheless, there are species-specific differences among eggs reared in the same conditions, as shown in Table 5. Incubation period is in general proportional to adult body weight, and the incubation period of precocial species is longer than that of altricial species. For instance, although eggs of the precocial Gambel's quail (*Lophortyx gambei*) require longer incubation than those of the smaller precocial Japanese quail, the periods for both are longer than that of the altricial Rock Dove (*Columba livia*), which is a larger bird than either of the quails (Table 5).

Candling, Culling, and Marking of Eggs The state of embryonic development during incubation can be ascertained by candling eggs, a technique in which a strong light is passed through an egg in a darkened room. Hanson (1954a) describes a portable egg candler, a device to measure egg volume, and techniques of photographing the contents of eggs. He provides a useful series of photographs of eggs of two species of ducks and the Bobwhite at various stages of incubation (1954b).

Candling is routinely performed about one-third of the way through incubation for domestic species, but many investigators candle every 5

TABLE 5 Incubation Periods of Some Common Laboratory Species

	Incubation period, h.	
Species	**A & C**[a]	**W & W**[a]
Ruffed Grouse (*Bonasa umbellus*)		534 ± 8
Bobwhite (*Colinus virginianus*)		559 ± 7
California quail (*Lophortyx californica californious*)		559 ± 7
Gambel's quail (*L. gambeii*)		539 ± 7
Japanese quail (*Coturnix coturnix japonica*)	393.6 ± 1.2	460
		414 ± 5
		395 ± 15
Ring-necked pheasant (*Phasianus colchicus*)	581.6 ± 2.9	550
Red Jungle Fowl (*Gallus gallus*)		504
Rock dove (*Columba livia*)		404 ± 5
Budgerigar (*Melopsittacus undulatus*)		405 ± 4

[a]A & C = Abbott and Craig (1960) measurements on individual eggs; W & W = Wetherbee and Wetherbee (1961b), measurements on egg batches (using forced-draft, 600-egg capacity, chicken incubator at 37.8°C and 64 percent RH), in which hatching of the last egg is taken as the incubation period.

days or so throughout incubation. Examination of the air cell by candling and weighing the egg helps to estimate water loss (Rahn and Ar, 1974); abnormal water loss can be counteracted by increasing the humidity in the incubator.

Candling also helps predict the time of hatching of good eggs and permits culling infertile or dead eggs. The internal pressure caused by gas that builds up from invading bacteria inside dead eggs eventually causes the eggs to explode. This is very undesirable, not only because of the odors released, but also because the organic material spattered over the insides of the incubator causes further spread of microorganisms.

The eggshells of some wild birds are so heavily pigmented that identification of infertile or infected eggs by candling may be difficult or impossible. In this case, visual, tactile, auditory, and olfactory inspection must suffice. In addition to bad odor, the eggs should be inspected for "sloshy" contents, softness of shell, and cracks or holes from which contents ooze out. These techniques require experience with a given species. Records should be kept for each species, especially concerning the ultimate fate of any eggs of questionable quality allowed to remain in the incubator.

Eggs may be marked in various ways. Unpigmented or lightly pigmented eggs can be marked with a blunt, soft-lead pencil. China marking pencils of a light color such as orange are recommended for more heavily pigmented eggs. If too much of the eggshell is covered with oily or waxy marking substances, however, gas exchange through the shell may be undesirably reduced, especially at the blunt, rounded end of the egg containing the air-space requisite to embryo development (and where eggs are ordinarily marked).

Hatching in Incubators Many incubators are equipped with special apparatus for hatching. Large incubators with many egg trays often contain a special hatching tray near the bottom, to which eggs should be transferred at the first signs of pipping. These are always open trays with adequate head room for the newly hatched bird. Incubators sometimes provide special controls for temperature, humidity, and oxygen near the hatching tray. Newly hatched birds, moving hesitantly in the dark, fall a short distance from the tray to the bottom and are thereby segregated from the eggs still hatching. Hatching trays should be kept scrupulously clean to minimize bacterial and fungal infections.

Hatching conditions in the incubator are normally somewhat different from natural conditions. Vents should be closed to prevent drafts on the newly hatched birds and to help maintain higher humidities. Humidity must often be raised, perhaps to 80 percent for species incubated at only 50 percent and to 90 percent for species having 70–80 percent incubation humidity. High humidity prevents drying of the membranes that must be penetrated by the emerging chick. Hatching temperatures, on the other hand, should be slightly lower (perhaps 1°–2°C below incubation temperatures). Positioning of hatching trays at the bottom of the incubator makes it easier to meet all these requirements simultaneously.

The cumulative experience of investigators who have reared chickens, ducks, falcons, and gulls indicates that helping a pipping egg to hatch is not wise, in part because the membranes surrounding the chick are still functional tissues that can be damaged by interference. Usually, if a chick cannot hatch in proper environmental conditions, it will prove weak and eventually die, even if successfully extricated from the egg. The only generally useful interference (in gulls, at least) is to break away fragments from eggs in order to moisten membranes that have dried too much.

Any dishes of water placed in incubators to increase humidity should be removed to prevent drowning of newly hatched birds that cannot hold their heads up for minutes to hours after hatching. Since wet birds chill readily, hatchlings should remain in the incubator for a few hours until they are dry and, in downy species, until their feathers have fluffed out. Breeders allow some species to remain in the hatching compartment for up to 24 hours.

Hatching Synchrony In the wild, broods of some precocial species must hatch relatively synchronously, because the mother leads the young away from the nest soon after hatching. To assure synchrony, there has evolved in some species a special communication system among embryos. In Japanese and Bobwhite quail, vibrations and possibly the sounds of other fetal birds nearing hatching accelerate the progress of less-developed birds (Vince, 1966; see also Drent, 1973). Synchronous hatching may be useful to laboratory investigators, merely as a convenience in incubator scheduling or as a research technique to obtain many individuals of the same age. However, some species have evolved mechanisms to ensure asynchronous hatching, apparently as an adaptation to an unpredictable food supply (Cody, 1971).

To hatch synchronously, the embryos must be able to communicate by means of vibrations. In nature this occurs through direct contact among eggs. In incubators, where the close packing characteristic of nests is either undesirable or infeasible, the communication medium can be a rigid, suspended substrate on which the eggs rest, for example, a wooden frame tray with a wire mesh bottom. Isolated eggs, such as those packed in paper or other soft materials, cannot communicate through vibrations, and it is unlikely that they will hatch synchronously.

Incubation by Foster Parents An alternative to man-made incubating devices is to place the eggs for hatching under a foster parent of a species that commonly reproduces in confinement. Only two species are commonly used as parental surrogates for incubation—domestic hens and canaries. A broody hen will incubate eggs larger or smaller than her own, or even mixed clutches of various sizes of eggs. Broody hens readily accept eggs for incubation in artificial nests of shavings or straw. Canaries, on the other hand, usually must first build their own nests, which they will readily do from a variety of materials in a cup fastened to the side of the cage.

Canaries, because they are small, are used primarily to incubate songbird eggs. They can incubate four or five eggs of a size similar to their own, fewer larger eggs, and more smaller eggs. A broody hen (about 2 kg) can cover about 12–14 chicken eggs, about 9–11 duck eggs, or about 4–6 goose eggs. A hen will turn small eggs, but goose eggs must be turned by hand under the incubating hen (see the section "Egg-turning" above). Leghorns are poor incubators, but any general-purpose breed, such as New Hampshire and Plymouth Rock, will incubate eggs well.

Surrogate parents should generally not be used for duties beyond incubation. Since hens do not feed their young, hatchlings unable to feed themselves must be taken away from the hen immediately and fed. Canaries will feed any young bird that begs, but the young will not necessarily accept any food given to them. The adult canary eats seeds, which it does not feed to the young, but it will readily bring certain kinds of insects to the young. A good solution is to train canaries to feed hard-boiled eggs to their own young; once trained, they will reliably do this with foster young that they themselves have hatched. Eggs are a convenient and acceptable food for the young of many species in captivity.

Young birds left with the parental surrogates that incubated them may imprint upon that surrogate, a phenomenon described below (see p. 75).

Rearing of Young Birds

Young birds taken from their parents in confinement, and those hatching after artificial incubation, must be hand-reared. This is often difficult because it entails many diverse, special requirements, as elaborated upon below.

Environment Newly hatched birds require protective environments that mimic those provided by natural parents. Since the maturation of thermoregulatory apparatus is roughly correlated with complete feathering in young birds, hatchlings must be kept for various periods in controlled environments with temperatures near those required for incubation. Precocial species, such as domestic fowl and waterfowl, require only a few hours or days; altricial species, such as doves, canaries, and budgerigars, may require several weeks.

Lanyon and Lanyon (1969) describe an artificial nest, with heating, for the young of altricials that must be kept at about incubation temperatures. Precocial species may be kept in an environment in which they may select their own ambient temperature by moving along a gradient. Ordinary heat lamps at one end of a pen provide such a gradient.

Although altricials usually require high humidity—about 70 percent for maximum success—young are not as sensitive to humidity changes as are their eggs. Moderate lighting during part of each day is probably necessary to prevent retinal degeneration in young birds.

Food and Water The nutritional needs of most young vertebrates are similar, but special diets are often required for the young of certain bird species. Precocial birds, relying on internal reserves, do not voluntarily feed for the first day or two after hatching. Most gallinaceous precocial birds may be fed with commercial starter feeds developed for such domestic species as fowl and turkeys. Quail and pheasants must be fed a higher-protein, game-bird starter mash. The problems encountered when feeding other species involve simulation of the nutritional content of natural foods, as well as the form in which foods are acceptable to the young. Pigeons and doves that are fed by regurgitation of parents' crop-milk may be artificially fed on high-protein soups administered with a pipette.

Fisher (1972) has successfully reared ringdoves on a wide variety of diets, ranging from pediatric formulas to slurries of chicken starter feed. He reports that feeding frequency is more important to growth than is exact nutritional composition. Gull chicks, which feed upon regurgitated seafoods and carrion partially digested by the parent, readily eat fish-flavored commercial cat food diluted with water. Combined with vitamin supplements, this diet brings about normal growth.

Raptors may be fed tiny bits of meat, which can be increased in size as the young bird grows. Live prey are not proven necessary to the diet of young raptors. If live food is given, however, they should be allowed to fast for a day beforehand, so that there is no risk of their digestive tracts becoming engorged. As they grow older, young raptors can accommodate feathered avian prey and mammalian fur, but it is usual practice to eviscerate mammals for feeding to young as well as adults.

Young passerines may be fed insect larvae, although the insect species must be selected carefully. Mealworms are very chitinous and can cause gastrointestinal blockage. Wax moth larvae (*Galleria*) are far better, but are difficult to purchase commercially and very time-consuming to raise. Honeybee larvae appear to be good food (Gary *et al.*, 1971), but pupae of the same species may be even better (Lanyon and Lanyon, 1969); termite larvae are also appropriate. European warblers (*Sylvia* spp.) have been successfully reared on a diet consisting predominantly of ant pupae, either fresh (Berthold *et al.*, 1970) or freeze-dried (Berthold, personal communication). Woodpecker young and many passerines, which are in nature fed insects and grubs by their parents, can be reared on mealworms and wet meal dog food (Spring, 1965).

No one insect seems to suffice for most species. Supplements of calcium, vitamins, and carbohydrates are desirable. Commercial starter mashes usually contain sufficient vitamins for precocial species, but other species often need addition of polyvitamins of the kind designed for human infants. Birds require vitamin A, some B vitamins, and vitamin D, but do not require external sources of ascorbic acid. Carbohydrate sources include molasses and water, honey, and sucrose solutions. Finely diced vegetables such as carrots may provide carotenoids and some minerals beneficial to young birds.

The young of precocial species should be provided with food and water *ad libitum*. Altricial young frequently must be fed small amounts by hand during the daylight hours. Some young birds do drink minute amounts of water transported by the parents, but most young altricials obtain the needed free water from their food.

It is preferable to feed small amounts at frequent intervals. Large amounts administered less often may result in an excess of undigested food in the gut or crop of young birds, which may decay and cause either infection or impaction of the gastrointestinal tract.

Effects of Deprivation Complete light deprivation, or continuous light, may lead to eye enlargement and retinal degeneration in chickens (Voitle and Shirley, 1968). Deprivation of patterned light can cause other abnormalities of the visual system. Auditory deprivation often results in abnormal songs, although its effect on hearing has not been studied. In general, to produce normal, healthy birds, a stimulus-rich environment is desirable.

Social deprivation has generally unpredictable effects, but may be extremely important in the development of normal behavior. Some relatively solitary species, such as hawks, can probably be reared in social isolation without severe repercussions; but deprivation in highly social species may produce birds that later fail to show normal social and sexual behavior. Since rearing in social isolation may produce birds that will not properly reproduce in confinement, this approach is not recommended if a reproducing colony is desired.

Fostering by other bird species, or humans, may lead to heterospecific attachments. Precocial gallinaceous birds and waterfowls can form firm social attachments with parental surrogates after experiences of minutes or hours. This phenomenon, termed imprinting, is very long-lasting in most species and may play a large role in determining later mating behavior. Imprinting on humans occurs in such altricial species as hawks. Birds imprinted on human caretakers often fail to socialize normally with members of their own species and may later court only humans. Undesired imprinting on other species can be avoided by rearing birds with their own species.

Similar attachments may form in species that ordinarily are fed by parents. In this case, the attachment is directed to the provider of food, which acts as a psychological reward for the social learning. Many species can become socially and sexually attached to nonliving things, if such objects are prominent in an otherwise impoverished early environment.

VI SURGICAL PROCEDURES

RESTRAINT

All avian surgical procedures require handling of the bird and involve some type of restraint. Careful handling of small birds is critical; improper restraint techniques can be fatal. Graham-Jones (1965) and Gandal (1969a) report that some avian species are susceptible to injury and shock merely from physical restraint. Donovan (1958), Arnall (1961a), and Minsky (1966) indicate that most small pet birds usually do not experience sudden shock or death when handled carefully.

A small bird may be restrained by holding its head and neck between the index and middle fingers (Donovan, 1958) or between the thumb and forefinger (Graham-Jones, 1965) with its back in the palm of the hand and its feet held in place by the ring and little fingers. The bird is then in the supine position and can be readily examined or given intramuscular injections. However, the supine position impedes respiration and substantially reduces tidal volume in the chicken (King and Payne, 1964), and also presumably in other species. This probably results from visceral encroachment upon the dorsally located air sacs.

Care must be taken not to constrict the abdominal region of a bird when holding it. Expansion of the thoracicoabdominal cavity during inspiration involves ventral movement of the sternal–coracoid complex, which pivots at the coracoid–scapular–clavicular joint at the base of the neck (King and Molony, 1971). Thus, any restriction of sternal movement will interfere with normal respiration mechanics and could lead to respiratory distress and death.

Small birds can be restrained for weighing, anesthetizing, surgery, or recovery from anesthesia by wrapping them in heavy aluminum foil, allowing their heads and tails to protrude (Tudor, 1970); by placing them in a tubular, gauze sleeve whose ends can be gently pulled to apply more restraint if the bird struggles (Graham-Jones, 1965); or by placing them in a cardboard tube (Donovan, 1958). Larger birds such as ducks or pigeons can be restrained in simple, inexpensive holders (Nelson and Peck, 1964) with little danger from shock or injury.

BLOOD COLLECTING

Blood can be collected, usually without anesthetics, by three methods, depending on the bird's size and age: by venipuncture, by cardiac puncture, or by collecting effluent after rupturing a vein.

Venipuncture Three veins are commonly used: the cutaneous ulnar vein (wing vein), the right jugular vein, or the medial metatarsal vein. All three can be entered with a 23- to 25-gauge needle in a bird the size of a pigeon or larger and blood can be withdrawn into a syringe.

The cutaneous ulnar vein of large birds (Fredrickson *et al.*, 1958) can be successfully exposed by restraining the bird on its back with one wing extended, then removing the feathers overlying the vein where it crosses the elbow joint. The vein can then be entered with a 23-gauge needle. After removal of the needle, pressure must be applied to the vein for several minutes to prevent formation of a hematoma.

The medial metatarsal vein is superficial and is more stable but less visible than the cutaneous ulnar vein. It can be entered in the mid-metatarsal region by inserting a 23-gauge needle in a proximal direction through the skin overlying the vein with the needle almost parallel to the skin. Hematoma from this vein is less likely because surrounding structures are rigid.

The jugular vein has been used for birds as small as 1-day-old sparrows (McClure and Cedeno, 1955; Stevens and Ridgeway, 1966), but only the larger right jugular vein is suitable for venipuncture.

Cardiac Puncture Cardiac puncture has been used satisfactorily for a variety of both large and small birds (Genest, 1946; Hofstad, 1950; Sooter, 1954; Garren, 1959; O'Meara, 1960; Utter *et al.*, 1971). In the suprasternal approach the needle is inserted horizontally in the midline of the interclavicular fossa while the bird is on its back. The heart can also be reached from the left side, between the fourth and fifth ribs, in the center of a triangle formed by the head of the humerus, that of the femur, and the anterior end of the sternum. Cardiac puncture results in low mortality with nestlings of many species except pigeons and doves (Sooter, 1954), and repeated samplings with this method are often possible.

Collection from Ruptured Veins Kern *et al.* (1972) have described a technique for obtaining repeated blood samples from the vena tibialis postica of such small birds as the White-crowned Sparrow (*Zonotrichia leucophrys*). The vein is ruptured over the intertarsal joint and blood is collected in a heparinized capillary tube.

Leonard (1969) indicates that blood may be obtained easily from the budgerigar (*Melopsittacus undulatus*) by clipping a toenail with a fingernail clipper midway between the base and the end of the vessel visible in the nail. Blood may then be collected directly into a pipette or capillary tube. In this method, the amount of blood taken can be easily controlled; blood flow is easily stopped by applying firm pressure to the toe with the thumb and forefinger and then cauterizing the surface of the nail with a silver nitrate applicator stick.

Prime consideration must be given to the quantity of blood withdrawn, especially from small birds. The total blood volume of most birds is approximately 7 percent of the body weight. Blood samples should not exceed 20 percent of the total blood volume. A blood sample taken from a 30-g bird with a total blood volume of 2.1 ml should not exceed 0.42 ml. Furthermore, if the method of restraint used to obtain the blood sample does not allow unhindered respiratory movements, severe respiratory distress may result.

ANESTHETIZATION

What is the purpose of an anesthetic? An anesthetic agent may be used as:

- an analgesic;
- a chemical restraining agent to assist in the positioning or posturing of a bird for manipulations, sampling, or surgery;
- an agent to remove fear of prolonged handling that could produce shock or collapse;
- a muscular relaxant.

General anesthetics produce all the above effects. However, drugs such as tranquilizers or neuromuscular blocking agents produce some of the effects but definitely do not produce analgesia (insensibility to pain). Furthermore, in small doses, many anesthetics produce narcosis during which pain is still perceived. It is important, therefore, to recognize the drugs (or the doses) that produce narcosis as being distinctive from those that produce anesthesia.

Many parts of the bird's body appear to be remarkably insensitive to painful stimuli. However, stimulation of other parts, such as the head, beak, mouth, eyes, ears, scaled parts of the legs, and vent, produce pronounced motor responses (Arnall, 1964).

The magnitude of the motor responses has been recognized by Arnall (1961a) under the subject "Criteria of Planes of Narcosis and Anesthesia." He has divided narcosis into three planes:

- *Light narcosis.* The main signs are those of sedation; the bird is lethargic and more tolerant of being approached. The eyelids tend to droop.
- *Medium narcosis.* The feathers become ruffled. The head hangs progressively lower until it reaches the floor, but the bird can be easily roused. Only a little struggle occurs when threatening movements are made near the bird's head or when it is picked up.
- *Deep narcosis.* There is little or no response to sound vibration, but there may be some attempt at coordination when the bird is placed on its back. Purposeful voluntary movements (fluttering) are seen when painful stimuli are applied, and in some cases shrill cries are emitted after the stimulus is discontinued. The latter is more noticeable with barbiturate narcosis. Respiration is usually fairly rapid, regular, and deep but, after stimulation, it may become irregular.

Arnall has also divided anesthesia into three planes;

- *Light anesthesia.* No response is provoked by vibration or postural changes but, although no voluntary purposeful movement is performed, all reflexes—palpebral, corneal, the cere, and the pedal—are present and brisk. Pedal response may continue after stimulation ceases.
- *Medium anesthesia.* The palpebral reflex is lost; corneal and pedal reflexes are sluggish, delayed, and intermittent. Respiration is slow, deep, and regular. Most surgical operations can be performed at this level of anesthesia.
- *Deep anesthesia.* Corneal, digital, cloacal, buccal, and cere re-

flexes are absent. Respiration is very slow but usually regular. If anesthesia is further deepened, the respiration becomes slower and shallower and finally ceases.

Local Anesthetics

Local anesthetics that have been tried with birds are summarized in Appendix E. To avoid toxicity to small birds (Altman, 1968), local anesthetics should be carefully administered in recommended doses (Klide, 1973). These anesthetics are useful and safe for certain surgical procedures with such large birds as ducks or chickens. They can be injected at the site where anesthetization is desired or sprayed on viscera or mucous membranes.

General Anesthetics

Three routes are used to administer general anesthetics: inhalation, parenteral, or per os.

Inhalation Appendix E lists different types of inhalation anesthetics that have been tried with birds. Much of the early literature indicates that ether is not suitable for birds because it persists in their air sacs. Since the gas volume of the air sacs is several times larger than that of the lungs, the ether concentration in the gas passing through the lungs is not rapidly reduced following its removal from the inhaled gas. Therefore, it is easy to give an anesthetic overdose. However, many investigators report that ether is a satisfactory anesthetic when carefully administered under close observation so that it can be discontinued at the first sign of respiratory distress.

Two volatile anesthetics, halothane and methoxyflurane, induce anesthesia rapidly, can be used for prolonged surgical procedures, are neither explosive nor flammable, and allow rapid recovery after removal of the inhaled gas mixture. Each can be administered in a variety of ways, but the safest appears to be an anesthetic machine that allows the bird to breathe from a flowing gas stream of controlled composition. Lumb (1963) has reviewed both drugs. Lumb and Jones (1973) and Anderson (1967) have described a simple procedure for administering them.

Parenteral Parenteral anesthetics have been used much more frequently with birds than have inhalation anesthetics. No one parenteral anesthetic appears best for all surgical procedures; some have a relatively short duration while others maintain anesthesia for several hours. The risks, as with any anesthetic, are greater when unhealthy birds are used. Appendix E lists parenteral anesthetics that have been tried with birds.

A mixture of pentobarbital sodium, chloral hydrate, and magnesium sulfate, injected intramuscularly, is commonly used for small birds. When using this mixture, it is important to weigh the birds to the nearest gram to ensure correct calculation of dose. Pentobarbital sodium, injected intravenously, has also been used frequently with large birds, but its relatively short duration (about 30 minutes) necessitates frequent additional doses to maintain a surgical plane of anesthesia. Hence, with this drug, the anesthetic plane changes continuously. This may profoundly affect certain experimental procedures. Phenobarbital sodium appears to alleviate this problem, at least in such birds as chickens, because it acts as long as 36 hours and changes in the anesthetic plane are slow.

Some parenteral anesthetics are best administered intramuscularly (in either the pectoral or leg muscles) and some intravenously. However, birds have renal portal systems that drain the leg and tail region, and it is unclear if drugs injected in those regions are excreted by the kidney before they pass into the general circulation.

Per Os Some anesthetics (as indicated in Appendix E) have been administered orally or as rectal suppositories. Oral administration of drugs also has been useful for capturing birds in the wild and for administering tranquilizers in an attempt to calm birds before moving or handling them (Peek, 1966).

Fasting small birds before anesthetization is generally considered detrimental to recovery because food reserves in the gut are needed to supply energy during the stress period (Keymer, 1960a; Altman, 1968). However, in the case of chickens and other large birds that often regurgitate their crop contents when anesthetized, it is recommended that food be withheld for 12 hours preceding anesthetization so that the crop and the gastrointestinal tract will be relatively empty.

Artificial Respiration If the plane of anesthesia becomes too deep and respiration ceases, artificial respiration can be accomplished by gently "pumping" the tip of the sternum. Such compression and relaxation of the abdominal and caudal thoracic air sacs will cause gas to move through the lungs. Supplemental oxygen in the inhaled gas mixture is recommended, since pulmonary ventilation may be less than normal. An alternative and more controllable artificial ventilation procedure involves flowing oxygen into a cannulated clavicular air sac. The air sac can be readily and quickly entered with a hypodermic needle inserted in the interclavicular space. The gas would then pass from the air sac through the lungs and out the trachea in an undirectional manner, thereby ventilating the lungs (Whittow and Ossorio, 1970).

SURGERY

Many different surgical procedures for birds, both experimental and therapeutic, have been described. A comprehensive account of the instruments, materials, and procedures used in surgery involving the various organ systems has been given in a series of articles by Arnall (1961 a,b,c,d).

Therapeutic surgical procedures for cecal ablation, ascites, wounds, bumblefoot, cropectomy, crop impaction, comb or wattles amputation, spur trimming, fractures, preen gland impaction, feather cysts, and tumor removal have been described by a number of authors: Barger *et al.*, 1958; Puckett, 1959; Snow, 1959; Keymer, 1960a,b; Brownell and Sadler, 1969; and Gandal, 1969b. Other procedures detailed in the literature involve egg-bound condition (Gandal, 1960, 1969b; Friedburg, 1961; Hoge, 1966), flight control or pinioning (Schroeder and Koch, 1940; Van den Akker, 1947; Young, 1948; Gandal, 1969b; Williamson and Russell, 1971), removal of a portion of the beak to control cannibalism (Schwarte, 1965), and devoicing to silence a bird (Durant, 1953; Tudor and Woodward, 1967).

Surgical procedures such as caponization (Elley, 1913; Barger *et al.*, 1958), sexing, or observing gonadal condition via laparotomy (Bailey, 1953), installation of a bypass to prevent the feces and urine from intermixing in the proctodeum (Neuberne *et al.*, 1957; Dixon and Wilkinson, 1957), removal of the pineal gland (Foss *et al.*, 1972), implanting electrodes in the brain (McFarland and Wilson, 1965; Stetson, 1968; Biedermann-Thorson, 1970), and thyroidectomy (Marvin and Smith, 1943) are also described in the literature for many avian species.

Blood loss should be minimized to ensure successful surgery on small birds. Even extremely small amounts of blood loss from small birds frequently cause death (Wichmann, 1961; Murray, 1967). Reduction in body temperature, which almost always accompanies anesthetization, should be kept to a minimum by an external heat source during both surgery and recovery. During recovery from anesthesia birds should be kept in a box or room free from drafts and at an even temperature of at least 21°C, but preferably between 27°C and 30°C (Arnall, 1961a). A bird that does not get back onto its feet within an hour should be turned from side to side at 30 minute intervals (Gandal, 1969a). Although the administration of oxygen has been advocated to hasten a low recovery (Altman, 1968; Gandal, 1969b), it may not be necessary (Murray, 1967).

To prevent birds with powerful jaws from interfering with wounds and reopening incisions, an Elizabethan collar formed from soft aluminum sheeting can be used (Arnall, 1961a; Gandal, 1969b).

EUTHANASIA

Euthanasia is the inducement of a quiet, painless death. Whenever an animal is killed, humane techniques that insure euthanasia but do not interfere with data interpretation must be used.

Satisfactory methods of euthanasia have been described by Jones (1965) and Breazile and Kitchell (1969). Intravenous administration of an overdose of pentobarbital sodium appears to be the best method for birds large enough for easy venipuncture. To insure rapid respiratory arrest, three to five times the anesthetic doses should be given. Commercial preparations for euthanasia containing pentobarbital sodium are available. They may be administered intraperitoneally, but the time required for the drug to reach lethal levels in the blood is increased; therefore, death does not occur as rapidly as with intravenous administration. For small birds, in which venipuncture is difficult, an inhalation agent may be used for euthanasia. Although ether and chloroform frequently have been used to kill birds, they do not produce euthanasia. Their vapors irritate mucous membranes, and both agents cause considerable excitement before loss of consciousness. Inhalation of high concentrations (40 percent or greater) of carbon dioxide gas appears best suited for true euthanasia, with little danger to the operator.

APPENDIX A:

Addresses of Federal, State, and Provincial Regulatory Agencies Concerned with the Capture, Transportation, and Possession of Protected or Harmful Species of Birds and Their Parts, Eggs, and Nests

FEDERAL REGIONAL OFFICES, UNITED STATES*

ALASKA
813 D Street, Anchorage, AK 99501

HAWAII, IDAHO, OREGON, WASHINGTON
P.O. Box 3737, Portland, OR 97208

CALIFORNIA, NEVADA
Room E 1924, 2800 Cottage Way, Sacramento, CA 95825

COLORADO, MONTANA, UTAH, WYOMING
P.O. Box 25486, Denver Federal Center, Denver, CO 80225

IOWA, KANSAS, MISSOURI, NEBRASKA, NORTH DAKOTA, SOUTH DAKOTA
P.O. Box 1038, Independence, MO 64051

ARIZONA, NEW MEXICO, OKLAHOMA, TEXAS
P.O. Box 329, Albuquerque, NM 87103

ILLINOIS, INDIANA, MICHIGAN, MINNESOTA, OHIO, WISCONSIN
P.O. Box 45, Twin Cities, MN 55111

ARKANSAS, LOUISIANA
546 Carondelet Street, Room 408, New Orleans, LA 70130

ALABAMA, FLORIDA, GEORGIA, MISSISSIPPI, PUERTO RICO
P.O. Box 95467, Atlanta, GA 30347

KENTUCKY, NORTH CAROLINA, SOUTH CAROLINA, TENNESSEE
P.O. Box 290, Nashville, TN 37202

DELAWARE, DISTRICT OF COLUMBIA, MARYLAND, PENNSYLVANIA, VIRGINIA, WEST VIRGINIA
95 Aquahart Road, Glen Burnie, MD 21061

*Direct correspondence to:
Special Agent in Charge, U.S. Fish and Wildlife Service (at these addresses).

NEW JERSEY, NEW YORK

Hangar 11, Room 1-49, John F. Kennedy Airport, Jamaica, NY 11430

CONNECTICUT, MAINE, MASSACHUSETTS, NEW HAMPSHIRE, RHODE ISLAND, VERMONT

P.O. Box 34, Boston, MA

STATE NATURAL RESOURCES AGENCIES, UNITED STATES

ALABAMA

Director, Department of Conservation and Natural Resources, 64 N. Union Street, Montgomery, AL 36104

ALASKA

Commissioner, Department of Fish and Game, Subport Building, Juneau, AK 99801

ARIZONA

Director, Game and Fish Department, 2222 W. Greenway Road, Phoenix, AZ 85023

ARKANSAS

Director, Game and Fish Commission, Little Rock, AR

CALIFORNIA

Director, Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814

COLORADO

Director, Division of Game, Fish, and Parks, 6060 Broadway, Denver, CO 80216

CONNECTICUT

Director, Board of Fisheries and Game, State Office Building, Hartford, CT 06115

DELAWARE

Secretary, Department of Natural Resources and Environmental Control, P.O. Box 457, Dover, DE

FLORIDA

Director, Game and Fresh Water Fish Commission, 620 S. Meridian, Tallahassee, FL 32304

GEORGIA

Director, State Game and Fish Commission, Trinity-Washington Building, 7th Floor, Atlanta, GA 30334

HAWAII

Director, Division of Fish and Game, Department of Land and Natural Resources, 1179 Punchbowl Street, Honolulu, HI 96813

IDAHO

Director, Fish and Game Department, 600 S. Walnut Street, P.O. Box 25, Boise, ID 83707

ILLINOIS

Director, Department of Conservation, 102 State Office Building, Springfield, IL 62706

INDIANA

Director, Department of Natural Resources, 608 State Office Building, Indianapolis, IN 46204

IOWA

Director, State Conservation Commission, State Office Building, 300 4th Street, Des Moines, IA 50319

KANSAS

Director, Forestry, Fish and Game Commission, Box 1028, Pratt, KS 67124

KENTUCKY

Commissioner, Department of Fish and Wildlife Resources, State Office Building Annex, Frankfort, KY 40601

LOUISIANA

Director, Wildlife and Fisheries Commission, 400 Royal Street, New Orleans, LA 70130

MAINE

Commissioner, Department of Inland Fisheries and Game, State Office Building, Augusta, ME 04330

MARYLAND

Director, Fish and Wildlife Administration, State Office Building, P.O. Box 231, Annapolis, MD 21401

MASSACHUSETTS

Director, Division of Fisheries and Game, 100 Cambridge Street, Boston, MA 02202

MICHIGAN

Director, Department of Natural Resources, Stevens T. Mason Building, Lansing, MI 48926

MINNESOTA

Commissioner, Department of Natural Resources, Centennial Office Building, 658 Cedar Street, St. Paul, MN 55101

MISSISSIPPI

Executive Director, Game and Fish Commission, Game and Fish Building, 402 High Street, Jackson, MS 39205

MISSOURI

Director, Department of Conservation, P.O. Box 180, Jefferson City, MO 65101

MONTANA

Director, Department of Fish and Game, Mitchell Building, Helena, MT 59601

NEBRASKA

Director, Game Parks Commission, State Capitol Building, Lincoln, NE 68509

NEVADA

Director, Department of Fish and Game, Box 10678, Reno, NV 89510

NEW HAMPSHIRE

Director, Fish and Game Department, 34 Bridge Street, Concord, NH 03301

NEW JERSEY

Director, Division of Fish, Game and Shellfisheries, Department of Environmental Protection, P.O. Box 1809, Trenton, NJ 08625

NEW YORK

Commissioner, Department of Environmental Conservation, Conservation Department Building, State Office Building Campus, Albany, NY 12226

NORTH CAROLINA

Executive Director, Wildlife Resources Commission, P.O. Box 2919, Raleigh, NC 27602

NORTH DAKOTA

Commissioner, State Game and Fish Department, 2121 Lovett Avenue, Bismarck, ND 58501

OHIO

Director, Department of Natural Resources, 907 Ohio Departments Building, Columbus, OH 43215

OKLAHOMA

Director, Department of Wildlife Conservation, P.O. Box 53465, Oklahoma City, OK 73105

OREGON

Director, State Game Commission, P.O. Box 3503, Portland, OR 97208

PENNSYLVANIA

Executive Director, Game Commission, P.O. Box 1567, Harrisburg, PA 17120

RHODE ISLAND

Director, Department of Natural Resources, 83 Park Street, Providence, RI 02903

SOUTH CAROLINA

Director, Wildlife Resources Department, 1015 Main Street, P.O. Box 167, Columbia, SC 29202

SOUTH DAKOTA

Director, Department of Game, Fish, and Parks, State Office Building, Pierre, SD 57501

TENNESSEE

Director, Game and Fish Commission, P.O. Box 40747, Ellington Building, Agricultural Center, Nashville, TN 37220

TEXAS

Executive Director, Parks and Wildlife Department, Reagan State Building, Austin, TX 78701

UTAH

Director, Fish and Game Division, 1596 W. North Temple, Salt Lake City, UT 84116

VERMONT

Commissioner, Fish and Game Department, Montpelier, VT 05602

VIRGINIA

Executive Director, Commission of Game and Inland Fisheries, 4010 W. Broad Street, P.O. Box 11104, Richmond, VA 23230

WASHINGTON

Director, Department of Game, 600 North Capitol Way, Olympia, WA 98504

WISCONSIN

Director, Department of Natural Resources, Box 450, Madison, WI 53701

WYOMING

Commissioner, Game and Fish Commission, Box 1589, Cheyenne, WY 82001

PROVINCIAL NATURAL RESOURCES AGENCIES, CANADA

ALBERTA

Director, Fish and Wildlife Branch, Department of Lands and Forests, 109th Street and 99th Avenue, Edmonton, AB

BRITISH COLUMBIA

Director, Fish and Wildlife Branch, Department of Recreation and Conservation, Victoria, BC

MANITOBA

Director, Wildlife Branch, Department of Mines and Natural Resources, Winnipeg, MB

NEW BRUNSWICK

Director, Fish and Wildlife Branch, Department of Natural Resources, Fredericton, NB

NEWFOUNDLAND

Director of Wildlife, Department of Mines, Agriculture, and Resources, Confederation Building, St. John's NF

NORTHWEST TERRITORIES

Superintendent of Game, Government of the Northwest Territories, Yellowknife, NT

NOVA SCOTIA

Director, Wildlife Conservation Division, Department of Lands and Forests, P.O. Box 516, Kentville, NS

ONTARIO

Director, Wildlife Division, Fish and Game Branch, Ministry of Natural Resources, Toronto, ON

PRINCE EDWARD ISLAND

Director, Fish and Wildlife Division, Department of Environment and Tourism, Charlottetown, PE

QUEBEC

Director, Wildlife Division, Fish and Game Branch, Department of Tourism, Fish, and Game, Quebec City, PQ

YUKON TERRITORY

Director, Game Branch, Yukon Territorial Government, Box 2703, Whitehorse, YT

APPENDIX B:

U.S. Zoos That Confine Birds

OVER 1,000 BIRDS

Los Angeles Zoo, 433 Zoo Drive, Los Angeles, CA 90027

San Diego Zoological Garden, Zoological Society of San Diego, P.O. Box 551, San Diego, CA 92112

National Zoological Park, Washington, DC 20009

Busch Gardens Zoological Park, 3000 Busch Boulevard, Tampa, FL 33604

Honolulu Zoo, Kapiolani Park, Honolulu, HI 96815

St. Louis Zoological Park, Forest Park, St. Louis, MO 63110

New York Zoological Park, Bronx Park, Bronx, NY 10460

Dallas Zoo, 621 E. Clarendon Drive, Dallas, TX 75203

San Antonio Zoological Gardens and Aquarium, 3903 N. St. Mary's Street, San Antonio, TX 78212

FROM 500 TO 1,000 BIRDS

Phoenix Zoo, P.O. Box 5155, Phoenix, AZ 85010

Lion Country Safari, Inc., 8800 Moulton Parkway, Laguna Hills, CA 92653

Sea World, Inc., 1720 S. Shores Road, San Diego, CA 92109

San Francisco Zoological Gardens, Zoo Road and Skyline Boulevard, San Francisco, CA 94132

Busch Gardens, 16000 Roscoe Boulevard, Van Nuys, CA 91406

Denver Zoological Gardens, City Park, Denver, CO 80205

Crandon Park Zoo, 4000 Crandon Boulevard, Key Biscayne, FL 33149

Chicago Zoological Park (Brookfield Zoo), Golf Road, Brookfield, IL 60513

Lincoln Park Zoological Gardens, 100 W. Webster Avenue, Chicago, IL 60614

Lee Richardson Zoo (Finnup Park), Garden City, KS 67846

Detroit Zoological Park, P.O. Box 39, Royal Oak, MI 48068

Rio Grande Zoological Park, P.O. Box 1292, Albuquerque, NM 87103

Buffalo Zoological Gardens, Delaware Park, Buffalo, NY 14214

Zoological Society of Cincinnati, 3400 Vine Street, Cincinnati, OH 45220

Cleveland Zoological Park, 601 E. 72nd Street, Cleveland, OH 44103

Toledo Zoological Gardens, 2700 Broadway, Toledo, OH 43609

Philadelphia Zoological Gardens, 34th Street and Girard Avenue, Philadelphia, PA 19104

Pittsburgh Zoological Gardens, P.O. Box 5072, Pittsburgh, PA 15206

APPENDIX C:
Specially Formulated Diets

The following dietary information was obtained from the Bronx Zoo, New York, the Philadelphia Zoological Garden (Ratcliffe, 1966), the Zoologischer Garten, Basel (Wackernagel, 1966), the Honolulu Zoo, and the University of California, Davis (P. Vohra, 1969). The requirements for most species are not greatly different from those of poultry.

Three formulas are given for each basic type of diet. The aviculturist can select the diet best suited to his needs. The three formulas from Ratcliffe (1966) were developed as a result of his experience at the Philadelphia Zoo.

DIETS FOR OMNIVOROUS BIRDS

Diet O-1 (Ratcliffe, 1966)

Ground yellow corn	15%	Alfalfa leaf meal	5%
Ground whole wheat	15%	Brewers' yeast	10%
Ground whole barley	10%	Dried skim milk	10%
Ground rolled oats	10%	Oystershell flour	2%
Peanut meal	10%	Iodized salt	1%
Soybean meal	10%	A–D feeding oil	2%
TOTAL			100%

This diet is prepared in bulk as needed, but never stored longer than 2 weeks. Take nine parts of (the above mixture), one part of ground boiled meat, and sufficient meat broth or water to make a stiff mash. Mix thoroughly and press into shallow pans. Refrigerate 24 to 48 hours to harden, then cut into sections for feeding. This ration supplies about 4 kcal/g. Allow 1/20 to 1/2 oz/lb (3 to 30 g/kg) of body weight, depending upon weight and opportunity for and tendency to spontaneous activity.

Diet O-2 (Wackernagel, 1966)

Basic Mixture		*Vitamins Added per kg of Feed*	
Ground plate maize	15%	A	50,000 I.U.
Ground wheat	10%	B_2	50 I.U.
Ground barley	10%	D_3	10,000 I.U.
Rolled oats	10%	C	300.0 mg
Groundnut oil meal	8%	E	40.0 mg
Soybean oil meal	8%	B_1	8.0 mg
Nettle leaf meal	6%	B_6	6.0 mg
Dried yeast	12%	B_{12}	2.0 mg
Skimmed milk powder	10%	K	2.0 mg
Soybean oil	5%	Folic acid	0.8 mg
Fat-soluble extract of lucerne	1%	Nicotinic acid	40.0 mg
		Pantothenic acid	20.0 mg
Bone meal	2%		
Salt	1%		
Premixture	2%		
TOTAL	100%		

Composition		*Trace Elements Added per kg of Feed*	
Crude protein	23.0%	Fe	20.0 mg
Crude fat	7.0%	Cu	2.5 mg
Crude fiber	3.0%	Mn	60.0 mg
Calcium	1.0%	Zn	40.0 mg
Phosphorus	0.8%	I	1.0 mg
TOTAL DIGESTIBLE NUTRIENTS	74.4%	Co	0.3 mg

Vohra points out that in this diet, used in the Basel Zoo, vitamins A and D_3 seem to be added in excessive amounts.

Diet O-3 (Vohra, personal communication)

This diet, along with Diets S-3 and C-3, were formulated in 1973 by Vohra. The ingredients in all three diets can be obtained from most poultry feed manufacturers.

Ingredients	*g/kg Diet*
Ground milo	160
Ground corn	160
Ground whole wheat	110
Ground barley	100
Ground oats	100
Soybean meal (44% protein)	220
Fish meal (66% protein)	60
Brewers' dried yeast	10
Dried whey products	25
Alfalfa meal (20% protein)	20
Dicalcium phosphate, hydrated	12
Limestone, ground	10
Salt, iodized	2.50
Manganese sulfate monohydrate	0.25
Zinc oxide	0.25
Vitamin mixture—V-2	10
TOTAL	1,000.00

Vitamin Mixture 2 (V-2)		
A	10,000	I.U.
D_3	2,500	I.C.U.
E	20	mg
C	100	mg
Antioxidant (Ethoxyquin)	1,000	mg
Choline chloride	1,200	mg
Thiamine HCl	2	mg
Riboflavin	3	mg
Niacin	40	mg
Pyridoxine HCl	2	mg
Calcium pantothenate	10	mg
K	2	mg
Folic acid	0.5	mg
B_{12}	20	mg
Mix with starch to make 10 g		

Calculated metabolizable energy = 2,720 kcal/kg

% Crude protein = 22.40
% Calcium = 1.18
% Phosphorus = 0.77

Instead of Diets O-1 or O-2, the above Diet O-3 can be substituted to make the remainder of the diets.

SUPPLEMENTED DIETS FOR CAGED BIRDS

Diet S-1 (Ratcliffe, 1966)

Most birds in zoological gardens (are) Passeriformes and are widely varied in adaptations and food habits. A combination of foods that allows them some self-selection seems to solve the major difficulties of feeding these birds. The following composite ration, combined in varying proportions with Diet C-1, and supplemented by diced oranges and by escarole, can be recommended for these birds.

Diet O-1	50%
Ground raw carrots (pulverized and suspended in their own juice)	20%
Ground cooked meat	20%
Ground hard-cooked eggs and shells	8%
A–D feeding oil	2%
TOTAL	100%

Mix fresh daily as needed; will keep at least 48 hours under refrigeration.

Diet S-2 (Wackernagel, 1966)

Diet		*Composition*	
O-2	50%	Crude protein	ca. 19.0%
Minced cooked meat	25%	Crude fat	6.0%
Ground carrots	20%	Crude fiber	2.0%
Ground hard-boiled eggs with shell	5%	Calcium	0.6%
		Phosphorus	0.4%
TOTAL	100%		

Diet S-3 (Vohra, personal communication)

Omnivorous Diet O-3	500 g/kg
Cooked ground meat	200 g/kg
Ground hard-boiled whole eggs	50 g/kg
Ground carrots, raw	200 g/kg
Vitamin mix V-2	50 g/kg
TOTAL	1,000

Mix fresh daily. Store under refrigeration for not more than 48 hours and add 100 mg Canthaxanthin/kg diet for pigmentation.

DIETS FOR CARNIVOROUS BIRDS

Diet C-1 (Ratcliffe, 1966)

Mineral Mixture

Oystershell flour	50%	Raw ground meat	86 or 87%
Powdered skim milk	40%	Mineral mixture	12 or 13%
Iodized salt	5%	A–D feeding oil	1 or 2%
Gevral protein	5%		
TOTAL	100%	TOTAL	100%

Two formulas are given to allow the use of A–D feeding oil or a more complex vitamin mixture.

Mix fresh daily as needed; it will keep at least 48 hours under refrigeration. Allow 0.5 to 2 oz/lb (25–75 g/kg) of body weight.

Diet C-2 (Wackernagel, 1966)

Raw meat (minced meat)	93%
Supplement	7%
TOTAL	100%

Supplement

Skimmed milk powder	42%
Dried brewers' yeast	42%
Steamed bone meal	8%
Ground calcium carbonate	3%
Salt	2%
Premixture	3%
TOTAL	100%

Vitamins Added per kg of Supplement

A	10,000 I.U.
B_2	40 mg
D_3	7,500 I.U.
C	1,000 mg
E	1,000 I.U.
B_1	50 mg
B_6	30 mg
B_{12}	40 mg
K	1 mg
Folic acid	20 mg
Biotin	3 mg
Inosit	3,500 mg
Para-aminobenzoic acid	150 mg
Nicotinic acid	100 mg
Pantothenic acid	350 mg

Composition

Water	10.0%
Crude protein	33.0%
Crude fat	1.0%
Crude fiber	0.5%
Digestible crude protein	30.9%
Nitrogen-free extract	7.5%
Ash	18.0%
Calcium	4.4%
Phosphorus	2.2%

Trace Elements Added per kg of Supplement

Fe	250.00 mg
Cu	125.00 mg
Mn	240.00 mg
Zn	400.00 mg
I	8.60 mg
Co	6.25 mg
Antioxidant (Ethoxyquin)	150 mg/kg

The supplement may either be mixed with or sprinkled on the meat. Large birds of prey may also be given pigeons, rabbits, rats, and mice.

Fish-eaters should be given a commercial multivitamin capsule daily. An easy way to do this is to insert the capsule in a fish. See below for suggested vitamin mix (Wackernagel, 1966).

Vitamin Mix V-1—Contents of the Vitamin Capsule Fed to Fish-Eating Birds

A	2,500.00 I.U.
B_1	2.00 mg
B_2	1.50 mg
Nicotinamide	10.00 mg
B_6	1.00 mg
Pantothenic acid	10.00 mg
Biotin	0.05 mg
B_{12}	0.10 mg
Folic acid	0.25 mg
C	50.00 mg
D_3	500.00 mg
E	1.50 mg

Diet C-3 (Vohra, personal communication)

Horse meat or any other raw ground meat	870 g/kg
Ground, steamed bone meal	80 g/kg
Dried milk powder	35 g/kg
Vitamin Mix V-2	10 g/kg
Iodized salt	5 g/kg
TOTAL	1,000 g/kg

PIGMENTATION DIETS

Diet P-1 (Ratcliffe, 1966)

Diet O-1	90%
Ground broiled meat	10%

Mix thoroughly and moisten with fresh pulverized carrots and carrot juice (1 gal to 20 lb by dry weight) to give an easily crumbled food. Refrigerate and use within 6 hours. Allow 1/2 to 3/4 lb per bird (flamingo) per day. Divide food into morning and afternoon feedings. Allowance must be increased if starlings, pigeons, and other free wild birds have access to food containers.

Diet P-2 (Wackernagel, 1966)

Carotenoids Added per kg of Feed

Canthaxanthin	100 mg
Carophyll	25 mg
Aureomycin	40 mg/kg

The Zoological Garden at San Diego has a diet that gives a beautiful color in flamingos.

Flamingo Diets (Total for 50 birds for 1 Day)

Ingredients	*Amounts, kg*
Bird-of-prey meat	0.91
Game Bird Breeder Layena	2.27
Cooked Milo	1.362
Frozen shellfish	1.135
Trout pellets	0.45
Ground carrots	0.227
Premix	0.566
TOTAL	6.920

Premix

Ingredients	*Amounts*
Paprika powder	225
Roxanthin Red (10 %)*	6
Vitamycin	50
Manganese sulfate	10
Salt, trace mineralized	75
Dehydrated alfalfa meal	200
TOTAL	566

*10% Dry Canthaxanthin—Beadlets, Roche Chemical Division/Hoffman-La Roche, Inc., Nutley, NJ 07110

Cordier's Hummingbird Food

Salted meat extract	3g
Sweetened condensed milk	40g
Honey	100–180g
Add water to make vitamin mixture:	1,000ml
Vitamin A	6mil. I.U.
Vitamin D	100thou. I.U.
Add water to make:	30ml
Almond oil	4drops

Shake well and keep under refrigeration; bring to room temperature before feeding.

Add four drops (formula per liter) of vitamin A and D mixtures consisting of 6,000,000 I.U. of A and 100,000 I.U. of D to 20 ml of almond oil.

Large amounts of honey can cause fungal infection in hummingbirds' tongues. If such infections occur, sugar should be substituted for the honey.

APPENDIX D:

Some Methods Used to Capture Wild Birds Alive and Selected References

Methods	References
Stationary mist nets	
general	Low, 1957; Bleitz, 1970
special	Williamson, 1957; Harris and Morse, 1958; Nolan, 1961; Johnston, 1965; Greenlaw and Swinebroad, 1967; Dykstra, 1968; Humphrey *et al.*, 1968; Reisinger, 1968; S. G. Martin, 1969; Whitaker, 1972
Cannon- or rocket-projected nets	Lacher and Lacher, 1964; Thompson and DeLong, 1967; Arnold and Coon, 1972
Traps: general	Brownlow, 1952; Hollom and Brownlow, 1954; Dennis, 1955; Williamson, 1957; Larsen, 1970; Norris and Whitehouse, 1970
Traps for:	
shorebirds and allies	Liscinsky and Bailey, 1955; Holgerson, 1953; Serventy *et al.*, 1962; Nettleship, 1969
gallinaceous birds	Schultz, 1950; Tarshis, 1956; Chambers and English, 1958; Edwards, 1961; Tomlinson, 1963
waterfowl	Hunt and Dahlka, 1953; Weller, 1957; Coulter, 1958; Sugden and Poston, 1970
raptors	Seiskari, 1954; Tordoff, 1954; Berger and Mueller, 1959; Ward and Martin, 1968
hole-dwelling birds	Rumsey, 1968; L. Smith, 1970; Martin, 1971; Stewart, 1971
miscellaneous	Spellerberg, 1969; Johnson, 1970; Weaver and Kadlec, 1970; Burger, 1971

Methods	References
Spotlighting	Labisky, 1959; Cummings and Hewitt, 1964; Ralph and Sibley, 1970
Drugs	Mosby and Cantner, 1955; Murton, 1962; Murton *et al.*, 1965; Williams, 1966; N. G. Smith, 1967; Beck, 1969; Schafer and Cunningham, 1972; Williams and Phillips, 1972b; Houston and Cooper, 1973
Miscellaneous	Edgar, 1968; Gavrilov, 1968; Myrberget, 1968; Gill *et al.*, 1970

APPENDIX E:
Anesthetic Agents That Have Been Tried With Birds

LOCAL

Generic Name	*References*
Butacaine	Sweebe, 1925
Dibucaine	Arnall, 1961a
Ethyl chloride	Arnall, 1961a; Friedburg, 1962
Lidocaine hydrochloride	Grono, 1961; Murray, 1967; Brownell and Sadler, 1969
Procaine hydrochloride	Young, 1948; Michael, 1960; Arnall, 1961a; Grono, 1961; Gandal, 1967; Gandal, 1969a
Tetracaine hydrochloride	Friedburg, 1962; Brownell and Sadler, 1969

INHALATION

Generic Name	*References*
Chloroform	Elley, 1913; Lee, 1953; Arnall, 1961a; Murray, 1967
Cyclopropane	Arnall, 1960; Arnall, 1961a; Hill and Noakes, 1964
Ether	Lee, 1953; Snow, 1959; Burger and Lorenz, 1960; Jordan *et al.*, 1960; Arnall, 1961a; Grono, 1961; Friedburg, 1961, 1962; Sykes, 1964; Murray, 1967; Foss *et al.*, 1972
Ethyl chloride	Friedburg, 1961, 1962
Halothane	Arnall, 1961a; Grono, 1961; Marley and Payne, 1964; Graham-Jones, 1965; Desmedt and Delwaide, 1966; Anderson, 1967; Murray, 1967; Mapletoft and Futter, 1969; Myers and Stettner, 1969; Whittow and Ossorio, 1970; Alsager *et al.*, 1971; Mulder and Brown, 1972

Generic Name	References
Halothane–ether mixture	Cooper, 1968
Methoxyflurane	Brinkman and Burch, 1964; Leininger, 1965; Hoge, 1966; Gandal, 1967; Gandal, 1969a; Whittow and Ossorio, 1970; Mandelker, 1970, 1971; Kessler *et al.*, 1972
Methoxyflurane–halothane mixture	Whittow and Ossorio, 1970
Nitrous oxide	Jordan *et al.*, 1960; Arnall, 1961a
Nitrous oxide + halothane	Wingfield and DeYoung, 1972

PARENTERAL

Generic Name	References
Amobarbital sodium	Fretz, 1932; Lee, 1953
Chloral hydrate	Hole, 1933; Jordan *et al.*, 1960
Chloral hydrate–magnesium sulfate mixture	Arnall, 1961a
Chloralose, alpha	McGinnis *et al.*, 1972
Chloralose–pentobarbital sodium mixture	Raper and Bowman, 1968
Chlorpromozine hydrochloride	Jordan *et al.*, 1960; Grono, 1961
Codeine	Schneider, 1961
CT 1341	Cooper and Frank, 1973
Diethylthiambutene hydrochloride	Grono, 1961
Ketamine hydrochloride	McCarthy *et al.*, 1965; Kittle, 1971; Mandelker, 1972; Borzio, 1973; Chiasson *et al.*, 1973; Mandelker, 1973
Ketamine hydrochloride–chlormethlazole mixture	Webster and Hollard, 1973
Ketamine hydrochloride–pentobarbital sodium mixture	Bree and Gross, 1969
Methodone	Schneider, 1961
Methohexital sodium	Desforges and Scott, 1971; Scott and Stewart, 1972
Metomidate (R 7315)	Marsboom *et al.*, 1965; Cooper, 1970; Edwards, 1971; Houston and Cooper, 1973; Cooper, 1974
Metomidate + halothane, N_2O and O_2	Ryder-Davies, 1973
Metomidate–pentobarbital sodium mixture	Abegg and Skarda, 1974
Morphine sulfate	Schneider, 1961
Paraldehyde	Wyse and Nickerson, 1971
Pentobarbital sodium	Durant and McDougle, 1935; Warren and Scott, 1935; Marvin and Smith, 1943; Bailey, 1953; Morgan, 1957; Donovan, 1958; Jordan *et al.*, 1960; Arnall, 1961a; Friedburg, 1961, 1962; Graham-Jones, 1961; Grono, 1961; American Animal Hospital Association, Committee on

PARENTERAL (Continued)

Generic Name	*References*
	Avian Medicine and Surgery, 1963; Sykes, 1964; Delius, 1966; Gotoh and Momiyama, 1968; Håkansson and Malcus, 1969; Spellerberg, 1969; Burhol and Hirschowitz, 1970; Desforges and Scott, 1971; Foss *et al.*, 1972
Pentobarbital sodium, 9.6 g/l, chloral hydrate, 42.6 g/l, magnesium sulfate, 21.2 g/l, mixture	Gandal, 1956; Sanger and Smith, 1957; Gandal and Saunders, 1959; Gandal, 1960, 1962, 1967, 1969a, 1969b; Jordan *et al.*, 1960; Friedburg, 1961, 1962; Petrak, 1961; Wichmann, 1961; American Animal Hospital Association, Committee on Avian Medicine and Surgery, 1963; Seidenstricker and Reynolds, 1969; Desforges and Scott, 1971; Foss *et al.*, 1972
Pethidine	Schneider, 1961
Phencyclidine hydrochloride	Kroll, 1962; Gerlach, 1969
Phenobarbital sodium	Jordan *et al.*, 1960; Sykes, 1964; Wyse and Nickerson, 1971; McGinnis and Ringer, 1965; Peterson and Ringer, 1968; Anderson *et al.*, 1972; Krag and Skadhange, 1972
Phenobarbital sodium–pentobarbital sodium mixture	Jordan *et al.*, 1960
Reserpine	Earl, 1956; Kobinger and Oda, 1969
Thimylal sodium	Dilbone, 1965
Thiopental sodium	Lee, 1953; Jordan *et al.*, 1960; Sykes, 1964; Spellerberg, 1969
Thiopental sodium-pentobarbital sodium mixture	Sanger and Smith, 1957; Church, 1957; Jordan *et al.*, 1960
Urethane	King and Biggs, 1957; Desmedt and Delwaide, 1966; Desforges and Scott, 1971
Xylazine	Levinger *et al.*, 1973

ORAL AND RECTAL

Generic Names	*References*
Chloral hydrate	Lee, 1953
Chloralose, alpha	Williams, 1966; Williams and Phillips, 1972b
Chlordiazepoxide	Peek, 1966
Chlorpromazine hydrochloride	Spellerberg, 1969
Pentobarbital sodium	Peek, 1966; Spellerberg, 1969; Leonard, 1969
Promethazine hydrochloride	Spellerberg, 1969
Reserpine	Lumb, 1963
Tribromoethanol	Mosby and Cantner, 1955; N. G. Smith, 1967; Cline and Greenwood, 1972; Williams and Phillips, 1972b
Thiopental sodium	Spellerberg, 1969

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