FRONTISPIECE

FALCON PROPAGATION

A Manual on Captive Breeding

Edited by

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INTRODUCTION

Tom J. Cade

In the late 1960's and early 1970's when the idea of breeding falcons and other raptors in captivity first began to capture the imaginations of falconers and conservationists, the small community of interested "breeders" kept in touch through the "Breeding Project Information Exchange" organized by *The Raptor Research Foundation, Inc.* After a time the Information Exchange became too unwieldy and impractical to continue, but near the end of its existence, BPIE No. 90 by Weaver and Cade (printed in *Hawk Chalk* 13(1):31-43, 1974 and reprinted in *Captive Breeding of Diurnal Birds of Prey*, 1(4):22-27, 1973, 1974) appeared as an attempt to summarize our early experiences, after three years of work with several species, in a way that would be helpful to others who were just starting out. This information was revised and updated extensively by Cade *et al.* in a special issue of *Raptor Research* (11:28-48, 1977). We have reason to think that these two reports proved to be helpful in getting several projects started; but they have long been out of print and out of date, and it is time for something new.

Since *The Peregrine Fund* began its work in 1970 interest in the breeding of falcons and other raptors in captivity has grown to such an extent that we can no longer give an accurate estimate of the numbers of private individuals, organizations, and governmental agencies involved in some kind of breeding project. We do know that the interest is worldwide and that we annually receive requests for information from dozens of parties, not only in the United States and Canada, but also from south of the border in Mexico, Panama, and Argentina, from Europe, the Middle East, Tunisia, Zimbabwe, South Africa, Mauritius, India, Australia, New Zealand, the Philippines, and Japan.

Everyone wants to know the magic formula for success — how to get all eggs fertile, all eggs hatched, and all chicks raised! **There is no magic formula**, but success is proportional to the intensity of interest, the personal involvement, and the amount of hard work that go into a breeding effort. After a dozen years of working to breed raptors in captivity and to identify the procedures that work best, we still agree with Cade and Fyfe (1978) who concluded that propagating falcons "will never become easy or routine. Each pair is a special case, requiring much trial and error experimentation and intuitive insight by the breeder to bring the mates into reproductive condition. All these procedures are time consuming and laborious, and consequently the propagation of falcons on a large scale will always be a costly undertaking.

"Dillon Ripley in his forward to David Zimmerman's book *To Save A Bird in Peril* (Zimmerman, 1975) has identified the essential elements in the success of our breeding programs. They relate to people — to 'greenthumb' people, as Ripley calls them — 'who have an innate skill which probably can never be learned and certainly has nothing to do with the possession of a higher educational degree.' And finally, 'A sense of kinship with nature and a single-mindedness of purpose appear to be the touchstones of success in this work.'"

In the spring and summer months our telephones at Cornell, Fort Collins, and Santa Cruz are often kept busy into the early hours of the morning by calls from worried breeders who have questions about — everything — a tiercel that refuses to copulate with a very sexy female, a female who drops her eggs all over

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the place instead of laying them neatly in a scrape, how to get a stuck chick out of its eggshell, what to do about an unretracted yolk-sac, how to prevent "green gut" or "sour crop," and a thousand other nitty-gritty problems that come up during the course of a breeding season with captive birds. We have always tried to be as helpful as possible within the limits of our own schedules and goals, and continuing in that spirit, we offer this manual on the methods, procedures, and equipment that have worked well for us. We hope these suggestions and guidelines are sufficiently clear and detailed to be of assistance to anyone involved with birds of prey.

ACKNOWLEDGMENTS

FACILITIES

James D. Weaver

Buildings

The peregrine breeding facilities located at Cornell University in Ithaca, New York were constructed in 1970 (Cade et al. 1977). They are of simple, economical "pole barn" type construction. The buildings have a life expectancy of at least 20 years and because of their durability and ease of maintenance are well suited to propagating falcons. The main barn is 227 feet (69.2m) long and 47 feet (14.3m) wide. The building is positioned to allow either morning or afternoon sunlight to shine directly into the rooms (Fig. 1). The height at the peak of the gable roof is 20 feet (6m) sloping to a 14 foot (4.2m) sidewall. The roof and endwalls are painted metal sheeting. White is the preferred color owing to its ability to reflect heat. The roof of each room offers complete cover and includes a single, three by eight foot (0.9x3m), translucent fiberglass panel to allow more light to enter. Sidewalls are open to the weather with vertical bars of one half inch (1.3cm) thin wall electrical conduit on the inside to prevent the birds from contacting the wire mesh on the outside. The bars are two and one half inches (6.2cm) apart and separated from the wire by a space of six inches (15cm). In order to reduce the amount of drifting snow in the rooms, the lower three feet (0.9m) of the sidewall are paneled. A wire mesh predator barrier is buried all around the building, and a security fence encloses the entire facility.

Fig. 1 The main barn at the Ithaca facility.

Fig. 2 Lower service hallway, Ithaca facility.

This building contains 40 identical rooms. Interior walls are of typical stud-wall construction with plywood sheeting on both sides, creating smooth, safe surfaces. The rooms measure approximately 10 by 20 feet (3x6m), a size we feel may be optimal in that it is probably the smallest room that still provides enough space for real flight for species up to the size of gyrfalcons, a factor not to be overlooked when considering the safety and condition of the birds. Each room has its own pass door opening into the lower hallway (Fig. 2). This area as well as the utility rooms is insulated and heated. The upper hallway (Fig. 3) is not heated, but it is insulated and carpeted allowing observers to move about

Fig. 3 Upper observation hallway, Ithaca facility.

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quietly. Birds may be observed through one way glass windows from both the upper and lower hallways. There is also an upper and lower feeding port and a small access door to the corner nesting ledge.

Construction of the Fort Collins, Colorado facility began in 1974 on Colorado Division of Wildlife property. To minimize the effect of a fire or disease outbreak the complex consists of several smaller buildings of the same "pole barn" type construction (Fig. 4); room dimensions are the same. The drier climate of Colorado allowed the opening of the roof where we had used the fiberglass panel in Ithaca. The opening is barred and screened the same as the sidewalls. This change increases the flow of fresh air and effectively ventilates the room. Since the buildings are not designed to be heated, the hallways are not insulated, nor are they sheeted on the inside. The lack of sound proofing formerly afforded by these features made it difficult for a person to move about the hallways without disturbing the birds. This problem was partly solved by playing radios during daylight hours in the hallways. Eventually the use of a television monitoring system was initiated to decrease this disturbance, and it has proven to be superior in many ways to direct observation (Fig. 5).

Other changes included improved viewing ports which allow a wider field of view, safer sliding pass doors, and a pedestal holding the bath pan with an access door as a means to change water without entering the rooms. Buildings and weathering areas where gyrfalcons are occasionally held are screened against mosquitoes; this action was taken after an outbreak of avian malaria (Kingston, et al, 1976). Finally, the layout of perches and nest ledges was changed to conform to the field of view afforded by the TV system.
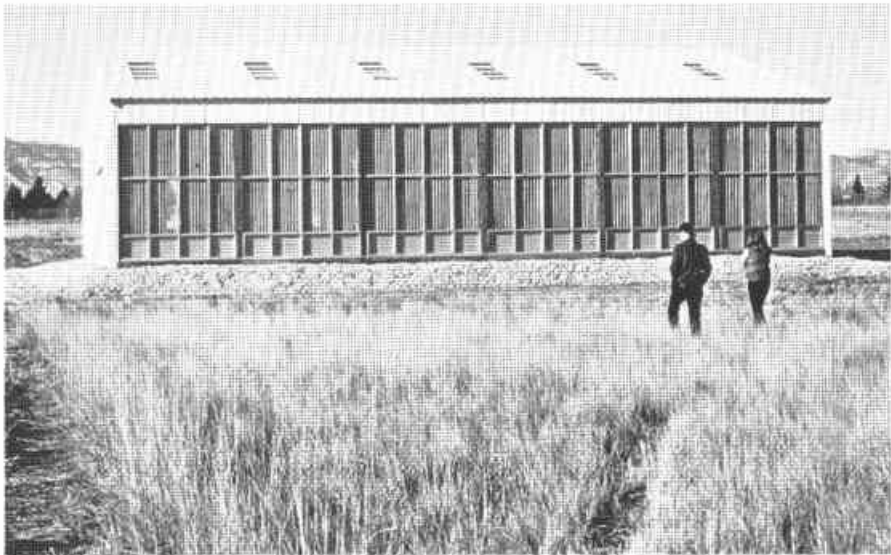
Fig. 4   Breeding barn, Ft. Collins facility.

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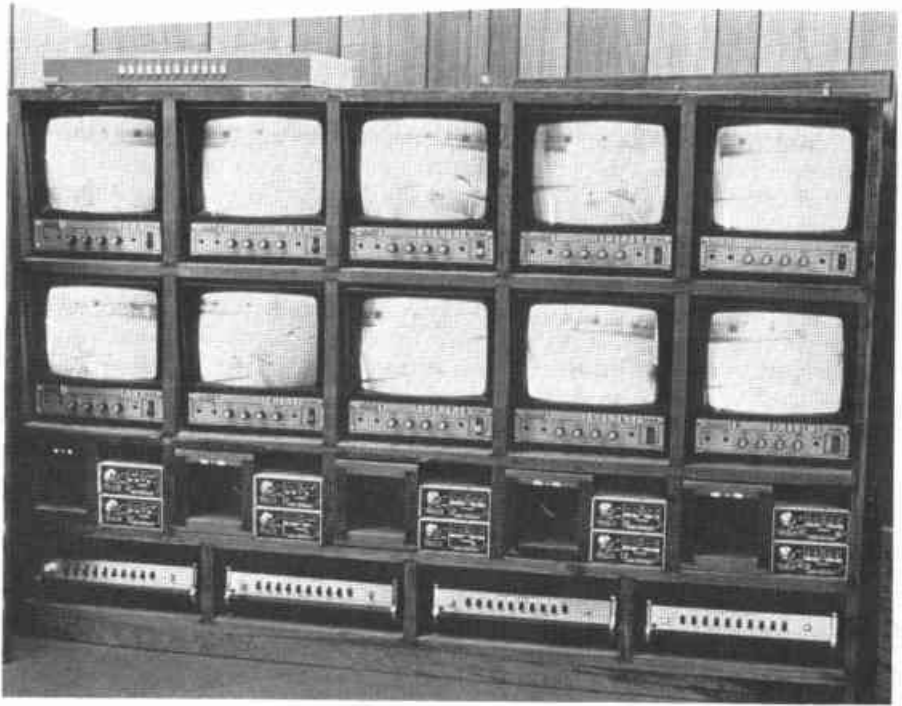
Fig. 5 Television monitors, Ft. Collins facility.

At the Santa Cruz facility in California, the falcons occupy an open topped building with closed sides. Established by Dr. James Rousch and Russell Tucker in 1975 with the co-operation of the University of California, Santa Cruz, these facilities have expanded as funds became available until the present capacity for 13 pairs and nine sexually imprinted birds was reached. This closed side cage design (Hurrell, 1970) works well when outside disturbances are likely to be troublesome and may be especially good for accipters or other "nervous" raptors. Ventilation is no problem here, and in this mild climate there is no worry of blowing snow causing problems with early nesters. The covered sections over nest ledges offer sufficient protection from rain and provide some sense of security for the birds. In areas where summer temperatures are excessive and sunlight intense, the lack of cross ventilation could create an oven-like condition inside the room. Louvered vents located low on the walls would help alleviate this problem.

The floor dimensions remain the same as in Ithaca and Ft. Collins, but the walls are 12 feet (3.6m) high, and the open, slatted roof is flat. Food is provided through a port onto an artificial turf mat on the floor just inside the main access door. The bath is also on this mat and can be changed without entering the room. Nest ledges are filled with clean aquarium sand.

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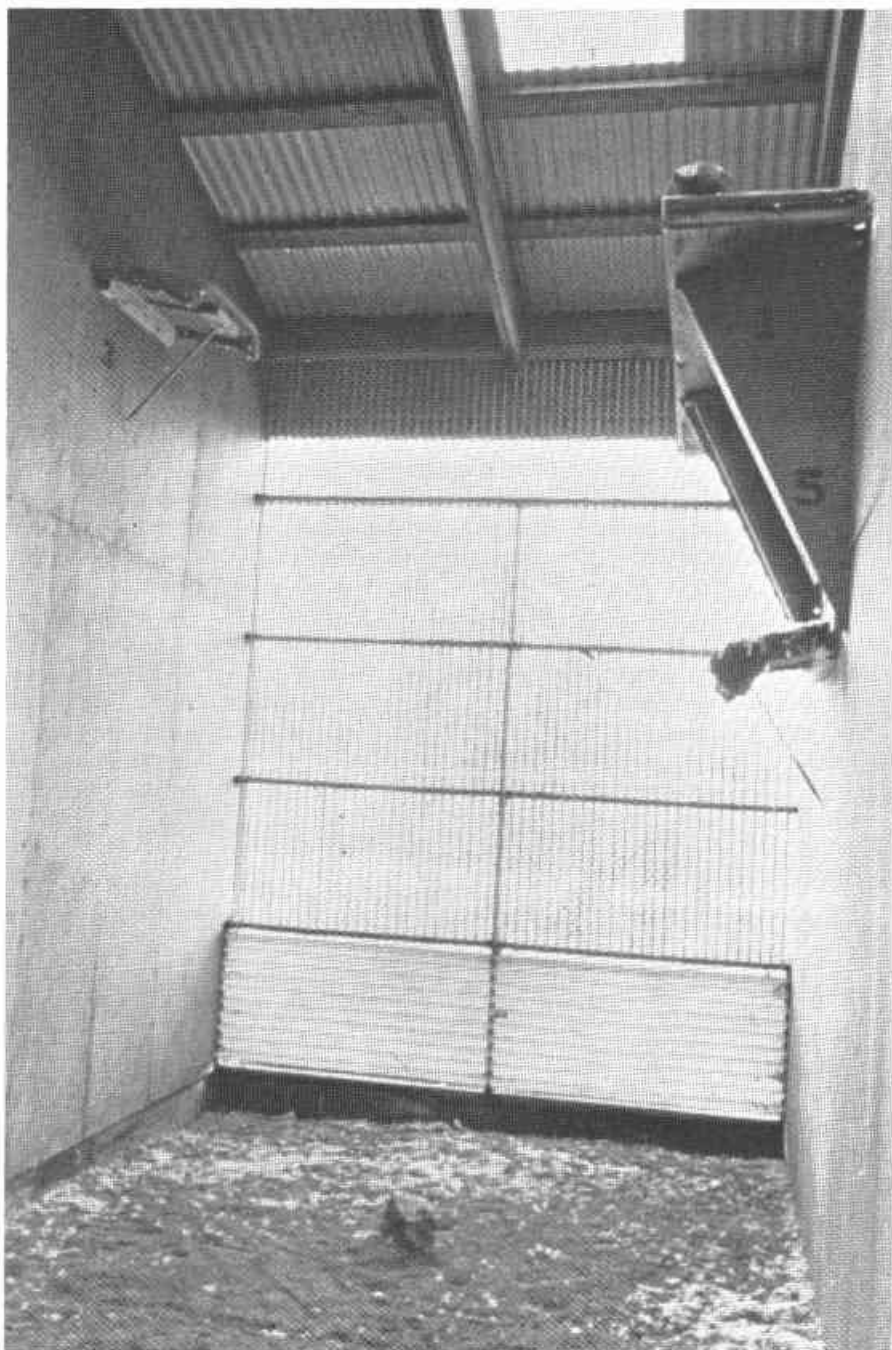
Fig. 6 Typical chamber interior, Ithaca facility.

Interiors

While it is obvious that the building itself, if structurally sound, has relatively little to do with success or failure, it is equally clear that there must be some thought given to how the interior of the facility is designed. Perches should be arranged to allow a minimum of three to four feet (1.2m) of head room, enough for copulations and limited flight displays (Fig. 6) . The branch perches should be the highest perches in the room. Slightly above the nest ledges, they serve the purpose of a "prominent perch" so often seen in the wild and may also be an important part of the courtship ritual in captivity. Use of this perch also provides relief from the other nearly flat perching surfaces. Large smooth rocks, one on the floor and one on the edge of each nest ledge, also afford diversity. Good quality coco fiber door mats are recommended for the other perches in the room (Fig. 7). They are long lasting, clean, prevent bruises to the feet from hard landings, and seem to provide a comfortable surface. These perches are mounted with a slight downslope to simulate a more natural situation. Use of the larger, 20 x 30 inch (50x75cm) sized mats provides adequate room for ledge displays and other courtship activities. We have suggested the use of two gravel filled nesting ledges in the past, and it still is probably not a bad idea but may create problems when the birds nest on a ledge to which there is no access to the eggs from a port in the wall. A ladder must be used to get to such a ledge. If a video system is to be used, it is advantageous to use one ledge so all nesting activity is confined to the camera field of view. The nest ledges we use are much larger than necessary simply for nesting. We have found that they function well as a "playground" and keep the birds off the floor and away from old food and droppings. The leading edges of these areas are covered with synthetic turf or open loop carpeting to prevent bruises. Open loop carpeting is used since it will not catch sharp talons and become a hazard. Lower perches and bath pans are located so as not to become splattered by mutes from upper levels.
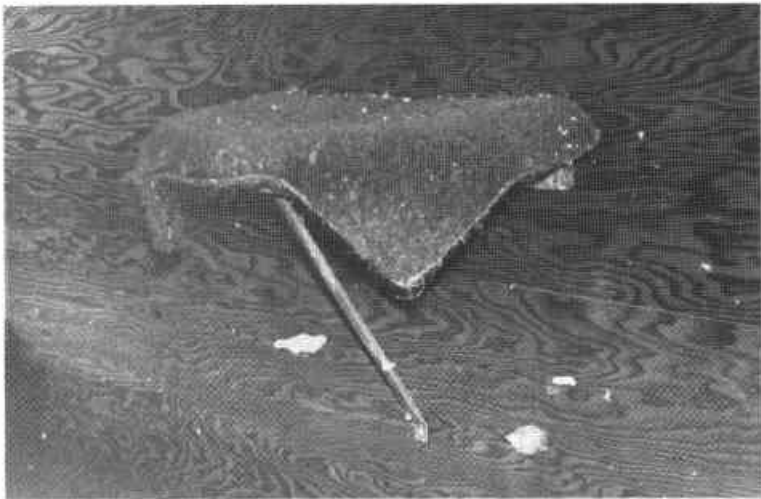
Fig. 7 Coco mat perch.
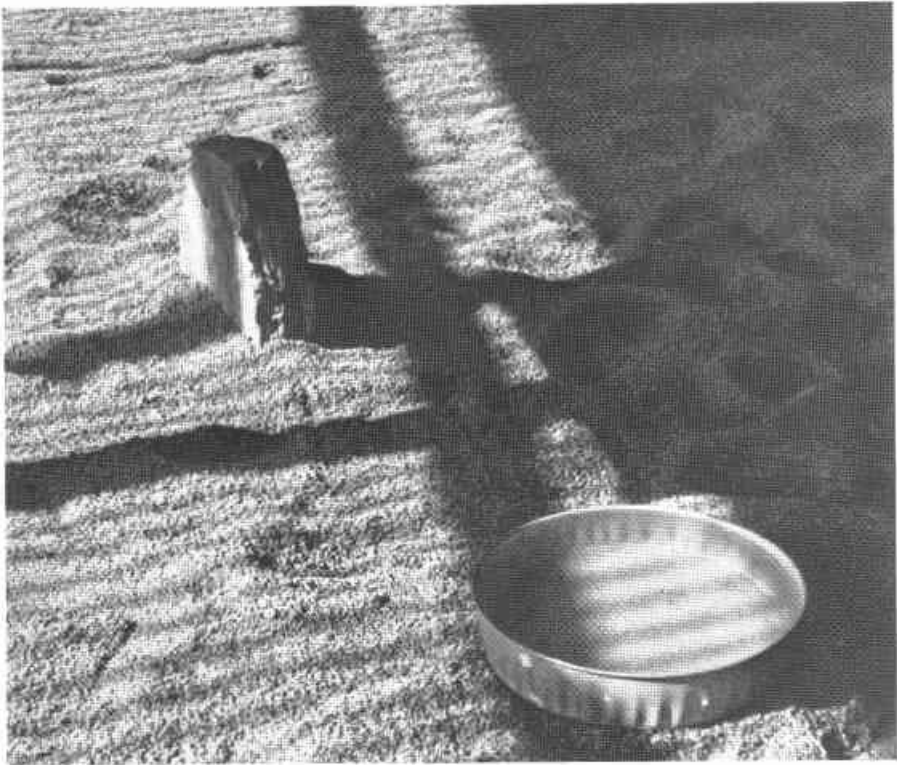
Fig. 8 Gravel floor, typical chamber.

Floors are coarse gravel fill, over which is added at least four inches (10cm) of pea sized gravel. This material has rounded edges, is not dusty, does not compact to create a hard, dangerous surface conducive to foot problems, and it also aerates well and dries rapidly (Figs. 8 & 9). This same material is used as nesting substrate; its small uniform size prevents egg breakage as long as a sufficient depth is provided. A minimum of three inches (7.5cm) is suggested.

Fig. 9 Recommended gravel size for floors and nest ledges.

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Each room is equipped with some light source, if not for photoperiod manipulation then for night work or in case of an emergency such as a brooding bird off eggs in the dark. **Caution:** If the rooms are to have solid roofs, some means to ventilate the area must be arranged. Heat buildup under metal roofs can create a very serious problem. At the Ithaca facility, a full width vent has been cut at the top of the inside wall in each room allowing natural air currents to move the warm air out.

At the Ithaca facility, space is available inside the main building for offices, labs and utility functions. A variety of support buildings serve these purposes at both Ft. Collins and Santa Cruz. Incubators and brooders at all facilities are housed in rooms specifically for their functions. This system allows the operator to monitor and control the environmental factors in these critical areas more easily.

MANAGEMENT AND MAINTENANCE

William Burnham   Brian J. Walton   James D. Weaver

Breeding Stock

The original falcons kept as breeding stock at our facilities can be loosely grouped into five categories according to their backgrounds. There were nestlings taken from the wild at less than four weeks of age, hand raised in sibling groups and then kept by using falconry methods for varying lengths of time before being paired. Another group was acquired from interested falconers; these birds were trapped as first year migrants and paired at various ages. They may or may not have had any falconry experience. In 1972, four pairs of falcons were brought in from the wild at fourteen to twenty days of age. They were hand raised in groups and handled minimally after fledging. Pairs were made up during their first year. This method has been in continual use at both the Ft. Collins and Ithaca facilities since 1975 (Cade and Fyfe, 1978). Our first successes in 1973 provided an opportunity to create a fourth category for prospective natural breeders. Most of the young produced that year and four birds from the wild were placed with adults and allowed to fledge from the very ledges where they would later be expected to breed. It was felt that this experience would alleviate any problems that might arise with acceptance of the breeding enclosures themselves. The majority of these birds were transferred to large communal holding rooms shortly after fledging and allowed to associate freely with one another in hopes of identifying early natural pair bonds. They were very wild and nervous.

One new variation has been added since these beginnings. At the Santa Cruz facility young birds are placed with adults and fledged in the chambers. A few weeks after fledging they are taken down and handled intensively using falconry methods including hooding. They are not flown, but pairs are fed together and given full rations to forestall the possible development of food related aggression. This handling lasts from three to four months, after which the birds are completely tame and are returned to the facility and released in rooms as pairs.

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It is probably easier to answer the question as to which of these five major categories has produced the most desirable results by indicating which have been least effective. There can be no doubt that the birds trapped as migrants show the least potential as breeders in the captive situation. There are always exceptions to such a generalization, but they are few and surely the slim chance of success does not warrant the effort. Realize, of course, that we are speaking only of the large falcons and of the peregrine in particular. Some smaller falcons, notably the kestrels, will breed readily in captivity when taken as adults. Next in the ranking comes the fledging of young by adults without subsequent handling and conditioning. It appears that only about half of these birds will breed within a reasonable period of time, for our purposes, five years. Egg laying will only rarely occur before three years of age, and an inordinate number of these females will require artificial insemination during their second and third productive years and perhaps longer. Many males in this category have never developed satisfactory courtship behavior.

The remaining three methods of conditioning all seem to produce the same results within the limits of individual variability. There is a fair percentage of two year old egg layers and a reduced necessity for artificial insemination after the second productive season. We favor the hand-raising of potential natural breeders in group situations as a means of insuring the maximum percentage of successful pairs. In a large operation, intensive post-fledging handling of the young birds using falconry methods may prove to be too labor intensive to be practical.

In any activity involving the handling of these prospective breeders be aware of the possibility that the birds might become totally dependent on the handler and therefore "imprinted" in varying degrees, a condition that may render the prospect useless in one or both reproductive modes. Such a bird will not respond to its mate's courtship attempts nor will it relate to the human handler. It is suggested that actual hand feeding be kept to a minimum after 14 days of age. Allow the group to feed from the same bowl in the presence of the handler and feed often enough so there is not a clamoring for the food when it is presented. It is also important to spend time that is not food related with these youngsters.

Food and Feeding

Good quality fresh food is critical to the successful management and reproduction of any animal. Chickens and coturnix quail provide the bulk of the whole carcass diet fed to the falcons under our care. We have held and reared most species of large falcons on this diet for 14 years with no ill effects. We avoid the use of wild or domestic pigeons because they are more likely to carry diseases. The chickens and quail are also more easily raised, and both can be produced in large numbers fairly economically; 60,000 quail are produced annually at our Ft. Collins facility alone. Chickens (cockerels) may be obtained from hatcheries as day-old chicks and then reared at our facilities, or they may be reared for us by a commercial poultry operator. In either case, it pays to insure that these food animals are maintained on the highest quality feed and under the most sanitary conditions practicable.

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At Ft. Collins, approximately 60% of the falcons' diet consists of quail; the remainder is five-week-old chickens, weighing about 10 oz. (283 g). In Ithaca, where facilities for raising food animals are limited, the diet consists of up to 5% day-old cockerels, 75% five-week-old chickens and 20% quail which are used mostly during the spring and early summer.

We usually provide no live food to the falcons. After 24 hours of fasting to allow clearance of materials from the digestive tract, food animals are killed with CO_2 and quick frozen. Daily rations are thawed as needed and fed immediately. The chickens are cut in half, the two halves providing an ample meal for a pair of peregrines. Most of the quail are killed when they reach 60 days of age, but some may be killed when smaller and used to encourage food transfers during the breeding season. Quail which are held longer than 60 days may begin to develop large amounts of undesirable subcutaneous fat. Careful control of photoperiod and diet can eliminate this problem.

Generally, all falcons at our facilities are fed once each day. In order to deter any food related aggression, pairs are always provided with two or more food items. Occasionally, winter temperatures will dip below 0 F. Since the food freezes quickly at such temperatures it is necessary to feed smaller amounts twice daily and to watch closely to be certain that all the falcons, especially the males, have enough to eat. We always check before feeding to determine the condition of the falcons and that of the chamber in general, including the amount of food left from the previous feeding. Falcons are not encouraged to eat spoiled food; if excessive food remains are seen, the amount being fed may be reduced. If there are no food remains present we may presume that we are not feeding enough. A well fed pair will leave chicken feet and wings uneaten. Untouched food is an indication that something may be wrong with one or both of the falcons; we initiate careful observation at once. The behavior of the falcons at the food port will also provide clues to the amount of food necessary to maintain a particular pair. We watch for unusual eagerness or mantling when food is presented. As a rule of thumb, it is always better to overfeed slightly.

With the onset of the breeding season the feeding regime is altered somewhat. We begin feeding smaller amounts of food several times each day to encourage food transfers. This is especially useful for the younger pairs. The smaller quail mentioned earlier seem to be particularly attractive to most males. We take care to guard against feeding too heavily at this time for, even though the males are eager to take the small offerings, most of them will be cached after transfer and may be left to spoil. We understand that some individuals with breeding falcons have attempted to allow only the males to obtain food, thereby enouraging food transfers. We have not used this technique, but it might benefit certain pairs if serious aggression can be avoided.

Beginning in 1980 a vitamin supplement (Avitron) was injected into all major food items throughout the breeding season (February through June). Since there has been no control group, the effects of this supplement have been difficult to ascertain. We do feel that such a supplement, when used in addition to, and not as a substitute for, good basic nutrition, can do no harm. We were particularly concerned about the older falcons and those routinely laying large numbers of eggs. We plan to continue the use of this supplement indefinitely.

Water

The water provided in each chamber for drinking and bathing is periodically replaced. We prefer to use a cleaned and disinfected bath pan each time the water is changed. During warm weather we change the water as needed or about once each week. We also renew the water any time we have occasion to enter a chamber, especially during the breeding season. In the winter months when freezing is a problem, water and pans are changed when warm spells occur.

Capture of Birds

Occasionally it is necessary to capture and handle the falcons. All of the falcons in our program have to be handled at least four times each year when they are moved so we can clean the chambers. They must be caught and released in a holding room, and then they must be caught and returned to their own chamber. Any capture and subsequent handling should be accomplished as quickly as possible and with a minimum of stress. Falcons too wild to be taken up willingly are quickly caught with a long handled net. This method is far superior to a protracted chase around the chamber.

When we plan to enter a chamber to catch a falcon for any reason, we first make some slight noise to announce our intentions. This helps reduce the chance of a panic flush from a perch into the wall or the bars that might result in injury. We then enter the chamber and net the bird we want as quickly as possible, usually in a matter of seconds. An assistant allows the falcon to grip his gloved hands to prevent self-inflicted foot punctures. Talons are clipped severly but not to the point of bleeding. The beak is also trimmed if it is overgrown. The falcon may be hooded if the operation is to take more than a few moments. When a falcon has to be handled we always take the opportunity to make a brief examination of its general condition.

Chamber Cleaning

All our chambers are completely cleaned and reconditioned twice each year, in January and July. Following our philosophy of minimizing stress and maintaining a respectable level of cleanliness, we feel this schedule is both adequate and appropriate. The chambers must be cleaned, but stress and the possibility of injuring a falcon during handling must be considered. The size of the chambers themselves, the perch layout, and the fact that they are open to the air and sunlight are factors also influencing our decision in regard to this infrequency of cleaning. In addition to the biannual general cleaning, some food remains are removed anytime we have occasion to enter a chamber.

Once the falcons are removed, we spray the entire chamber with water to settle the dust and feathers. We rake the floor and nest ledges, removing feathers and debris. If the gravel in the nest ledges is badly soiled, it is replaced. Gravel removed from the floor during cleaning is also replaced. We clean and inspect all perches and replace any that show excessive wear. Coco mats are best cleaned with a wire brush. We give the floors, interior walls and ceiling a heavy wash and a disinfectant rinse and finally check out the lighting and clean the observation windows. The heavy wash and rinse may be eliminated during the winter cleaning if the weather is too severe. The plywood walls may require periodic resealing with wood preservative.

A secondary result of the accumulation of food remains in our chambers is the phenomenal number of dermestid beetles present. While they perform a service in the cleanup of food remains, they also exact a toll when the larvae burrow into the wood of the buildings to pupate. Without resorting to fumigation, we have found that heavy paint is the only means to thwart their burrowing.

Physical Problems

Minor physical problems are unavoidable in any operation involving large numbers of animals. Most of those seen in our falcons result directly from capture and handling. Self-inflicted foot punctures will occur occasionally no matter how careful we are. These punctures may cause a low level foot infection (small scabs and limited swelling). We do not attempt to treat these minor infections. We feel that the additional stress would negate any benefits. A clean and stable environment is the best medicine. If the condition becomes serious, surgery may be necessary, and an expert should be consulted. However, we have never had a serious chronic foot problem develop in any falcon premanently housed at our facilities.

One other problem we encounter rarely but also related to capture and handling is that of a sprained wing. There is little that can be done to correct this condition, which may last from a few hours to several weeks. We provide perches at intermediate heights to assist the falcon's movements, and if possible we may provide food on the upper level to limit unnecessary flight. Again, a stable environment is essential for recovery. Any deterioration in the falcon's condition is reason for closer examination and an expert's opinion.

Courtship

We would like to suggest that those individuals without some background in avain biology avail themselves of the fine ornithological text books available. Some understanding of avian reproductive physiology will greatly improve chances of success and certainly answer many of the questions that one might have.

It is impossible to say when courtship actually begins, since we cannot be sure of the falcons' physiological state based only on behavior. This is especially true of established reproducing pairs because some level of activity continues throughout the year; it is not unusual for courtship activity to intensify during the fall season. A very tame peregrine falcon is known to have laid small and infertile eggs in October after a normal spring season.

Several good discussions are available on the behavior of breeding pairs of peregrines, both in the wild and in captivity, including: Wrege and Cade (1977), Cramp and Simmons (1980), and Ratcliffe (1980). The description provided here is very generalized and presented only as an example of what can be expected for large falcons and peregrines in particular. We will restrict it to what we will assume is a normal and well adjusted pair.

We expect the intensity of the courtship activities to increase gradually as spring nears and the days grow longer. Inexperienced falcons may require

weeks or months to develop noticeable behavioral changes. Normally, the earliest signs of courtship activity are (1) "flybys" by the male, (2) scraping by one or both birds, (3) the female waiting longer before going to obtain food, and (4) the female pushing or driving the male. "Flybys" occur when the male flies near the female. The flight of the male is not the typical "hitch-winged" display flight. Instead, his wings are carried in a slightly higher than normal position relative to his body and he will go out of his way to fly near the female. The second and more obvious behavioral change becomes evident when either falcon begins to scrape in the gravel of the nest ledges. Either falcon, but usually the male, may stand in the scrape and call to its chamber mate. The female may now be waiting longer than normal before flying to the food ledge after the technician feeds. She may also begin to fly to, and land near, the male if he ignores the food, causing him to fly to another location. The female may continue pushing or driving the male until she gives up and gets her own food, or he goes down to the food ledge. A variation of this behavior may be seen as the pair begins food transferring. The female will fly to the nest ledge or perch and call to the male while apparently looking for cached food. When the male obtains food the female may fly to him and attempt to take the whole thing, or she may stand next to him as he eats and take small pieces. If the male flies away with the food a chase may ensue. These food transfers, no matter at what level, are important for development of normal reproductive behavior. As the pair's behavior progresses, food transfers should increase in frequency. A female that is not hungry will usually accept and cache the food. Some males will retrieve and transfer the same food many times.

The display most commonly described in the literature is the "ledge display" where one or both falcons are in "head low" postures while vocalizing with the "eechip" call (Fig. 10). The intensity of this display and associated vocalizations increases as the birds approach each other. Whatever aggressive component this display may have had early in the season will have disappeared by the time food transfers become routine. The "flybys" at this point should have evolved into the typical "hitch-winged" flight display in which the wings are held high and the body is held nearly vertically with the legs and head forward. The male usually overflies the edge of the perch or ledge with a bounding motion and appears almost mechanical in his movements after landing. A modified "hitched-wing" flight is used by the male to fly to the female to copulate.

Before egg laying the female should begin to solicit copulation by holding her head low while raising her tail. A whining vocalization may accompany this posture. She should be facing away from or perpendicular to the male as she solicits. Some females solicit in ways or in physical situations that make it nearly impossible for the males to copulate. The first copulations are always awkward and ineffective. Many pairs require more than one season to learn to copulate well enough to fertilize all or most of the eggs.

As egg laying becomes imminent, the female will become even more reluctant to go for food or to move from the area of the ledge in general. She will look heavy and appear to move with difficulty; her mutes will be more viscous and voluminous. To put it simply; she will look sick (Fig. 10). This condition is called "egg lethargy" and is quite normal. It may last anywhere from three days to two weeks and is highly variable among individuals. It is possible for a paired but uncourted female to exhibit this condition and not lay eggs.

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Mutual ledge display.

Male displaying over egg.

Female in egg lethargy.

Female approaching to resume incubation.

Female in full incubation.

Fig. 10 Peregrine falcon courtship and egg laying.

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Management for Production

There is no one proper management procedure suited for every pair of falcons. We make adjustments according to observations of, and experience with, each pair. We do not stress first time breeders by attempting to inseminate or double-clutch them, though we may occasionally extend the clutch to provide more time for copulation to occur. Sequential egg removal appears to work better during the second and subsequent breeding seasons. The first two laying years are frequently sacrificed to allow the pair to develop on their own.

Pairs of falcons that fail to breed after two or three years of sexual maturity may benefit from separation and recombination with new mates. We normally make these switches in the early fall by separating copulating pairs of falcons that are near the end of their reproductive lives and placing them with inexperienced young birds. This procedure has, in most cases, helped to bring the younger bird into reproductive condition. The older falcons court and provide their young chamber mates with the opportunity to interact and learn.

Switching of mates is also a means to correct behavioral abnormalities. Nervous pairs, for example, may benefit from re-pairing with individuals that are more relaxed. New pairs must be watched closely for several days to make sure they are compatible and not unusually aggressive. If a falcon becomes aggressive (usually females during the non-breeding season) to the point of endangering it's chamber mate, then the pair is separated until just prior to the next breeding season. If aggression persists, the offending individual may have to be replaced.

The age of a falcon at the onset of egglaying or spermatogenesis is highly variable (Cade & Fyfe, 1978). It appears that Scottish peregrines (*F.p.peregrinus*) and the Peale's peregrine (*F.p.pealei*), for example, are one or two years slower to mature than are many other races of peregrines in our program. This type of information must be considered when trying to determine the status of potential breeding pairs by comparing their courtship behavior to that of other pairs of differing backgrounds and origins. Also of interest is the case of two pairs of peregrines taken from the same locale during the same season and at the same ages. One of these pairs breeds a full four weeks later than the other. Both pairs have an almost perfect record of fertility. We have no idea what might account for this disparity in laying dates, but again the message is clear; the status of one pair should not be judged by the activities and progress of another.

Occasionally falcons will lay although no apparent stimulation has been provided by the chamber mate. It is not unusual when this happens for the bird to lay the eggs in several locations around the chamber, possibly dropping some from the perches. If these birds are disturbed by insemination attempts or sequential egg removal, it usually only worsens the problem. The sight of the eggs will occasionally stimulate the male to begin courtship.

We have falcons that will lay no more than four eggs in a clutch regardless of how or when the eggs are removed. Other birds will lay twelve or sixteen perfect eggs at precise intervals when eggs are removed sequentially. When and how eggs are removed may be determined in part by the method of fertilization and/or how we plan to incubate them. If eggs are removed sequentially then incubating falcons or chickens must be available to provide early natural incubation. If they are not available then we may elect to remove the eggs by clutches after five to ten days of incubation. If artificial insemination is used as

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we describe, it may be desirable to remove the first two eggs immediately as they will probably be infertile. Incubate them anyway just in case copulation occurred undetected.

Good annual records and common sense are the best tools in determining how to manage each pair of falcons. An established pair of breeders can be expected to tolerate more disturbance than a young or nervous pair. When nervousness and fear turn to aggressive territoriality the pair will be more tolerant of manipulation for accelerated production.

Certain precautions are in order before entering the chambers during the breeding season. The incubating or brooding falcon must be alerted to our intentions by gently tapping on the door before entering. If the falcon is startled, eggs may be broken or chicks ejected from the ledge as she bolts. Once the falcon is off the eggs or young, we enter the chamber and net the female. She is almost always released without handling and then discouraged from returning to the ledge until we are finished with the removal or exchange.

Some falcons will refuse to leave the nest ledge even when we enter the chamber. We have a stuffed glove attached to the opposite end of the net handle which is raised to the nest ledge so that the female will clutch it with her feet and can then be lowered to the floor. Males are seldom a problem, and are ignored except for preventing them from breaking an egg or hurting themselves as they fly about. In any case, two or three people are always required for these operations.

Transfer of Young to Adults

When young are exchanged for eggs, the chicks are grouped on the ledge against the wall near the scrape. A few dead quail are also placed about the ledge. The adults will quickly return to the ledge when we leave, so it is important to have someone ready to watch and intervene if a problem should arise. The male, while potentially dangerous, is less of a threat than the female. He is usually not bold enough to attack a group of young, even if he does not immediately accept them. If he should begin to vocalize defensively upon seeing the young, the female may become more apprehensive, and if she is going to attack, will seldom hesitate, especially if only one young is introduced. Even an experienced female will appear aggressive on her initial approach to the group. The slightly hungry young may begin to food beg as she approaches, but she will be intent on brooding. If older chicks refuse to be brooded and are defensive of the falcon's advances, she may try to force her intentions by pulling at them. Serious injury and death may result. Good judgement and discretion must be used in deciding when and if intervention is necessary. Tapping on the wall is usually enough to stop mild aggression by either of the pair.

Once the pair has accepted the young, fresh food is provided three times each day. The young are carefully observed to make sure that all are being fed. Although we have provided adult prairie falcons with as many as nine young to care for, we seldom give peregrines more than four. It is simply not safe, especially late in the season. One adult pair may be given two or more successive broods of young to rear during the season, depending on how long each group remains with them. **Adults will tire** of raising young and become less attentive so caution is advised.

At some breeding facilities, technicians introduce young to experienced adults immediately after hatching with minimal losses. This procedure is useful if adequate numbers of experienced pairs are available. The majority of imprinted birds, both male and female, have proven to be good parents for young that require no brooding (Fig. 11).
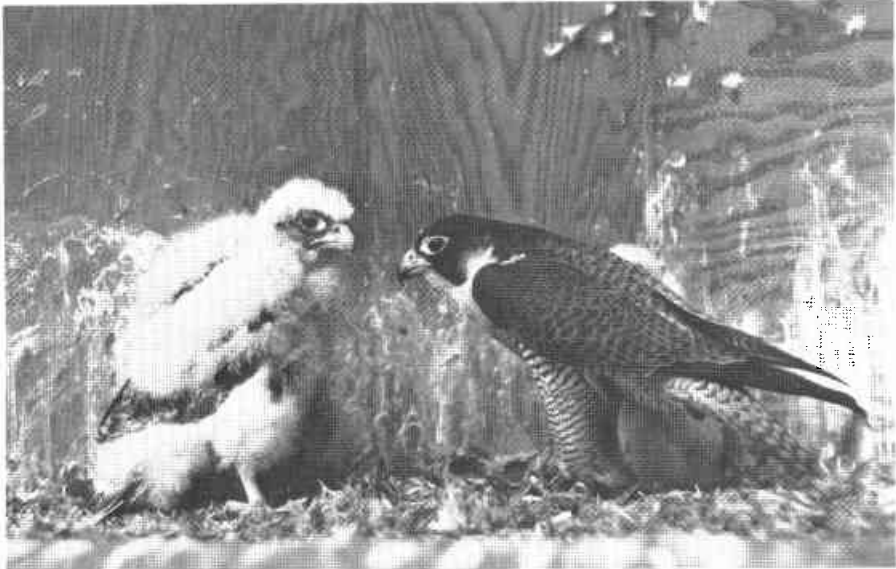
Fig. 11   Peregrine falcon feeding young.

ARTIFICIAL INSEMINATION

James D. Weaver

Preliminary Considerations

When artificial insemination is required, the prospect need not be viewed with trepidation. It is our experience that fertility is much improved by inseminating directly into the everted oviduct rather than just into the cloaca (10% vs 75%). The technique has been widely used in poultry since 1939 and in birds of prey since the early 1970's. At this writing, certainly, over 1000 inseminatioins of raptors have been made with few problems. It should not be attempted, however, until the handlers have a complete understanding of the mechanics involved. Practice on quail, chickens, pigeons or other birds is an important prerequisite. There are enough dangers inherent in the procedure to warrant caution and careful consideration.

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We generally do not inseminate paired females in their first laying year. It is preferable to let the pair develop without undue disturbance. Problem pairs must be monitored closely, and an all out effort made to correct behavioral breakdowns as they are identified. A serious disturbance, such as capture for insemination, at this point could cause a complete cessation of courtship behavior in one or both birds. If, in their second season, the pair in question is not copulating or at least increasing the level of courtship daily as the date of laying nears, then we prepare to inseminate and watch closely for the first egg. We do not usually inseminate prior to the first egg for two reasons. The oviduct is not particularly easy to see at this time, and the timing is too critical. The female can usually be induced to lay a large number of eggs, so the extra trauma of pre-laying insemination in unwarranted. Sacrificing fertility in the first egg or two in order to insure the fertility of the rest has proven to be the best plan. On the other hand, imprinted females in a co-operative mode can, and should, be inseminated whenever they will accept it.

Ideally, the insemination should be made within six hours of laying in order to fertilize the next egg. Any later and the egg will be unavailable to the sperm. In actual practice, we generally miss the second egg, since the first is usually laid during the night. We do not bother our birds at night since it might be disruptive and dangerous to other pairs in the building.

Presently, we favor insemination after each egg. Forced insemination should not be attempted later than 16 hours post laying. The chances of bursting an egg in the oviduct or causing premature laying are increased as the egg moves down the oviduct. The usual interval between eggs is about 52 hours although an interval of 72 hours is not unusual and occasionally, an egg seems to be skipped. It may be that the pressure applied during insemination has caused the ovum to be completely displaced into the body cavity.

The next egg should follow in its proper sequence. The incidence of falcons becoming egg bound is rare; therefore, caution in arriving at this diagnosis is suggested in the event of a late egg.

Semen Collection

To collect semen, the male is caught, wrapped in a towel, and taken to a well lighted room where he is placed breast down on a foam pillow. In Ithaca we like to use three people; a two person team is used at our Ft. Collins facility. One person's sole responsibility is to hold the falcon and assure its safety. This leaves the other(s) free to concentrate on the massage and collection. Other techniques are in use around the country and have proven equally successful.

To begin the actual collection, the male's legs are drawn down and out of the way, and a gentle massage is begun on the lower back, belly, and sides using both hands. As the middle fingers of the left hand move from the keel of the sternum to the rear, they are followed on the lateral surfaces by the thumb and first two fingers of the right hand. After several such flowing motions, slightly heavier pressure is exerted, and as the middle fingers of the left hand reach between the pubic bones they stop and maintain light but steady pressure. At nearly the same time, the thumb and fingers of the right hand continue to the cloaca exposing the papilla. As the thumb and fingers come together at the papilla, a drop of semen should appear. This is collected immediately by the third person. A 0.8 to 1.0 mm capillary tube, at least 60mm long, clean and untreated, is best for this purpose (Fig. 12). Semen will appear as a slightly

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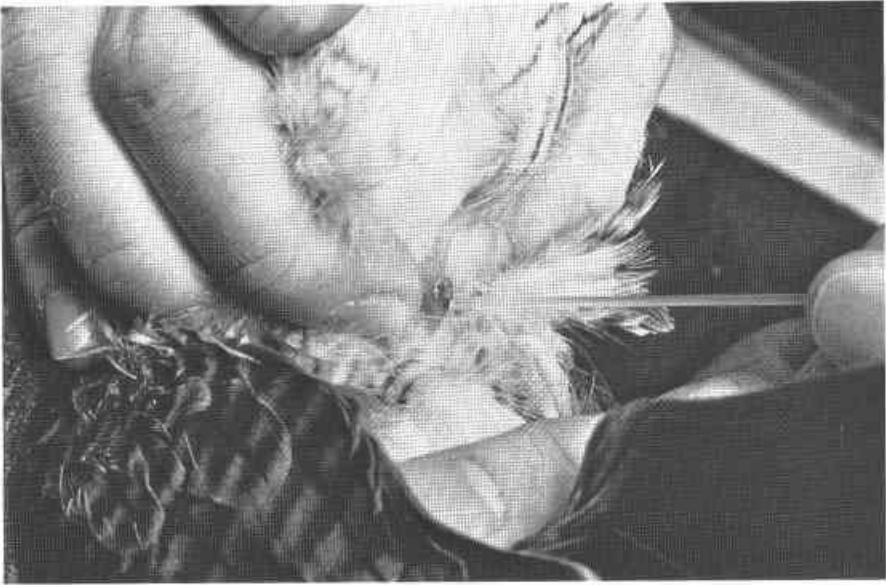
Fig. 12 Peregrine falcon semen collection.

viscous, somewhat cloudy fluid from colorless to yellow. Repeat the procedure, using a fresh tube for each collection to avoid urate contamination. Urates (mutes) will be milk white and more viscous. The samples can be combined later. Unless semen is needed for more than one insemination, a 20 mm collection should be sufficient. The bird is returned to the room and released. This operation should require three to five minutes. **Caution:** Do not pinch the papilla, as it will not help and may damage the delicate tissue. There should be no bleeding. To avoid urates in the sample we suggest that the male be captured just after he mutes and that the collection be made early in the morning before he has eaten.

Check the sample under a microscope immediately. The sperm count will appear inadequate when compared to that of poultry. This is normal, and at a magnification at which the tails are just visible (430X), a dozen motile spermatazoa in the field indicates an acceptable count. We have begun experiments aimed at increasing the sperm count by spinning down large semen samples in a centrifuge. The concentrated portion is then used for insemination. It appears to have no detrimental effect on sperm quality, but it would be premature to say that the technique produces any benefit.

Oviduct Eversion and Insemination

The semen is carefully transferred to the insemination syringe (Fig. 13). We do not recommend the use of thin walled capillary tubes for inseminations as they may break and puncture or cut the oviduct. The sample is then taken to the female in her room; she is caught, her head and back covered with a towel, and then held by her folded wings breast down on the leg of the now crouching person who will be everting the oviduct. One person holds, another everts, and

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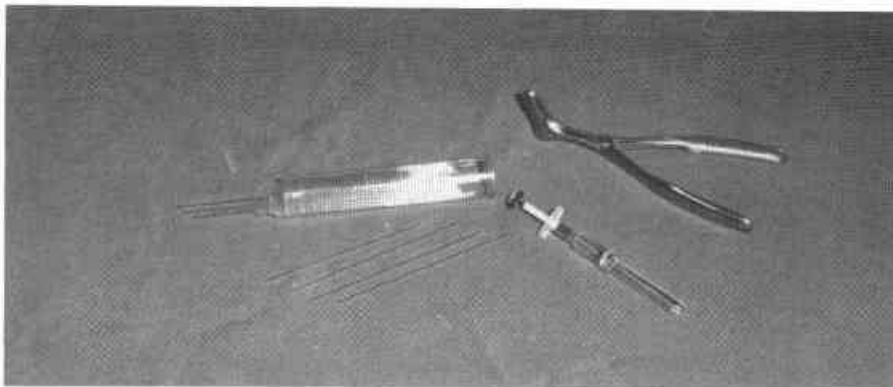
Fig. 13 Capillary tubes, syringe and nasal speculum.

the third actually makes the insemination. Gentle but firm pressure is applied to the abdomen with the flat of the fingers of the left hand. The steady pressure on the abdomen causes the oviduct to protrude through the cloaca, which has been eased open by the thumb and fingers of the right hand. The entrance to the oviduct will appear as a slight depression in the center of the protruding mass of tissue (Fig. 14). At this point, any fecal material, blood clots (created by the egg's passage through the oviduct), etc., should be wiped away by the person with the syringe. The tube is then inserted 2 to 3cm into the oviduct and the semen expelled by depressing the plunger. As the tube is slowly withdrawn, pressure on the abdomen is relaxed drawing the oviduct back to its normal position. **Caution:** Make sure the oviduct does not continue to protrude from the cloaca. Hold the bird gently for a few moments and then release her on the floor as the room is vacated. Total time involved should be around three minutes. Another word of caution here; when holding the female using this technique, be sure to hold by folded wings only. Be aware that too much pressure on her thorax in combination with the abdominal pressure will severely impair her breathing. Monitoring her condition is the prime responsibililty of the person holding. In some cases, when a bird is difficult to evert, one may wish to consider the use of a nasal speculum to open the cloacal sphincter. This device (Fig. 13), available through a hospital supply house, provides a mechanical advantage and greatly reduces the amount of pressure required for the eversion. It is also desirable to blunt talons and beak during this first encounter. It will lessen the chance of self inflicted foot punctures as well as bites and scratches to handlers. The process is much less complicated than it sounds, and there are several variations of the technique involving only two operators that work just as well. One such technique is used by the staff at our Ft. Collins facility and is described by Boyd, et al, (1977). It differs in that the person holding the bird also everts the oviduct.

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Fig. 14 Peregrine falcon oviduct eversion.

TRAINING IMPRINTED SEMEN DONORS

L. Lester Boyd   Charles H. Schwartz

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Raptors that have been imprinted on man can be trained to copulate voluntarily with their human handler when they become sexually mature. Experimental manipulations with the technique of breeding raptors using imprinted birds were pioneered by Hamerstrom (1970), Berry (1972), Grier, et al. (1972), Temple (1972), Grier (1973), Boyd, et al. (1977), and Boyd (1978). This section presents the methods we use to form artificial pair bonds with imprinted males for the purpose of obtaining fresh semen on a daily basis for our captive breeding work. A hat, specially modified for copulation and semen collection, is described. Our remarks apply primarily to the genus *Falco*. For detailed information on the courtship behavior of various species, the reader should consult the relevant literature (Wrege and Cade 1977, Cramp and Simmons 1980, Cade 1982).

Imprinting and Socialization

The mere imprinting of a young male falcon is not, by itself, enough to guarantee the later formation of a functional pair bond with a human companion. The social interaction necessary to accomplish this goal is an on-going process, continuing from the early stages of imprinting to the age of sexual maturity. The easiest way to achieve this result is by the traditional routines of falconry. Rafuse and Guthormsen (1975) and Schwartz and Browne (1978) describe training techiques that have worked well. We do not know why falconry is better than a more conservative and less risky management scheme, but our experiences indicate that this is true.

For example, we separately imprinted two male falcons and placed them in chambers. Neither was flown for falconry. One was free-lofted and the other was tethered to a perch in his room for most of the fall and winter. The socialization process seemed to be going as well or better than with the falconry birds for the first six months but then slowly degenerated as they lost their tameness. Although the tethered bird did not become as wild as the free-lofted one, both failed to establish artificial pair bonds when sexually mature. In contrast, we have succeeded at every attempt using birds that were flown for falconry.

An interesting exception to our experience is the peregrine tiercel "B.C." that has been an extremely productive semen producer at *The Peregrine Fund* facility in Fort Collins, Colorado. He was not flown but was handled by otherwise traditional falconry methods (J. Enderson, pers. com.). It would seem that by restraining the bird with jesses and leash and by caring for it in the classical manner (i.e., daily feedings on the glove), a socialization process was

enforced. In most instances, this approach may not provide the atmosphere for socialization to humans that daily flying and hunting does. It is important that the tiercel's sexual reactivity be in the most receptive state possible when it becomes reproductively mature. It is our opinion that this condition is facilitated when the physical as well as the psychological capacities of the bird are thoroughly cultivated and fixated on the human companion. Falconry apparently fulfulls these requirements.

Chamber Considerations

The size and layout of the breeding chamber, including the placement of windows, perches, and nest ledges, should be designed with a keen regard for the bird's courtship behavior and flying abilities. For larger species, a chamber 24 feet long, eight feet high, and eight feet wide is preferable. Long chambers provide the space necessary for male courtship flying and an even longer room would probably be better. We have trained birds in smaller pens, but the chamber described above seems to fulfull best the behavioral needs of large tiercels.

Perches should be arranged to provide soft landings at the end of predictable flight paths. If they are placed high enough to force the bird to stall as he lands, it will help prevent damage to the feet. Consideration should also be given to the human half of the pair-bonding relationship. Windows should be built where the male can see you as you perform other chores in the yard. This allows you to interact visually with him without entering the chamber. The nest ledge should be at least two and one-half feet by four feet for the larger species and should be filled to five or six inches with pea gravel to allow adequate depth for scraping. It is advantageous to position the ledge no higher than eye level to enhance your participation in ledge displays and other courtship activities.

Communication and Courtship

The tiercel will quickly become conditioned to your clothing, so you should always wear the same coat during the breeding season. The hat, which is described later, should also be worn at all times so that the bird learns to accept it as a part of your normal appearance.

Greeting the male with the appropriate vocalization for this species is the first step toward establishing an artificial pair bond. Breeders duplicating these methods should thoroughly review the courtship behavior of the species with which they are working. Descriptions of vocalizations and displays for large falcons are found in Wrege and Cade (1977) and for merlins in Campbell and Nelson (1975). "Eechip" is the greeting used for peregrines, "Kuduchip" for prairies, "Chittering" or rapid "Chupping" is used for gyrfalcons, and "Chip" or "Tick" is used for merlins. By patiently observing and interacting with your captive bird, you will soon learn which sounds go with which behaviors. All it takes is practice duplicating the sound with your own voice and you may begin communicating with your bird.

Positive indications that the tiercel is accepting you as his mate include ledge displays, food transfers, wailing when sounds suggest your presence, courtship flying, and a courting attitude in general. This courting attitude is very subtle but is easily recognized once you are familiar with it. It is typified by a stiff, almost frozen posture with the plumage sleeked down against the body. The bird avoids direct eye contact, and his gaze is fixed and empty as if he were staring at

something next to you. He may lean forward slightly for 10 or 20 seconds while in this state and then slowly relax into a normal, upright posture with fluffed plumage and full eye contact. This display is probably a precursor to the vertical bow and male solicitation displays which become more recognizable later in the season. At any rate, its presence is a good sign that the bird relates to you as a member of the same species and opposite sex.

Mutual ledge displays can be initiated by your vocalization with the appropriate greeting call. Bowing and avoiding full-faced eye contact as you approach will emphasize your intent to participate in this display. The tiercel will usually fly immediately to the nest ledge and begin bowing and chupping loudly (Fig. 15). By using your hand like a puppet, you can mimic the female role in this display. Your fist is her head, your hooked index finger is her beak, and your forearm is her body in the horizontal bow position. Your hand and arm approximate the correct shape of a displaying female, and you can touch the tiercel's beak with your bill (your index finger) as you loudly imitate the tiercel's vocalization. Since the female's role in a mutual ledge display is similar to the male's, the key here is to imitate him.
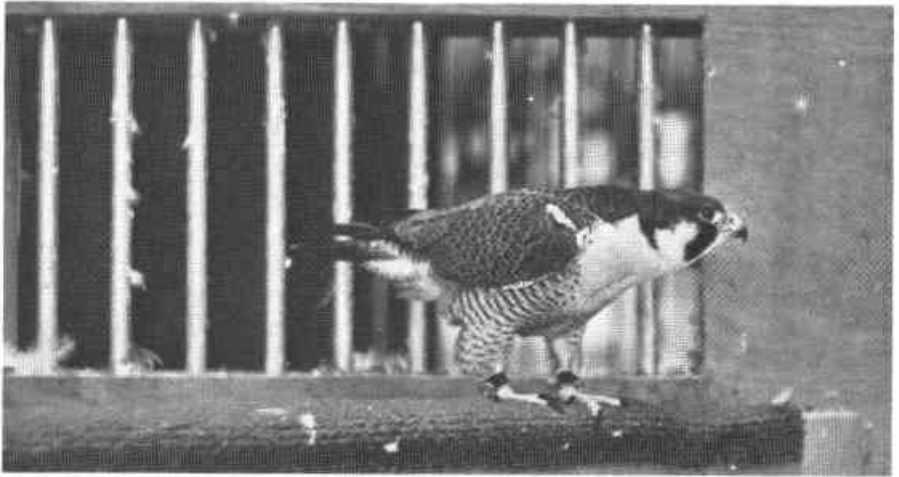
Fig. 15   Imprinted male peregrine ledge display.

Food transfers can be very subtle initially. The male may simply retrieve a food item and then return it to a cache without eating it. As his motivation increases, he will openly bring food to you and his vocalizations will become more insistent that you cooperate by taking it from him. Food transfers, like ledge displays, should be used to strengthen the growing pair bond. You can accept the food, return it, and re-accept it for indefinite periods of time (Fig. 16). This seems to intensify the interaction by prolonging the length of time you are actively communicating with the bird, thus strengthening the pair bond.

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Fig. 16 Imprinted male peregrine food transfer.

Ledge displays and food transfers are often integrated and will sometimes occur almost simultaneously. For example, the male may wail when he hears or sees you approaching his chamber after an absence. By the time you enter his room, he may already be at the ledge either scraping or in a horizontal bow. He will be "eechupping" excitedly (if he is a peregrine) and you should be doing the same. You should engage in a mutual ledge display by "eechupping" loudly and by billing with your hand. As the display loses its momentum, present him with a food item. This will cause him to renew his efforts at displaying, and he may then offer the food back to you, and, of course, you accept it as noisily as you can and after a short time return it to him. Behavioral interactions of this sort can greatly strengthen the pair bond.

Soliciting the male for copulation is the most stimulating form of interaction between you and the bird. This aspect of your involvement concentrates on the major purpose of courtship behavior. It is hoped that solicitation will result in copulation on the hat. In practice, it usually takes some time for this act to occur. In the course of wooing the male, solicitation becomes a mechanism for inducing courtship flight, which seems to be important to the male's copulatory role. Initially the male's response to solicitation is to fly low over your head rather than actually land and copulate. We utilize a routine of solicitation developed by Les Boyd and described below.

First announce your entrance into the chamber by using the greeting vocalization. The male will probably fly to the nest and perform a ledge display in the scrape as described earlier. You should briefly participate in the display; then turn your back to the bird and assume a kneeling position in the center of the chamber. Wait for 10 for 15 seconds or until the tiercel becomes silent and then begin a low, wailing call. There are several responses that can be expected.

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Either the bird will stand with a frozen stance staring intensely at your back (Fig. 17), or he might take a disinterested posture with one foot pulled up. If he is highly motivated, you might be so lucky as to have him make a low-flying pass over your head. This is the desired response and technically what we would term the initial stages of courtship flight. If you are not so lucky, turn and face the bird and use the "eechupping" or otherwise appropriate vocalization. This should provoke flight. Sometimes just facing the tiercel and staring intensely at him will stimulate flight. If this happens, turn your back and solicit again. If he does not respond, supplant him using eye contact and vocalizations as you approach. Bowing as you move in seems to help communicate your intentions.

This kind of provocation does not produce the low fly-by flight that solicitation does. Instead, it is a frantic flight giving the appearance of fright or panic (which it may be), but if his landings are characterized by the typical courting attitude, all is well. This pattern of interaction can take place for up to 10 or 15 minutes per session unless the bird actually lands on your head. Do not move when this happens. A complete sequence of copulatory activity consists of much wing flapping and thumping of the bird's tarsi, followed by one or more tail presses, and then a noticeable shudder as the bird ejaculates. When the tiercel leaves the hat, terminate the session and "chup" as you exit the chamber. Make six or seven visits each day spaced as evenly as practical considering other obligations. Once the tiercel is responding to solicitation and is attempting to copulate on the hat, you have succeeded in creating an artificial pair bond.

Fig. 17 Imprinted male peregrine pre-copulatory posture.

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Fig. 18   Copulation hat in use. W.G. Smith, 1981.

Semen Collection and Handling

The first semen-producing season does not usually commence with actual semen collection until after the bird is physiologically capable of giving semen. This is because it takes some time for the bird to learn how to copulate and ejaculate under artificial conditions. Subsequent seasons are quite different, and most males will start copulating well in advance of the time they are actually capable of producing semen. This is when you can truly appreciate all the labor of your first season, because once the tiercel has learned to copulate, he is forever mated to the *Homo sapiens* willing to court him.

A hat, modified for semen collection, has thus far proven to be the most successful device for capturing this valuable fluid (Fig. 18). A number of designs have been employed, and for this reason you should be prepared to apply some ingenuity. Hard hat liners or military hats with ear flaps that fasten under the chin are easily found at army surplus or industrial clothing stores. We use a two-inch diameter, neoprene tube attached to the hat with silicone caulking to

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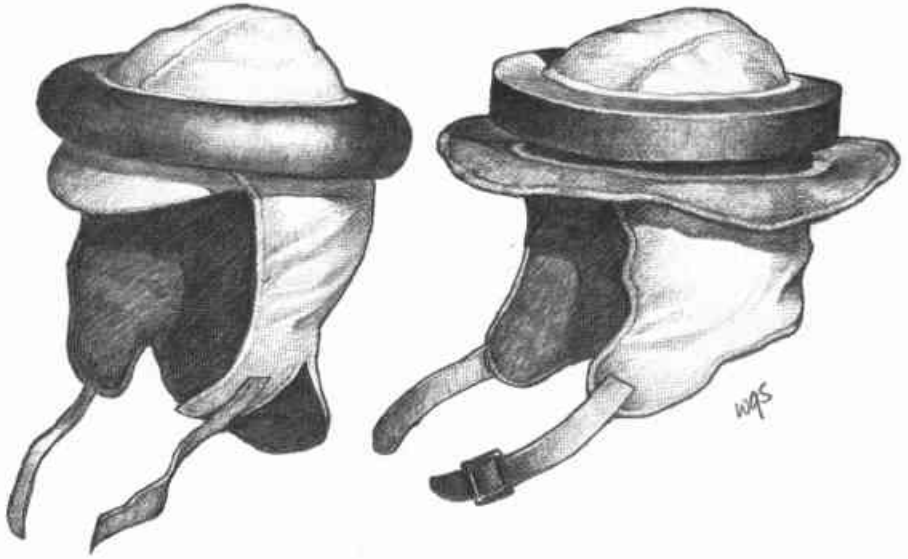
Fig. 19 Two types of copulation hat. W.G. Smith, 1981.

form a gutter to catch the semen. Neoprene tubing is used to insulate refrigeration pipes and can be found at refrigeration supply houses. It is also popularly used to pad roll bars on trucks and handle bars on dirt bikes. You may be able to find it in four-wheeler or motorcycle shops. In order to prevent the semen from soaking into the hat material, it can be waterproofed by rubbing it with paraffin.

The proper physical design of a hat may vary for different birds. The method of cloacal contact as well as traction in the area where the tarsi lie during copulation may be factors. The illustration shows several designs which have worked for us. Like a small child with his security blanket, each bird tends to develop a fixation to his own hat, and may reject modifications or new hats (Fig. 19). Perhaps the underlying message is to continue using the hat you start with, no matter what, and hope the tiercel will accept it. The end result should be a consistently collectable semen sample. With the best of luck, it will probably take most of the first breeding season to achieve this consistency.

The length of time that semen can be produced varies with individual birds and with species. Environmental factors will influence production. These include, but are not limited to, photoperiod, temperature, and behavioral stimuli. It would be safe to say that after the initial season, most tiercels are capable of producing semen for at least six weeks. The longest production periods we have experienced with falcons were three months in length. These birds were all hybrids, but the tiercel peregrine "B.C." (mentioned earlier) also produced semen for a full three months (Burnham, 1980).

With experienced birds, semen production can be started by increasing the number of social interactions per day and by commencing solicitation. Of course, this must be within the limits set by the natural reproductive timing of each species. The use of behavioral stimuli is definitely preferable to the manipulation of photoperiod, because artificially administered long days will almost certainly shorten the cycle.

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Semen can be collected a number of times each day, but we have adpoted a two or three times daily routine: morning, noon (when possible), and evening. We have tried collecting less often in the hope that it would increase the sperm count per sample but had to abandon this procedure as it seemed to reduce the birds' overall reproductive responses. Semen is collected from the hat with the same device used to inseminate the females. Although this equipment usually evolves to suit the person using it, the modification of a 1 cc syringe with a short piece of surgical tubing connected to a two-inch (5 cm) glass or plastic tube is a good basic system. This can be used to draw the semen from the hat into the tube. With a very small sample or one that has been smeared by the tiercel's copulatory activity, a semen extender, such as Lake's diluent or Ringer's solution, can be used to increase the volume so that it can be picked up. You should always have the extender with you when collecting semen in case it is needed instantly. However, it is preferable to use pure semen rather than diluted semen whenever possible.

Sperm motility can last a number of days under refrigeration, and there have been successful results with aged semen, but it is prudent not to store semen any longer than necessary. If a sufficient volume of semen is produced (an average collection may be 50 to 100 microliters), it can be held up to an hour at room temperature. If you need to hold it longer than one hour (up to 24 hours), dilute it approximately 50 percent with an extender and place it in the refrigerator. Be sure to cover the ends of the tube to prevent dessication of the sample. Semen quality varies from bird to bird and throughout the season with individuals. It is wise to check semen quality habitually under a microscope so as to familiarize yourself with the effectiveness of these storage methods.

The long term holding of semen by freezing or some other method would be the ultimate solution to an effective artificial insemination program. Current research with the freezing of falcon semen (Burnham, 1980) has resulted in a 50 percent survival of sperm cells, This is the most encouraging development of which we are aware. It is hoped that effective methods for long-term storage will be perfected in the near future.

IMPRINTED FEMALES

James D. Weaver

When training the imprinted female to accept her human mate it is necessary to go through the entire courtship repertoire of the male, stopping short of the high speed fly-bys. This certainly includes frequent vocalizations and all the mutual displays, especially those involving "head-bows" (Wrege and Cade, 1977; Cramp & Simmons, 1980; Cade, 1982). We have only recently begun to investigate the value of imprinted females for propagation, and at this point it appears that the method may be too labor intensive to be of use in a large operation. There is no doubt, however, that it is eminently suited to the individual falconers from whom the technique is borrowed. Falconry offers the means to keep the bird in the best of physical and mental condition.

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To facilitate the interactions and the "normal" courtship necessary for this method, the female must have special quarters. Our buildings designed for the maintenance of imprinted birds are simply smaller versions of the main building. Accordingly, rooms are scaled down to allow for interaction with the birds. No perch is higher than five feet (1.7m), and there is only one nest ledge available. There is a barred opening or small door to the nest ledge from the service hallway to allow contact during routine off-season feeding. The barred and screened sidewalls open onto areas of regular human activity. It is important that they see people frequently and actively court and are courted by them. (Fig. 20).

Fig. 20   Typical housing for imprinted falcons.

The actual training procedure for females closely parallels that described previously by Boyd and Schwartz (1981) for the male with allowances made for sexual differences. The only real difference comes to light in the final stages of courtship. This difficulty, if you want to call it that, arises from the fact that it is easier to train birds to **do something** that it is to train them to allow something to be **done to** them. You will not succeed at placing your hands on the back of a falcon facing away from you unless her hormone level is sufficiently high and your prior training has been adequate (Fig. 21). During all stages of training it must be kept in mind that by the time the falcon reaches maturity she must have no fear of hands. You must be able to place your hand on her back to steady her and simulate the mounting male. This tactile stimulation will be necessary if she is to accept an actual insemination voluntarily. The oviduct will probably not open to accept the semen unless this contact is made. The female will respond with a special vocalization, at which time the handler should deposit the semen via the syringe in the cloaca at about the eight o'clock (lower left) position. It is important to continue the stimulation as long as she will allow in order to maintain her receptive condition (Fig. 22). It appears that semen is drawn into the oviduct only for as long as she continues to wail. Do not attempt to force her to cooperate. Try several times each day and go only as far as she will allow.

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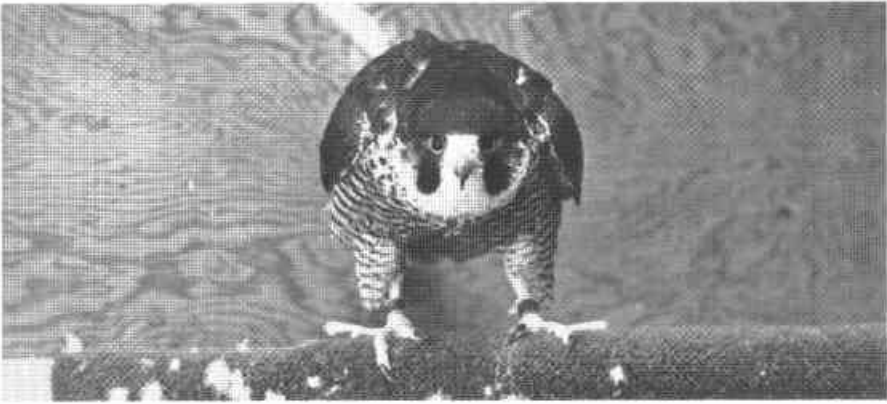
Fig. 21 Imprinted female peregrine not ready for "copulation".

Make as many inseminations as possible when semen is available. The progression in behaviors is the same as that seen in a naturally mated pair. It is advisable for the handler to become familiar with these behavioral signs through the literature or by direct observation.

In the case of a bird that will not allow cooperative artificial insemination, there are some options available. If the situation really appears hopeless, she can be captured in the dark and forcibly inseminated or, if she is a falconry bird, she can be hooded and inseminated. When done properly and with minimum roughness, most birds do not seem to resent this type of handling. Use discretion here in order to keep the female in laying condition. These imprinted birds can be expected to lay from eight to fourteen eggs without problems providing they are on an adequate diet.

Fig. 22 Imprinted female gyrfalcon accepting "copulation".

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INCUBATION AND REARING

Willard R. Heck   Dan Konkel

Incubator Room

Prior to the breeding season some thought should be given to where the incubation and other egg-related activities will be performed. The ideal situation is to have a room exclusively for these activities, but if that is impractical the first consideration would be to choose an area that is free of disturbance. Since the egg itself and the developing embryo are very delicate, incubators should not be located in high traffic areas where they will be subject to bumping, banging, or vibration. If located in the home, children and pets are factors to consider.

Room temperature is also important for proper incubator operation. The incubation area should generally be regulated to maintain an ambient temperature of 70 to 80 F (21 to 26 C). Extremes in room temperature make it difficult for the incubator to maintain a consistent internal temperature. When considering which room-heating or air-conditioning units to use, take into consideration the size of the incubator room and the number of incubators being used. This is especially important in late spring and early summer when an air conditioner must not only contend with the ambient outdoor heat level, but also the heat escaping from the incubators. The use of a larger than normal capacity air conditioner is therefore indicated.

In areas where ambient humidity is high, especially in the warmer months, a dehumidifier may be necessary to control relative humidity in the incubator room. "Relative humidity is the amount of moisture in the air at a particular temperature and atmospheric pressure relative to the moisture content possible under these conditions at saturation" (Moen, 1973). For example, at 50% relative humidity, the air at a particular temperature and pressure contains half as much moisture as it can hold. The capacity of air to hold moisture is strictly related to temperature; warm air can hold more moisture, cooler air can hold less. These physical principles are important in the incubator room. For example, in Ithaca when cool or cold March air is brought into the incubator room and warmed, the relative humidity is lowered and the capacity to accept additional moisture is increased. This capacity of the air is further increased when it is drawn into the incubator and further heated. Thus, the air in a dry incubator at this time of year has a relatively low relative humidity, since cool air is successively warmed without the addition of moisture. On a hot, humid day in June, however, the outside air is already hot and humid, so heating it increases its capacity to take on additional moisture to a lesser degree. The relative humidity in a dry incubator on such a day can be as much as 15% higher than on a cool day. It is therefore important on such days to reduce the incubator room humidity by means of a room dehumidifier. Although a dehumidifier does not necessarily dry the air to the low level seen on a cool day, it is helpful for maintaining consistent incubator room conditions.

The final consideration in choosing an egg handling area is light. A room with many windows may be difficult to darken sufficiently when candling the eggs. Also, excessive sunlight may heat the room beyond allowable limits. Under no circumstances should sunlight be allowed to fall directly on an incubator, as the greenhouse effect may heat the eggs excessively and kill the embryos.

Incubators

There is a wide variety of incubators available in the avicultural marketplace, and undoubtedly there are many that are suitable for incubating raptor eggs. We have consistently used the "Roll-X" incubator manufactured by Marsh Farms, and most of this discussion will, therefore, deal with this type of incubator (Fig. 23).

The "Roll-X" is used for incubating as well as hatching and is a desirable unit for a number of reasons. It is specifically designed for counter-top operation and therefore uses little space. It is easily cleaned, relatively inexpensive, and fairly easy to use once the operator becomes familiar with the idiosyncrasies of each unit. Despite these advantages, some modifications are necessary to increase the precision and reliability of the unit. These modifications are discussed below.

The number of incubators needed is dependent on the number of eggs to be incubated. We commonly operate as many as ten incubators and two hatchers simultaneously at each facility to handle a season total of 550 eggs. It is recommended that at least three incubators be available for even the smallest breeding project. In this way one can be used as an incubator, one as a hatcher, and a spare is then available to operate at another relative humidity level or to use when one of the other units is being cleaned.

The single most critical factor in an incubator is temperature control. Developing eggs are very vulnerable to over-heating but are somewhat less affected by short periods of cooling (Card & Nesheim, 1972; Romanoff, 1972). Safe incubator operation therefore requires a double temperature control system consisting of a primary and secondary, or override, thermostat (Burnham, 1978). The primary thermostat is simply the thermostat which normally controls the incubator temperature. The secondary thermostat, which is adjusted .25 to .50 F (.14 to .28 C) higher than the primary, will assume control of the heating element if the primary should fail, thus protecting the eggs from being overheated.

"Roll-X" incubators are factory equipped with one temperature control system and an emergency override. Until recently, the incubators were supplied with an ether-wafer micro-switch temperature control mechanism.
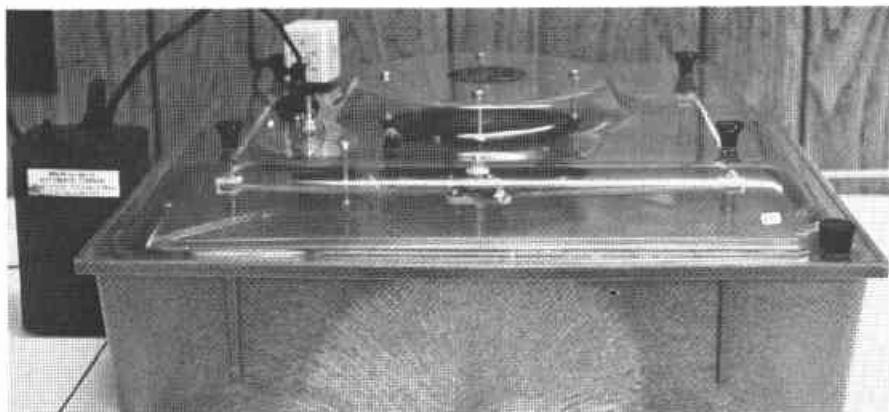
Fig. 23 "Roll-X" incubator.

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The wafer is filled with ether which expands when heated. The expanding wafer depresses a button on the micro-switch which turns off the power to the heating coil. A light on the incubator lid indicates when the heater is on. As the incubator cools and the wafer contracts, the switch clicks on again and power is returned to the heater. This mechanism is accurate to about 0.2 F (0.1 C) with constant ambient temperature and barometric pressure. However, fluctuations in temperature and pressure, most commonly associated with passing weather fronts, can cause considerable variation in incubator temperature. High pressure, for example, effectively compresses the wafer, which then requires a higher incubator temperature to expand it enough to depress the switch button. Low pressure, conversely, cools the incubator by allowing the wafer to over-expand, thus depressing the switch button for a longer time. Owing to this inherent unreliability, the ether-wafer thermostat is used as a secondary thermostat and a more reliable unit is installed as the primary thermostat. **Caution:** Should an ether wafer rupture, for whatever reason, the escaping fumes can kill eggs and chicks. Check wafers routinely and avoid over-expansion when washing with hot water.

More recently, "Roll-X" incubators have come equipped with a "solid state temperature controller". This is an electronic device which apparently controls the incubator temperature with a high degree of accuracy and reliability. We have not had the opportunity to test this controller very extensively, but preliminary use indicates it is satisfactory. These late model incubators have also come equipped with a bi-metal, high temperature, safety thermostat adjusted to turn off the heating coil at 110 F (43 C). This is much too high a temperature for developing eggs to withstand. The bi-metal thermostat is therefore removed and discarded, and a more reliable secondary unit is installed.

We have had a great deal of success over the years using the Robbins temperature control system, manufactured by Robbins Incubator Co., in both primary and secondary positions. The Robbins system consists of a "Sigma" relay and a fixed temperature mercury thermostat. The thermostat is a short, pre-adjusted (in increments of 0.25 F) mercury thermometer which is encircled by two lead rings (Fig. 24). The lead rings insert into mounting clips that both hold the thermostat in place and set up a potential circuit within it via an
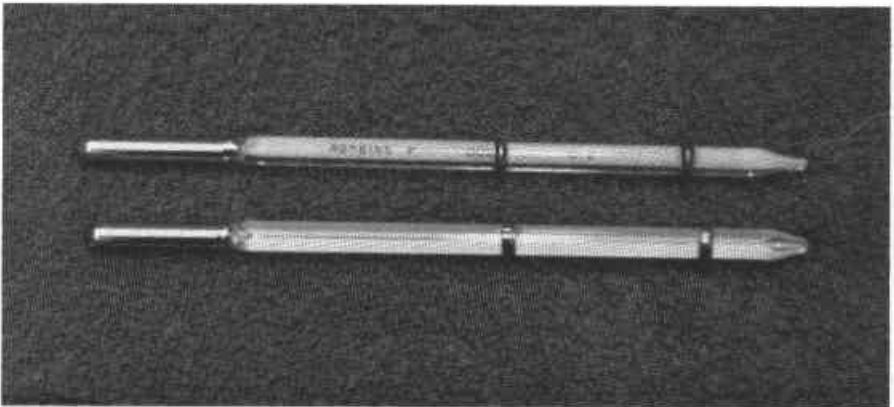
Fig. 24   Robbins thermostats.

electrical connection. As the mercury rises and falls in the thermostat, the potential circuit is completed or broken. This causes the relay to open or close another circuit which supplies the power to the heating element. The thermostat thermometer is installed on the underside of the baffle in the incubator lid while the relay is mounted on the top of the incubator lid (Fig. 23 & 25). This system, as with any secondary system, must be custom installed and is not provided from the factory. Installation requires some level of mechanical and electrical proficiency so that the incubator will not be harmed and all systems will work properly (see Burnham, 1978 for further explanation).

Any number of combinations of thermostat systems can be used to provide primary and secondary control. The two most common combinations we use are a Robbins primary with an ether-wafer secondary and a Robbins primary with a Robbins secondary. Both combinations have worked very satisfactorily over the years. Other combinations may work equally well. A few recently acquired incubators factory equipped with the solid state controller have been equipped with Robbins systems for secondary control and seem to work satisfactorily under preliminary testing. Undoubtedly, future advances in electronic technology will provide more precise and less expensive temperature controllers.
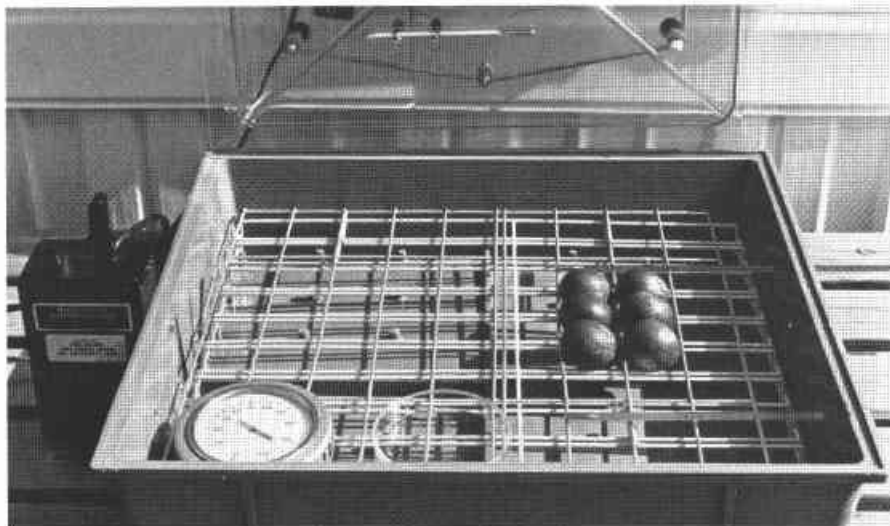
Fig. 25   Incubator interior.

Humidity Control

Proper control of incubator humidity is also critical for successful hatching of artifically incubated eggs as will be evident from the later discussions of egg weight loss. Incubator humidity is controlled by changing the surface area of the water available for evaporation in the incubator; the more surface area present, the higher will be the relative humidity. The "Roll-X" incubator comes factory equipped with a fountain type humidity controller which inserts through the incubator lid and meters water into a quadrant in the incubator bottom. These fountains are not very useful since they must be removed and reinserted

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whenever the lid is opened, and this action invariably allows excess water to flow into the incubator bottom. An easier and more precise way of regulating the humidity is to use small trays or dishes, which can be filled with water and placed either on or beneath the egg grid. Glass petri dishes are made in various sizes and are convenient containers to use. All containers should have straight sides so that the surface areas of the water remain constant as evaporation occurs. Furthermore, distilled water should be used to prevent mineral buildup in the dishes.

Turning of Eggs

Egg-turning during incubation is important as it prevents the developing embryo from sticking to the shell membranes, a problem which develops if the egg lies too long in the same position (Landauer, 1967). A survey of the poultry literature indicates that for optimal hatchability an egg should be turned at least eight times every 24 hours. Many incubators with automatic turning mechanisms, including the "Roll-X", turn the eggs once every hour. Regardless of the number of times an egg is turned each day, the intervals between turning should be evenly spaced throughout the twenty-four hour period. Furthermore, the egg should be turned in alternate directions, as turning in only one direction will increase embryo mortality (Landauer, 1967). Eggs can be turned by hand if desired, but maintaining regular turning intervals is frequently difficult if technicians are not available twenty-four hours per day to monitor the incubators. Automatic turning is, therefore, an important feature of an incubator.

The "Roll-X" turning mechanism consists of a sliding grid assembly and an enclosed motor-gear assembly. The motor slides the top grid back and forth over the lower grid, turning the egg by pivoting it around the small end. The egg moves through approximately 90° of rotation with each turn. A minimum of 45° of turn is necessary to produce optimal hatchability in poultry (Landauer, 1967).

This system works very well if the size of the egg matches the size of the turning grid. Use of a turning grid that is too large or too small for the egg size could result in broken eggs, as the eggs will become "pinched" in the sliding grids. It is important that the turning grid be properly adjusted and/or modified to eliminate this problem. First adjust the stops on the rod which connects the turning grid to the motor as per the instructions supplied with the incubator. Generally, this means making adjustments so that the egg is not moved along the lower grid by the top grid pushing on the mid-section of the egg after it has completed its turn. Further adjustment is accomplished by bending the top grid in such a manner as to increase or decrease the distance between the grid rods to accommodate the egg(s) properly. Never place eggs in the center grid spaces where they will be pinched against the single transverse cross-member on the lower plastic-coated grid. Beware, also, of placing eggs where they will contact thermometers, thermostats, hygrometers, or other accessories in the incubator. In general, most peregrine or prairie falcon eggs can be accommodated by the grid made for average size chicken eggs. Large eggs, such as those of the gyrfalcon, are better fitted to the grid made for large chicken eggs.

Another method of using the standard turning grid has been applied with great success by workers at our Santa Cruz facility. The grid is disassembled and the bottom, plastic coated part is returned to the bottom of the incubator. A piece of one-quarter inch (6.4mm) hardware cloth is then cut to fit snugly in the

incubator bottom atop the plastic-coated grid. The top grid is then inverted and placed on the hardware cloth. A slit is cut in the hardware cloth to accommodate the push/pull rod from the motor. The eggs are then laid on their sides in the turning grid and are rolled around their long axis on the hardware cloth. This produces at least 45° of turn. In addition, the eggs are rotated by hand end to end around the short axis three times per day. Perhaps the most attractive aspect of this system is that it is virtually impossible for the moving grid to break an egg. Furthermore, various size eggs can be accommodated on one grid. Whatever system one chooses, set it up carefully and know it's characteristics intimately before trusting it with a valuable egg.

Thermometers and Incubator Mapping

Once the incubator is in operation, it is necessary to monitor the temperature to be sure it is maintained within the desired levels. The "Roll-X" incubator comes equipped with a small alcohol filled thermometer to serve this function. This thermometer will not measure the close tolerances desired in the incubator, but it can be used in a still air brooder quite safely. Laboratory grade mercury thermometers should be obtained which will measure temperature to 0.2 F (0.1 C) accurately. Several extras should be obtained since even the most careful technician will break one occasionally. Holes should be drilled in the sides of the incubator bottom at about egg height and the thermometers inserted (Fig. 25). Position the holes so the thermometers will lie between the rows of eggs, and parallel to the direction the eggs move when turning. Before installing the thermometers, allow them all to equilibrate at room temperature and check for consistency. Any that vary more than 0.2 F (0.1C) from the group reading should probably be discarded. Lesser variations should be noted and considered when using the thermometer in the incubator.

After allowing the incubator to equilibrate for several hours, it may be noted that a thermometer placed in different areas in the incubator may indicate temperature variations of up to one degree. These variations can be caused by several factors. If the coils of the heating wire are not evenly spaced, then hot spots will be created where the coils are closer together and cool spots where the coils are farther apart. Some adjustment of the coil is possible by gently stretching or compressing the coils, but a highly non-uniform coil should be replaced. Also, if the space in the lid where the air moves down into the bottom of the incubator is not a uniform width all the way around, then hot and cool spots will again be created. Trim the plexiglass baffle to correct this problem.

Placement of the water dishes for humidity control also affects internal temperature. Areas close to the water dishes will be generally cooler owing to evaporation. Do not, therefore, place water dishes near the thermostat, for the cooling effect around the controller will cause it to overheat the remainder of the incubator.

These types of situations mean that in a Robbins controlled incubator, the measured temperature may not conform with the temperature designated on the thermostat thermometer. Several different thermostat thermometers should be kept on hand to correct these differences. For example, the individual peculiarities of some incubators require a 99.75 F Robbins thermostat in order to maintain an incubator temperature of 99.5 F.

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Be sure to allow an incubator to operate long enough for all parts to equilibrate at operating temperature before making judgments about the need for adjustment. At initial starting, allow several hours for the incubator to equilibrate and allow several minutes for it to re-equilibrate whenever it is opened. By moving the thermometer(s) around in the incubator one can effectively "map" the temperature zones and subsequently determine the best area for egg placement in the incubator.

Incubator Maintenance

Though all of the above incubator systems are very reliable when adjusted properly, a small inventory of spare parts should be kept on hand for quick repairs in the event of failure or malfunction in a part of the incubator. As previously mentioned, spare mercury thermometers should be on hand in case of breakage. This inventory should also include a spare turning motor assembly and a temperature control mechanism of whatever type is being used.

If the Robbins temperature control system is being used, several spare thermostat thermometers should be on hand for a variety of reasons: (1) the glass thermostats break easily in the hand, (2) a thermostat may not run a particular incubator at the same temperature as designated in the thermostat, and (3) the mercury may separate causing the thermostat to malfunction.

Mercury separation can usually be repaired by removing the thermostat from the incubator and placing it in warm water. Slowly raise the temperature of the water until the break in the mercury reaches the top of the column. Remove the thermostat from the water and let it cool to room temperature. The mercury separation should be gone. If not, repeat the process. When performing this repair, do not use hot water as the mercury may over expand and break the thermostat.

The most common equipment failure in the "Roll-X" seems to be the fan. The original equipment fan usually has a life of several seasons, but eventually the bearings go bad, and the fan starts to vibrate and make a grinding noise. Alternatively, the fans will begin to eject oil which can kill the embryos. Oil is easily seen on the inner surface of the incubator lid. In either case, **immediate** fan replacement is required.

For superior performance and economy we recommend that a 4 11/16 inch (119mm) square axial fan with a die cast metal venturi frame be used. It should be rated to move air at 100 cubic feet per minute. These fans are made by several manufacturers and are commonly used in computers and other electronic equipment. The mounting holes on the fans are on center to fit the studs in the incubator lid. These fans seem to be very reliable units and are also cheaper to buy than other replacement fans. An extra one should be kept on hand as part of the spare parts inventory. A molded plastic plug and cord set is available that fits the wiring terminals on these fans, and we recommend that it be installed as well at initial replacement as it makes future fan replacement a very easy task.

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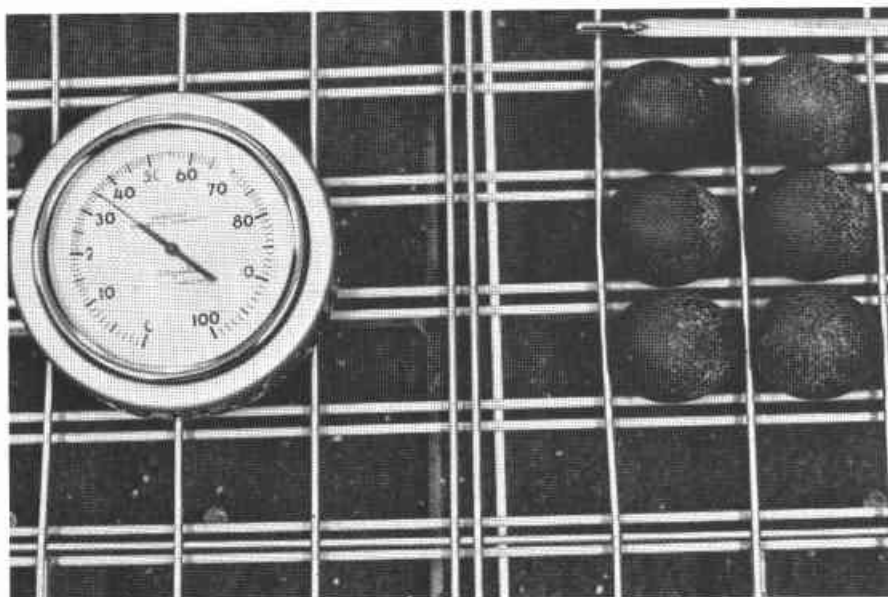
Fig. 26 Silica gel and hygrometer.

Measuring Humidity

A good dial hygrometer is necessary to monitor the percent relative humidity in the incubator (Fig. 26). Primarily, the operator is concerned that for a given combination of water pans, the incubator humidity remains constant. As was mentioned earlier, ambient outdoor and incubator room conditions can affect the relative humidity in the incubator. By monitoring relative humidity, therefore, the operator can adjust the water surface area in the incubator to maintain as constant a humidity as possible.

Many dial hygrometers tend to lose their adjustment over time, and we recommend, therefore, that they be recalibrated several times during the incubation season. The hygrometers are equilibrated at room temperature, and a sling psychrometer or wet-bulb/dry-bulb hygrometer is used to obtain an accurate measure of relative humidity. The hygrometers are adjusted accordingly and then returned to the incubator.

A dial hygrometer need not be precisely calibrated to be of use. Whatever value it reads while in the incubator can be said to be satisfactory as long as the egg's rate of weight loss is correct. A change in incubator humidity (an increase or decrease) will still be reflected by the hygrometer regardless of its calibration. If several hygrometers are used, however, it will be less confusing to calibrate them all and thereby standardize all the readings.

The hygrometer will disrupt the air flow in the incubator. This will cause warm and cool spots which will have to be mapped as previously described.

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Incubator Hygiene

The temperature and humidity in an operating incubator provide an excellent environment for the growth of a variety of bacteria and fungi. Many of these organisms can be harmful to the developing egg, and a regular routine of incubator cleaning and fumigation is therefore required. The need for proper incubator hygiene cannot be over-stressed.

Incubator cleaning is accomplished in several steps. The incubator bottom and any accessories which are waterproof are washed with disinfectant solution. Use a quality bacteriacidal and fungicidal disinfectant, which can be obtained from most veterinary supply houses. The incubator top, which houses all the electronics and wiring, should not be immersed in water. Instead, clean it with a quality spray plastic cleaner commonly available at glass shops which carry plexiglass and other plastics. These products clean the plastic well while preventing scratching and build-up of static electricity. Compressed air is a handy accessory to help clean any dust from the wiring, especially in the hatcher lid where dust from the down of hatching chicks will accumulate. The baffle in the incubator lid must be removed to clean the wiring and the lid's inner surfaces. After cleaning, the incubator should be reassembled including thermometers and hygrometers which will be used in the incubator during normal operation. Plug in the incubator and allow it to achieve near-operating temperature (80 to 100 F or 26 to 37 C). Spray the incubator interior with distilled water to create high humidity.

The final step involves fumigating the warm, humid incubator with formaldehyde gas. The gas is not only toxic to bacteria and fungi, but to other living things as well; it is **highly noxious,** so the incubator should be placed in a **very well ventilated** area away from people, pets, etc. The gas is created by mixing 0.4g of potassium permanganate ($KMnO_4$) with 0.8cc of formalin (37.5%) for each cubic foot of incubator space. It is not necessary to measure out the amounts of each chemical every time one needs to fumigate, but do measure them initially so that the amounts can later be visually approximated. Place the $KMnO_4$ in a small dish in the warm incubator and pour the formalin into the dish. Immediately close the incubator. Within a few seconds the mixture will begin to bubble violently as the chemical reaction takes place and the gas is released. After 15 to 30 seconds, unplug the incubator and allow the gas to circulate for at least 20 minutes. Then restart the incubator and prop the lid open a bit, leaving the incubator running to allow the gas to be removed more rapidly. The incubator is ready for use when all traces of gas are gone, usually after several hours of ventilation. Fumigate the incubator before use and every two weeks thereafter during the season. Do the same with the hatcher and still air brooder.

The poultry literature recommends fumigating eggs prior to incubation. However, since the embryo can be harmed if exposed to fumigant between one and four days of incubation, and since raptor eggs may be at various stages of development when placed in an incubator, we recommend that raptor eggs not be fumigated.

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Scale

As will be seen in later sections, proper loss of egg weight is an important factor for successful incubation. A quality scale on which to weigh eggs is therefore necessary. The scale must weigh accurately to 0.1 grams. Triple beam balances normally work very nicely (Fig. 27). More expensive electronic scales which weigh to 0.01 grams are quicker and easier to use and therefore can be real time savers if large numbers of eggs are involved.

Attach to the weighing tray a soft foam rubber cup which will safely hold the egg in position while it is being weighed. Place the scale on a level, sturdy, non-vibrating table or counter-top which is convenient to the incubator but in a non-traffic area. Recheck the scale "zero" daily and any time the scale is moved.

Depending on the physical layout of the breeding facility and the way in which the breeding pairs are manipulated, it may be convenient to have an additional set of scales to use at the breeding chamber. In this way, one or more eggs may be removed from the scrape, easily and rapidly weighed, and then quickly replaced back into the scrape in as short a time as possible.

Fig. 27   Triple beam balance and candler.

Candler

An egg candler is a lighting device which, when held against an egg in a dark room, allows one to see into the egg (Fig. 27). Most falcon eggs are rather easily candled with incandescent white light, the amount of shell pigmentation being the primary variable effecting what can be seen. Eggs of the osprey, Harris's hawk, bald eagle, and other large species are very difficult and many times impossible to candle as the shells of these eggs are very thick and opaque to white light. The turkey industry has developed an ultra-violet candler which works exceptionally well on thick shelled eggs, but since the radiation is intense, the egg should not be exposed to the light for more than 10 to 15 seconds.

Candlers are commercially available but plans for home-made models can also be found in some books written for the lay poultry breeder. If a homemade candler is constructed, use a light bulb no larger than 40 watts to prevent the egg from being exposed to excessive heat.

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Power-Off Alarm and Auxiliary Generator

A handy accessory for use with incubating, hatching, and brooding equipment is a power-off alarm, which will sound whenever the electricity supply is interrupted. Although incubating eggs can survive some degree of cooling, chicks are less tolerant, and the breeder will naturally want to become aware of this problem as soon as possible.

During a power failure, the incubating and brooding equipment can be helped to retain as much heat as possible by having blankets available to cover the equipment until power is restored. Another solution to the problem of power failure is to have available an auxiliary electricity generator. The need for such a power supply can be weighed against the reliability of the local power company.

Understanding the Egg

Before undertaking the artificial incubation of eggs of any type, it is necessary to acquire some knowledge of the structure, development, and other properties of the egg. This is best accomplished by undertaking a review of several poultry and ornithological references which present descriptions and explanations of the egg and its parts. A list of some appropriate references can be found in the suggested reading list.

Egg Handling

Once the anatomy and development of the egg is understood, it is not difficult to appreciate that the egg is a very delicate life system. The developing embryo, with its associated membranes and blood vessels, lives in a fluid environment and is therefore not rigidly fixed to any supporting structure. Extreme care must be taken, therefore, whenever handling the eggs, to ensure that the embryo and its associated parts are not injured. Rapid or jerky movements must be avoided, as abrupt changes in motion can cause membranes or blood vessels within the egg to tear. Smooth, even, and gentle movements are in order whenever the eggs are handled at any stage. If the eggs must be transported by vehicle to the incubation facility, they must be protected from vibration and jarring by seating them in foam rubber. Moreover, the eggs should be transported as early in incubation as possible, before the vulnerable blood vessel network develops. If incubated eggs must be transported a variety of portable field incubators are available.

Cleanliness is also important, and the technician should be sure to wash his hands thoroughly prior to handling eggs at any stage. This will reduce the possibility of transferring pathogens to the egg and/or incubator as well as prevent the build-up of body oils on the shell with repeated handling.

Egg Storage

Eggs which have received **no incubation** can be stored for several days while retaining high probability that they will hatch. Even in the best storage conditions, however, an egg's hatchability will start to decline as the storage period increases beyond a few days. We recommend that raptor eggs be stored only if proper storage conditions are available and that they be stored for as short a time as possible, but no longer than five days.

Eggs may need to be stored for several reasons. If one is removing eggs from a breeding female as she lays them, it may be desirable to wait and acquire a complete clutch before placing them under a surrogate parent for initial incubation. Alternatively, a surrogate parent may not be immediately available, and therefore the egg(s) must be held for a short time until incubation can begin.

Proper storage temperature for chicken eggs held for less than one week is 60 F (15 C) at a relative humidity of 75 to 80% (Card & Nesheim, 1972). Though the temperature at which embyronic development starts is approximately 70 F in chickens, prolonged exposure to this temperature is lethal, as the embryo will develop abnormally (Card & Nesheim, 1972; Romanoff, 1972). At the other extreme, eggs will freeze at 28 F (-2.2 C) (Stromberg, 1975). Although these values have been determined for chicken eggs, they are probably applicable to most eggs and are therefore valuable guidelines for storing raptor eggs. Before incubating a stored egg, allow it to equilibrate to room temperature.

The proper position for an egg in preincubation storage is subject to debate. We have had good success storing eggs with their large end uppermost and turning them through 90° at least twice daily.

Natural Incubation

Natural incubation is incubation performed by a bird, be it the raptor that laid the eggs, a surrogate raptor parent, or some type of setting chicken. A recent review of our incubation techniques over the years has shown that an initial period of natural incubation is very beneficial to the overall hatchability of an egg. Eggs that were placed in an incubator after receiving less than three to four days of natural incubation hatched at a rate of about 50 to 60%, but eggs that were naturally incubated for the first five to ten days hatched at a rate of 75 to 85% after being placed in an incubator (Burnham, 1983). We therefore highly recommend that the first seven to ten days of incubation be some form of "natural" incubation.

Removing eggs from a breeding pair after seven to ten days of incubation is a compromise in the sense that at that point the eggs have received enough natural incubation to enhance their hatchability in an incubator, but at the same time the parents have not incubated so long that they will probably not recycle and lay a new clutch if the first is removed. If a breeding pair is not to be recycled, the breeder may elect to let the birds carry through and incubate the eggs full term. Some birds will eat eggs and chicks at hatching; be especially watchful as hatching time nears.

Using Chickens for Incubation

If a female parent will not incubate a clutch of eggs, or the eggs must be pulled sequentially to enhance laying, then the eggs ideally should be placed with a surrogate parent to obtain the initial seven to ten days of natural incubation. In the absence of a raptor parent, chickens can be used quite successfully to carry out the task. Various breeders have reportedly used chickens for incubation with varying degrees of success, including, unfortunately, several broken eggs. It should be noted from the outset that if chickens are to be used to aid in incubation, the breeder must accept the fact that they must be managed as intensively as one's raptors. Not just any chicken that happens to be sitting on eggs will do. Many eggs have been lost when placed under random hens in the local barnyard. The chickens to be used must be of a recognized bantam setting

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breed. Many of the modern meat and egg producing breeds have lost the instinct to incubate. The flock, consisting of a rooster and several hens, should be obtained in the fall of the year before the breeding season in which they are to be used. Hens normally do not lay eggs until they are several months of age, so be sure to obtain individuals that are or will be old enough; they should be about nine months old to assure sufficient maturity.

Breeders of fancy poultry are frequently good sources of setting hens as they often use them to incubate waterfowl and other poultry eggs. Our Ithaca facility uses bantam cochens and houses the flock of one rooster and six hens in a cage that is 8 ft. x 8 ft. x 7 ft. tall (2.3 x 2.3 x 2m) (Fig. 28). Such a cage should be located in an area safe from disturbance by other animals. The floor is solid and wood shavings are used as litter. The chickens are fed a commercial pelletized poultry ration which is fed *ad libitum*. Most commercial rations have all the nutrients needed to maintain the flock in good health. Avoid feeding whole grain diets as they tend to be lacking in a variety of nutrients. Grit is also provided, as is ground oyster shell for calcium supplementation during egg laying.

The flock is obtained in the fall so that they can be tamed sufficiently before they are needed. Taming is accomplished by offering handfuls of scratch grain

Fig. 28   Chicken cage with nest boxes.

(cracked corn and wheat) as a treat several times per day. The chickens soon eat out of the hand and crowd around the cage door in anticipation when the handler arrives. Care must be taken, however, as too much scratch grain can interfere with the chickens' proper nutrition as mentioned above.

Around the first of January, the chickens' day length should be extended to 14 hours by means of artificial light. In this way they will lay eggs and start to incubate by about 1 March. When eggs start to appear on the floor of the cage, a set of nest boxes is put on the floor of the cage against a wall (Fig. 28). Nests of crushed sugar cane or some other suitable material are hand made in these nest boxes. Crushed sugar cane is a desirable material because it tends to hold its shape once formed into a nest. Soon the hens begin to lay their eggs in these nest boxes, and before long some individuals will be seen spending nearly all of their time incubating the eggs. At this point all hens should be color-marked so they can be precisely identified. In this way the handler will know exactly which individuals are incubating.
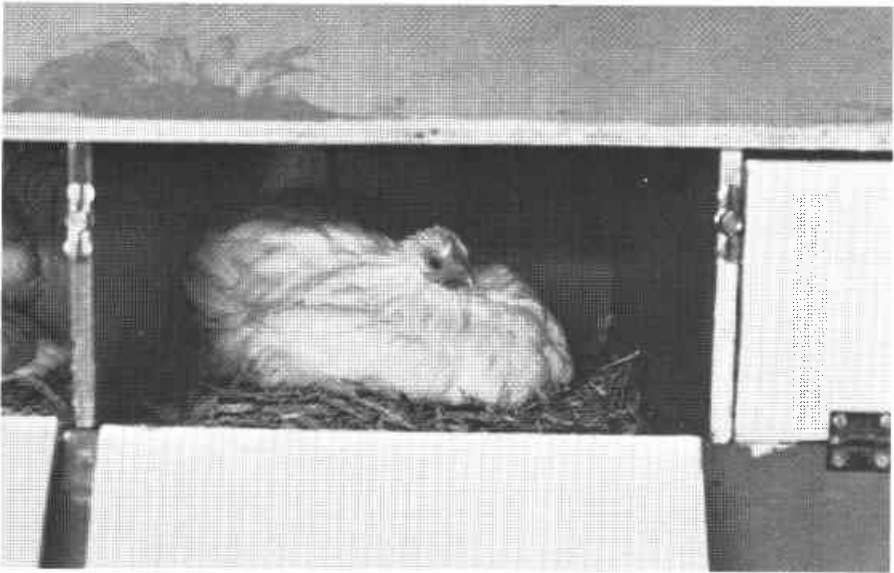
Fig. 29   Nesting lock-box.

After a hen has been incubating diligently for several days she can be moved to a locking nest box (Fig. 29). These are nest boxes similar to those placed on the floor, except that they have a latching door to confine the hen within the box, and they are mounted about chest height on the wall of the cage. In this way they are at a convenient height for the handler to service, yet too high for the cochens to fly up to (cochens are poor fliers). A sugar cane nest is constructed as for the floor nests, and a clutch of the hens' eggs is placed in the bowl of the nest. The incubating hen is then gently picked up from her nest on the floor and placed on the nest in the lock-box (Fig. 30). When incubation is well under way the hens are very tame and seem to be in a stupor while on the eggs. As a result, they are easily handled. After the hen is placed in the lock-box, gently close and latch the door. Stand by for several minutes to ascertain that the hen will continue to incubate. The incubating hen should then remain in the
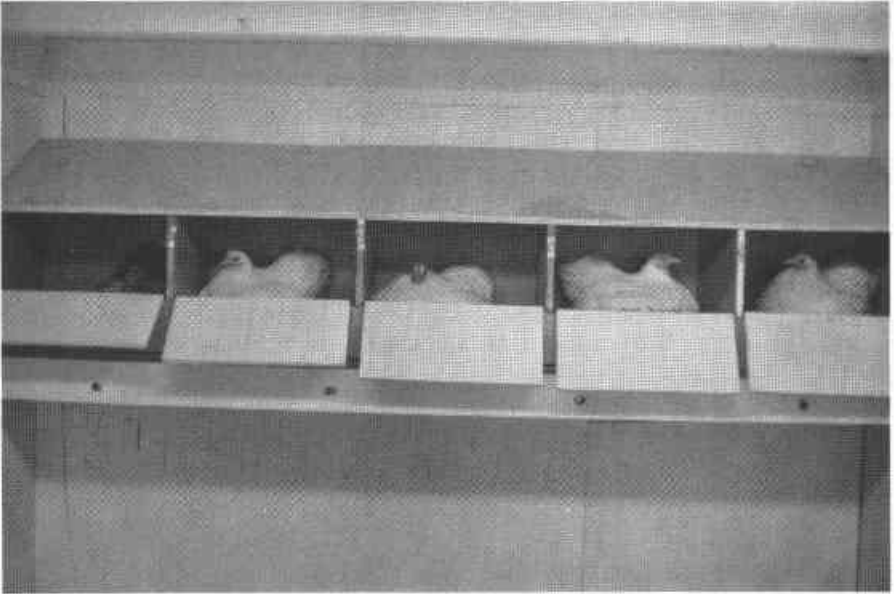
Fig. 30 Series of lock-boxes.

lock-box for the next 23.5 hours. At the appointed time, open the box and gently lift the hen off the eggs. Get into the habit of lifting her slightly and accounting for all the eggs before removing her to the floor, as occasionally an egg will remain tucked under a wing and may fall and break as she is removed.

Allow the hen one-half hour to feed, water, defecate, preen, etc. before replacing her in the lock-box. It is important that this "break time" be performed at the same time each day, as chickens, like trained hawks, thrive on a stable routine. After several days of this routine, the hens will be eagerly awaiting the return of the handler at the end of their break, and will jump to their roosting perch or gather around one's feet excitedly awaiting to be picked up and returned to the box.

When to replace the chicken eggs in the lock-box with raptor eggs is a decision that must be made on the basis of each hen's performance. Normally, a hen must incubate solidly in the lock-box for at least one full week before she is trusted with falcon eggs. At the other end of the scale, the hens will normally incubate solidly for 60 days.

We have started several hundred eggs under setting hens using this system, and as yet not a single egg has been broken. This record is attributed to careful management of the hens. A hen is **never** trusted with a falcon egg until her performance is **time-proven** on a clutch of chicken eggs. We do not recommend using chickens for full term incubation, though some breeders have succeeded in hatching a few raptor eggs under setting hens.

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Artificial Incubation

The two most critical factors in incubating an egg artificially are incubation temperature and proper egg weight loss from the time it is laid until it hatches. Egg weight loss can be in part controlled by regulating incubator humidity. Rahn and Ar (1974) suggest that eggs from all species of birds should lose 18% of the fresh egg weight by the time they hatch.

Temperature

Proper incubation temperature is critical for ensuring the maximum hatchability of the eggs as well as the best physical condition of the chicks that hatch. Variation from the optimum temperature affects growth rate and incidence of embryonic mortality and deformity (Romanoff, 1972). Use of suboptimal conditions is evidenced by poor hatching success or by chicks hatching with unretracted yolk sacs, poor vigor, and developmental problems.

We have successfully hatched raptor eggs in "Roll-X" incubators maintained at temperatures ranging from 97 F to 100.4 F (36 to 38 C). The optimum temperature, however, as with poultry, seems to be about 99.5 F (37.5 C).

Fresh Egg Weight

Weight is the simplest factor to measure in an egg. It is most desirable to weigh the eggs soon after laying to determine the fresh egg weight, but normally with breeding raptors this is only possible when dealing with an imprinted female or with a pair in which the eggs must be pulled sequentially. Since most eggs are not removed from the birds until after the clutch has received seven to ten days of natural incubation, fresh egg weights must be calculated or estimated.

Fresh egg weight calculations are accomplished by using a formula that requires knowing the length and breadth of the egg. Egg length and breadth are measured using a pair of calipers (see next section). Hoyt's (1979) generalized equation for calculating the fresh weight of avian eggs is used with a modified constant calculated for peregrine eggs (Burnham, 1983). The formula is as follows:

$W = K_w(LB^2)$ where W = fresh weight
K_w = observed weight coefficient for peregrine eggs (0.0005474) (Burnham, 1983)
L = length of egg(mm)
B = breadth of egg(mm)

A sample calculation for an egg 50mm long and with a breath of 40mm would look like this:

$W = K_w(LB^2)$
$= 0.0005474 (50 \times 40^2)$
$= 0.0005474 (80,000)$
$= 43.79$ grams

This calculated fresh egg weight can be in error by as much as 2%, which, in the above example, would mean the fresh egg weight would be between 42.9 and 44.7 g. Normally this error is not enough to affect the hatchability of the egg.

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Measuring Egg Length and Breadth

Egg length and breadth are necessary values for calculating fresh egg weights. They are determined by measuring the egg with a pair of dial calipers accurate to 0.01 mm. When closing the calipers on the egg use extreme care, as the mechanism in the calipers has some mechanical advantage and the careless user can crush an egg. As the caliper jaws close upon the egg move the calipers back and forth to determine better the outermost points that delimit the length and breadth of the egg. Since an egg is not perfectly symmetrical, it is important to rotate the egg several degrees and remeasure. Be sure the calipers are perpendicular to the egg when measuring, for if they are canted to one side a false measurement will result. By measuring the egg several times for each value, an average value for length and breadth can be obtained. It is important to measure each parameter as carefully and as precisely as possible, as small errors in measurement, especially errors in breadth, can greatly affect the calculated fresh egg weight. The calculated fresh weight value is only as good as the measurements used to determine it. Make the extra effort, then, to obtain accurate values for length and breadth.

Estimating Fresh Egg Weight

Frequently the fresh egg weight can be estimated without using the above formula, but to do so requires fairly accurate knowledge of the number of days of incubation the egg has received. Furthermore, the longer the time period between laying and initial weighing, the less reliable will be the estimate. For that reason, estimated fresh weights made after the egg has received over five to six days of natural incubation should be confirmed by determining the calculated fresh weight.

Before estimating the fresh weight, one must first approximate the weight lost per day of incubation for the egg. If the incubation time to pip is 31.5 days for most peregrines (Burnham, 1983), and the desired weight loss to pip is 15%, then the weight loss per day can be approximated by this formula:

$$Wl = \frac{0.15W}{31.5}$$

where Wl = weight loss per day(g)

W = fresh weight(g)

Simply stated, 0.15W is the total weight loss to pip and that amount is divided by 31.5 to determine the amount of weight lost during each day of incubation. The following examples show some expected daily weight loss values for several fresh egg weights in grams:

Fresh Wt.(g)	Daily Wt. loss(g)
40.0	0.19
41.0	0.20
42.0	0.20
43.0	0.20
44.0	0.21
45.0	0.21

To estimate the fresh weight of an egg that weighs 41.0g when removed from the nest after four days of incubation, refer to the egg weight loss information above. That information shows the daily weight loss for a 41.0 g egg is the same as for a 42.0 or 43.0 g egg. Therefore, knowing the days of incubation, an

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approximate fresh weight can be calculated by multiplying 0.20 g times 4 and adding 41.0 g. The result is 41.8 g. Eggs begin to lose weight as soon as they are laid, so if there is a reason to believe that the egg in question spent several days in the nest before the female began incubating, then a factor must be added to the above estimate to account for the weight loss during that time. Usually, the eggs of large falcons lose 0.03 to 0.05 g per day prior to the onset of incubation.

These procedures are based on the assumption that an egg is "normal". Poor eggshell quality or uncertainty about length of incubation or brooding will obviously affect the accuracy of this estimate. By checking the rate of weight loss during the first few days of incubation abnormal eggs can be identified and new calculations made. A mathematical method for making such calculations has also been developed (Burnham, 1983).

Determining the Number of Days of Incubation

Proper manipulation of egg weight loss requires knowing not only the fresh egg weight but also the number of days of natural incubation an egg has received prior to being placed in the incubator. Normally the breeder will determine the days of natural incubation by visually observing the breeding birds. The large falcons (peregrines, gyrfalcons, prairie falcons) usually begin incubating with the arrival of the second or third egg. There are exceptions, however, as some females may begin with the first or fourth egg. It is important to know the birds, particularly females, are actually incubating. Most falcons brood their eggs prior to the onset of actual incubation and thus may appear to be incubating when they are not. Since the large falcons lay eggs at 2 to 3 day intervals, there are eggs present in the scrape for several days before incubation starts. The parents are often seen sitting on or standing over the egg(s) at this point, particularly in cold weather. The female will normally spend the night in the scrape to buffer the eggs against freezing. Incubation has begun in earnest, however, when either parent is seen setting comfortably on the eggs with wings tucked neatly and the feathers of the lower back raised somewhat. The eggs, are left unattended for only very short intervals, usually for less than ten minutes. A good time to observe the clutch to determine the arrival of new eggs, etc., is at feeding time, as the female will leave the scrape to receive food from the male prior to his taking a turn on the eggs.

Since we recommend that all eggs receive some natural incubation, the clutch is normally removed seven days after the last egg is laid. This will mean that, for example, if incubation started with the third egg, the first three eggs will have nine to ten days of incubation while the fourth has seven. There are several ways to approach this difference in terms of artificial incubation. If the order of laying is unknown, the experienced breeder will be able to determine through candling which of the four eggs has received the lesser amount of incubation. The eggs can then be manipulated accordingly. If candling is not possible, owing to inexperience or opaque egg shells, the clutch can be treated as a whole with little compromising. In the above example, for instance, one might treat all eggs as having eight days of incubation by averaging the values of seven and nine days. As will be seen below in the discussion of total egg weight loss, eggs that receive some natural incubation hatch in a wide enough range of weight losses that such a compromise is quite satisfactory.

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In the event that there is little or no information on the natural incubation history of an egg, formulas which calculate the amount of incubation have been developed by Burnham (1983). For eggs that are thought to have ten or less days of incubation, the days of incubation can be approximated by:

$$I_d = \frac{W-X}{\dfrac{0.141\,W}{31.5}}$$

where I_d = days of incubation
W = fresh egg weight
X = weight of the egg when removed from the nest.
31.5 = number of days of incubation to pip for peregrines

Eggs that are believed to have received more than ten days of incubation are treated with the formula (Burnham, 1983):

$$I_d = \frac{W-X}{\dfrac{0.147\,W}{31.5}}$$

For example, for an egg that weighs 42.19 g when removed from the scrape after less than ten days of incubation, and has a calculated fresh weight of 43.79 g, the calculation to determine the number of days of incubation would be;

$$I_d = \frac{43.79-42.19}{\dfrac{0.141\,(43.79)}{31.5}}$$

$$= \frac{1.60}{\dfrac{6.17}{31.5}}$$

$$= 8.16$$

It must be realized that the accuracy of these equations is based on the assumption that the eggs were losing weight correctly during incubation. This is not always the case. If an egg is losing too little weight then the formula will indicate that the egg has received fewer days of incubation than it actually has. The reverse is true for eggs that were losing weight excessively.

The technician should use all the above techniques together, checking one result against the other to determine the correct length of incubation. As an example, the visually observed amount of incubation can be checked through candling and calculation. The value of each method should be weighed against the other two. If, for example, one has little or no experience candling eggs, then obviously the visual observations and calculations are to be trusted above any candling results.

Once it has been determined how many days of incubation an egg has received, the technician can move on to the process of manipulating the egg's rate of weight loss in a manner that will maximize hatchability.

Total egg weight loss

It was previously mentioned that, on average, avian eggs lose 18% of their fresh weight by the time they hatch. Peregrine eggs lose about 3% of their total weight in the relatively short period (approximately 50 hours) between pip and hatch (Burnham 1983). This accelerated rate of weight loss results from the opening in the shell created at pip. We attempt to regulate the weight loss of each falcon egg so that it will have lost 15% of its fresh weight at the time of pip. The acceptable weight loss at pip for an egg which has received seven to ten days of natural incubation falls into the range of 12 to 18% (Burnham, 1983).

As previously mentioned, an egg that is placed in the incubator without first receiving seven to ten days of natural incubation has a much reduced hatchability. If there is no possibility of giving the egg(s) any natural incubation, then the breeder should be especially concerned about achieving a weight loss of 15 to 16% to pip. Such eggs frequently fail to hatch at weight losses of 12 to 13% to pip (Burnham 1983).

It is generally wise to regulate the weight loss of all eggs to achieve as close to the optimum 15% weight loss to pip as possible. In that way the breeder helps to insulate the eggs against the effects of undetected variables, such as errors in determining fresh egg weight and number of days of incubation.

Regulating Egg Weight Loss

Once the breeder has determined the fresh egg weight and days of incubation for an egg, the next step is to assess how the egg must be treated to reach the goal of 15% weight loss to pip. An easy way to visualize egg weight loss and humidity requirements is to plot the known information graphically (Campbell and Flood, 1977).

Using Fig. 31 as an example, if the weight of an egg on a particular day falls below the 15% line at point X, then it is losing too much weight. The egg's rate of weight loss is then decreased by increasing the humidity in the incubator. This is accomplished by increasing the surface area of water in the incubator by adding additional pans of water or using a single, larger pan.

If an egg's weight after seven days of natural incubation lies far from the optimum position, similar to point Y on the graph, adjust the incubator humidity so that the egg will **gradually** return to the 15% line by the time it pips. Do not make drastic changes in the humidity level which will cause the egg weight to quickly jump back to the 15% line. Such dramatic changes in incubator environment can be detrimental to the developing embryo.

Eggs do not necessarily lose weight at a constant rate each day. It is important to be aware of factors such as weather, incubator room conditions, incubator temperature variation, and scale error which may affect or at least appear to affect weight loss. Weighing every three days will tend to average out these variables and depict the weight loss more realistically. When the desired rate of weight loss is achieved the time between weighings can be increased to no more than five days.

If the technician has reason to suspect that the rate of weight loss for a particular egg may be difficult to regulate, then daily weighing at the start of incubation may provide clues to whether or not special steps must be taken. For instance, an egg with a pitted shell would very likely lose weight much too rapidly and should be checked frequently so that corrections can be made early enough to be effective.
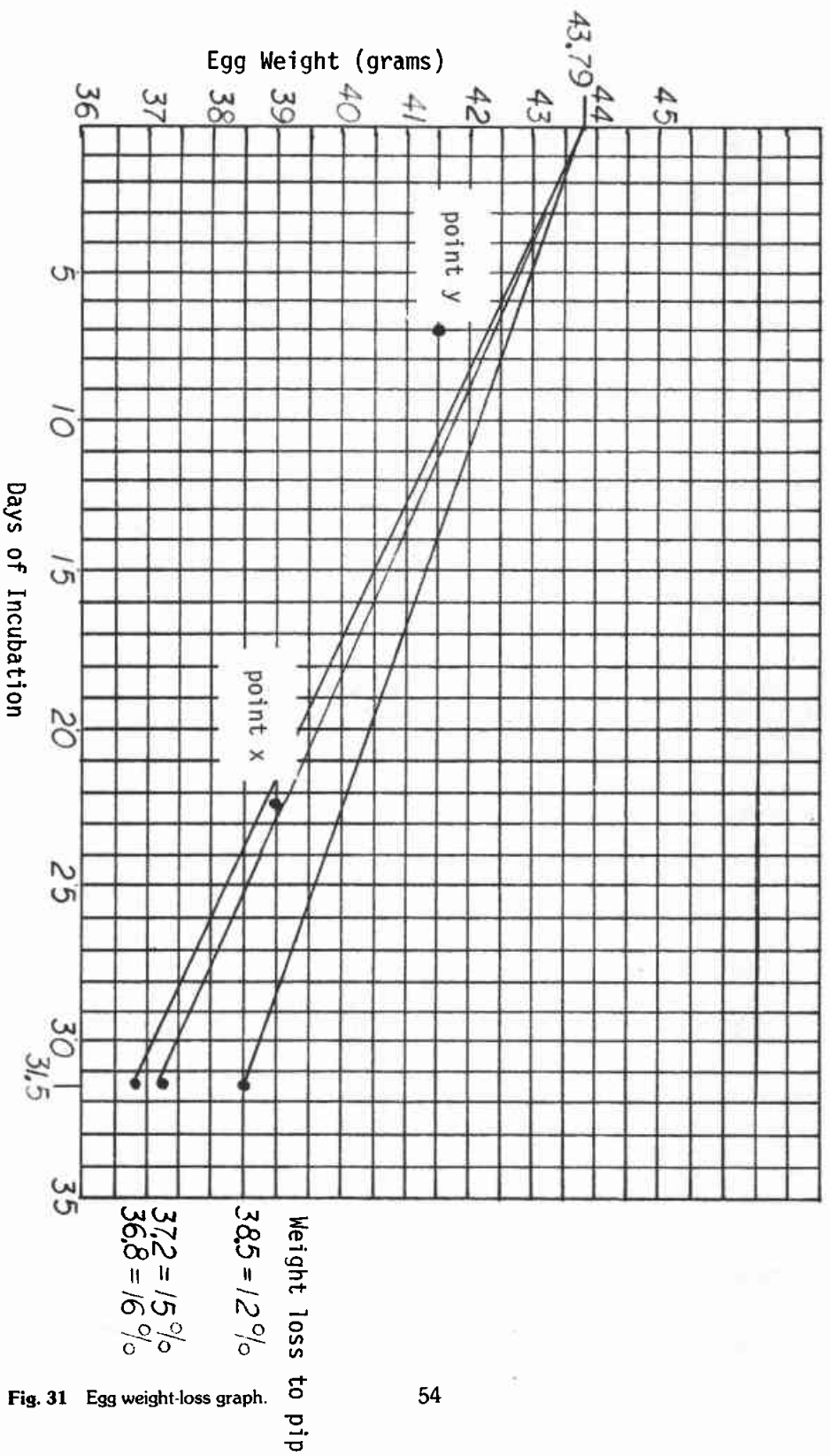
Fig. 31 Egg weight-loss graph. 54

Normally, artificial incubation of eggs is begun at 30% relative humidity with any adjustments made from there, depending on the rate of weight loss. Keep in mind that the important factor is not a particular value of relative humidity, but rather the rate at which an egg is losing weight. Not all eggs are the same, even eggs within the same clutch can be different. Therefore, do not fail to monitor egg weight loss by assuming that a given value for relative humidity is correct for all eggs.

Candling

Candling is a technique which facilitates observation of the inner contents of an egg without opening the shell. Useful not only to determine fertility and the extent of incubation, candling can provide information about the condition of the egg shell and air cell as well as the condition and position of the embryo. The inexperienced technician is encouraged to candle the eggs regularly, normally at each weighing, and relate what is seen to the parameters that are known for a particular egg. Previous experience with chicken or other easily candled eggs will prove beneficial to the novice. Avoid making critical management decisions about an egg based solely on candling until some level of experience is obtained. An egg's status is not always easily determined, especially when highly pigmented. If fertility is in question, continue to incubate the egg as if it were fertile until a positive determination can be made.

Whenever candling, remember that an egg should always be handled in a gentle, slow-moving fashion. Do not expose the egg to the candler light for more than five to ten seconds as the heat from some candlers can harm the embryo. The age at which fertility can be determined by candling varies among different eggs depending upon the amount of pigment and the experience of the observer. Day five is generally the earliest that fertility can be determined in the eggs of large falcons. If the egg is darkly pigmented then fertility may not be evident until day ten.

To candle eggs effectively, the room must be completely darkened. Begin with the egg on its side and slowly move it about over the light source. Identify the air cell and note its condition and shape; for a peregrine egg it should be about the size of a nickel (20mm) at seven days of incubation. Two other characteristics to look for are "half-shading" and "rosiness". The top half of a fertile egg, held horizontally, will appear shaded, hence the term "half-shading". This "shadow" is an early stage of the developing embryo and its accompanying network of capillaries and blood vessels. The "half-shading" should appear reddish or "rosy" colored in the fertile egg. Infertile eggs tend to appear yellowish or clear. Observe carefully, since the reddish pigment of many falcon eggs can make them appear to be "rosy" when, in fact, they are infertile.

By day ten of incubation the fertile egg is starting to undergo additional visible changes. Since the egg is losing weight, the air cell should be noticeably larger than on day seven, being roughly the size of a quarter (25mm). By outlining the air cell on the shell carefully with a soft pencil at each candling, the expansion of the air cell can be monitored. "Half-shading" should be very apparent at this stage, and a small embryo or "eye spot" can be seen. The embryo, which at ten days is about one cm long, usually floats to the top of the egg. If the candler is placed against the air cell end of the horizontal egg, the embryo should be visible along the top midline of the egg.

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By day 15, the developing network of blood vessels is easily seen. The embryo is rather mobile and often reacts to the bright light of the candler by moving in a manner reminiscent of a jellyfish.

During the last several days of incubation, the egg contents, except the air cell, will be opaque, and movement of the embryo may be difficult to see. About day 30 to 31, the air cell expands and extends down one side of the egg. This "draw-down" is easily seen when the egg is candled from the air cell end. Soon after draw-down, the embryo may break the membrane, and its beak will enter the air cell. The embryo may then be expected to pip the shell within a few hours.

Embryos that die during incubation not only cease developing in the way described, but also develop characteristics of their own. The embryos that die during the first 20 days of incubation may develop a "blood ring", which is a reddish ring that forms around the mid-section of the egg. This condition can be easily seen by candling. Dead embryos may continue to float within the egg, but the movement is not the characteristic "swimming" of a live embryo. The air cell in a dead egg may become less defined and sometimes cannot be seen at all.

Remember never to assume an egg is dead or infertile. Occasionally an egg that is thought to be dead or infertile is found to be viable at the next weighing and candling session. Always continue to incubate questionable eggs until their viability can be positively determined. Even experienced technicians will occasionally misinterpret the status of an egg. Incubate all questionable eggs at least to 37 days.

Problem Eggs

The weight loss of some eggs cannot be maintained in the 12 to 18% range by simple addition or removal of water from the incubator. An egg may continue to lose too much weight despite a high humidity level, or fail to lose sufficient weight even when no water is added to the incubator. Problem eggs are normally weighed daily until the rate of weight loss is brought under control.

Eggs that lose too much weight are moved to incubators with higher humidity. As humidity requirements increase, the small water containers can be abandoned in favor of flooding the quadrants in the incubator bottom until the rate of weight loss stabilizes. It may be determined that flooding the entire incubator bottom provides an insufficient humidity level to arrest the weight loss. At that point, one must begin sealing the egg shell with white glue ("Elmers") or paraffin to reduce the rate of water loss (Burnham, 1983). Both of these sealants are non-toxic. Glue is preferred over paraffin if automatic egg turners are used, as the paraffin softens at incubation temperatures, causing the egg to stick to the turning grids. Glue adds less to the total egg weight than does the heavier paraffin; always remember to allow for this weight change. Sealant is initially applied to a portion of the shell over the air cell. Begin by sealing only small sections. Once sealant is applied it is difficult to remove. Base the decision of how much area to seal on the severity of the weight loss. Weigh the egg daily to check the effectiveness of the previous treatment. It may take several treatments to bring the weight loss under control. Sealing over 50% of the air cell may cause the embryo to invert within the egg, placing its head in the small end of the egg rather than the large end (Landauer, 1967). If 50% of the air cell is sealed and the problem still exists, continue by sealing other portions of the egg. Eggs rarely require that severe a treatment and those that do have poor hatchability.

Eggs that lose insufficient weight despite the absence of water in the incubator are more difficult to manipulate. A technique for reducing the humidity in a dry incubator is to put a layer of desiccant such as silica gel in the bottom (Fig. 26). Silica gell is a crystalline subtance which will absorb moisture when exposed to air. Blue indicator silica gel turns pink when it is saturated with water and no longer effective. After saturation, the gel is removed and oven dried at 350 F (176 C) until it returns to its original color. When the gel is dry, remove it from the oven and immediately place it in an airtight, heat resistant storage container (the original container is satisfactory). Allow the gel to cool to room temperature before returning it to the incubator. Distribute the gel evenly over the bottom of the incubator, and be careful that it does not reach a depth that will cause interference with the automatic turning grids. Do not open the incubator unnecessarily as this will reduce the effectiveness of the gel.

L. Boyd has experimented with a technique used for waterfowl eggs (Mayhew, 1955). The technique involved spraying the large end of the egg with sterile distilled water at each turning. Some eggs on which this process was used lost weight at a greater rate. While we feel that this technique shows some promise we are not familiar enough with it to make further comment at this time.

The final method for increasing the rate of weight loss of an egg is drastic and should only be used as a last resort. It involves gently sanding and thus thinning the shell over the air cell portion of the egg to increase the rate of weight loss (Burnham, 1983). The air cell is sanded by hand with emory cloth or some other suitable sandpaper using **slow, even, gentle** strokes. Remember, the embryo and its associated blood vessels within the egg are very delicate and therefore subject to injury if the egg is handled roughly. As the shell is thinned it becomes weaker and therefore is more easily cracked. It is sometimes advisable to discontinue using the automatic turners and turn the sanded eggs by hand. Sand a little bit at a time, then weigh the egg after 24 hours to assess the effect and repeat the process as necessary. If the egg is continually sanded, the shell will begin to flex at some places. At those places the shell is nearly gone and one is approaching the inner membrane. If this membrane is broken the embryo will die. The more an egg is sanded, the less likely it is to survive. Sanding is therefore a trade off; on the one hand the weight loss will increase, but on the other hand the overall survivorship is reduced. To repeat then, sand an egg only as a very last resort after a careful analysis of all the factors. It is interesting to note that falcons can hatch many of these eggs quite normally, reaffirming our suspicion that we really are not as clever as we think. If the opportunity exists, we return eggs with this problem to an incubating adult as soon as possible.

The Hatcher

The hatcher is a modified incubator used to incubate the eggs during the interval from pip to hatch. We hatch eggs in a "Roll-X" incubator modified as previously described for incubation, except that no turning grid is used since eggs do not need to be turned at this stage. The turning grid is removed, and the two grids are separated. The top grid is discarded, and the bottom plastic-coated grid is returned to the incubator. A piece of one-quarter inch (6.4mm) hardware cloth cut to fit snugly inside the bottom of the incubator is placed atop the plastic coated grid. A piece of surgical gauze or crinolin hatching material is placed on the hardware cloth, and pipped eggs are placed on this material. A retaining ring made of plexiglas, aluminum, or hardware cloth is then placed around the eggs so that a hatched chick cannot crawl off the hatching material and become entangled at the edges of the grid.

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Hatching

The "pip" is the first stage in the actual hatching process and is defined here as the first crack in the shell made by the embryo. Approximately 24 to 48 hours before the egg pips, candling reveals that the air cell expands and gradually starts to extend down one side of the egg. This change in the air cell is called "draw-down". When draw-down begins, it is no longer necessary to turn the egg. Orient the egg on its side with the elongating air cell uppermost. Normally the pip, when it occurs, it will be located in the air cell. It is not unusual for the embryo to vocalize before pipping.

Usually, the pip is very easy to see and appears as a small uplifted portion of shell. Occasionally, however, little or no lifting is visible, though candling will reveal a crack that can be felt if one's finger is gently passed over it. After the egg has pipped, it is moved from the incubator to the hatcher unless additional weight loss is desired (Burnham, 1983).

The hatcher is normally operated at a relative humidity of 55 to 60%. This is accomplished by flooding one quadrant in the hatcher bottom. We use a hatcher temperature of about 1 F (0.55 C) below incubator temperature. At this hatcher temperature, the pip to hatch interval averages 50 hours (24 to 72 hours). Recently, it has been found that in hatchers maintained at the incubator temperature the pip to hatch interval is reduced with no loss of hatchability or chick vitality. In fact, it appears that in some cases vitality may be improved.

The pip to hatch interval is usually an uneventful time, even though the egg does undergo some noticeable changes. It is a time for the breeder to be patient and resist the temptation to "do something" unless absolutely necessary. One of the first visible changes is an enlargement of the pip, called "break-up", in which the embryo breaks the shell a number of times in the area of the pip. If the egg is gently placed against one's ear, intermittent "clicking" sounds can be heard. As the hatch progresses, the embryo will start "lifting" fragments of the shell in the break-up area. Chirping vocalizations can now be heard more frequently. If two or more eggs are in the hatcher at the same time, place them so their large ends contact each other. The embryos can then hear each others' clicks and vocalizations. This may serve to synchronize their hatching somewhat. Avoid unnecessary opening of the hatcher during the pip to hatch interval as this may cause excessive drying of the membranes. Just prior to hatching, the embryo may create a "hole" in the break-up area as shell fragments are pushed out and hinge on a flap of membrane, or fall away altogether. The embryo starts to hatch by turning within the shell and simultaneously breaking a line around the circumference of the large end of the egg by outwardly thrusting the upper mandible and egg tooth. When viewed from the large end of the egg, the embryo turns in a counter-clockwise direction. Typically this is a stop and go process. The embryo will turn and break a portion of the shell, accompanied by much vocalization, then fall quiet for a rest before resuming. The embryo will normally attempt to push off the egg cap before completing a full revolution. This last stage of the hatch should take from 15 minutes to 1 hour (Burnham, 1983). Once the chick has emerged (Fig. 32), the navel is swabbed with mild antibiotic ointment or 1% iodine. **Caution:** Some antibiotic ointments may be fatal to chicks. We recommend ointments containing Bacitracin alone or in combination with Neomycin and Polymyxin B; these are available at any drug store. If the chick is to be immediately placed on corn-cob litter in a K-pad brooder (Burnham, 1983), use the iodine as the litter will stick to the chick if ointment is applied.

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Fig. 32 Newly hatched peregrine falcon.

The newly hatched chick is wet with its down matted. Remove any remaining mucous or membrane with a cotton swab. Prominent features of the normal, newly hatched chick include the matted down, large bulging eyes, and a prominent *musculus complexis* or "hatching muscle". The hatching muscle appears as an elongated bulge, similar in appearance to a water blister, running down the back of the neck. This muscle is specialized for the hatching process and disappears by the time the chick is a day or two old.

Problem Hatching

Although most eggs hatch without assistance, there are occasions when some problems develop which might result in the death of the embryo if it were not helped. Nearly all hatching problems are incubation-related. Problems resulting from too much weight loss, too little weight loss, an unretracted yolk sac or dried membranes around the pip need not always be fatal.

The unhatched embryo is surrounded by the chorioallantois. These membranes serve as the respiratory organ of the embryo and function by diffusive gas exchange. During the period between pip and hatch the significance of this membrane system decreases as the lungs gradually assume the role of breathing. As the lungs function at increasingly greater capacity, the blood flow to these membranes is gradually reduced until, at hatching, it ceases. When blood has ceased to flow through these blood vessels, they are said to be "shut down". At this point, the chick can safely break the membranes and shell to hatch without risk of severing an active blood vessel and bleeding to death.

Deciding when to help the embryo is difficult, but becomes easier with experience. Improper action can be severely debilitating or fatal to the embryo. An easy situation to recognize is when an embryo stops for an extended period after turning one-quarter to one-half the way around, or when it turns a bit then reverses direction and returns to the pip site. In either situation the chick may be too wet and/or may have an unretracted yolk sac. After an embryo has made one quarter of a turn it is **fairly safe** to remove it from the shell. Using forceps, carefully remove small chips of the air cell portion of the shell. Remove enough so the embryo can be easily rolled out of the remainder of the shell. If the embryo is too wet and no unretracted yolk sac exists there is no particular danger. The tissues simply contain too much water resulting in an embryo that occupies so much space within the egg that normal movement is restricted.

Extreme care is in order if the yolk sac is completely or partially unretracted (Fig. 33). Remove the chick from the shell very slowly. The membranes which form the yolk sac are supplied by a major blood vessel, so care must be taken to avoid rupture as that will cause bleeding and death. The yolk sac is attached to the intestine in two places; one is for support while the other is a pathway for the blood vessels. Yolk sacs which are completely unretracted must be reduced for surgical reinsertion or removed entirely (Figs. 34 & 35). This operation can best be accomplished by two people, one to hold the struggling chick and one to perform the surgery. Use a gut suture to tie off the blood vessel connection to the intestine. Tie the knot tightly enough to stop the blood flow, but not so tight as to cut the membranes. Trim away the extra suture. Using sterlized surgical scissors, cut the blood vessel connection between the yolk sac and the knot. If the knot was tied correctly, there should be no bleeding. Also cut the other supporting connection. If a loop of intestine is also outside the body it must be
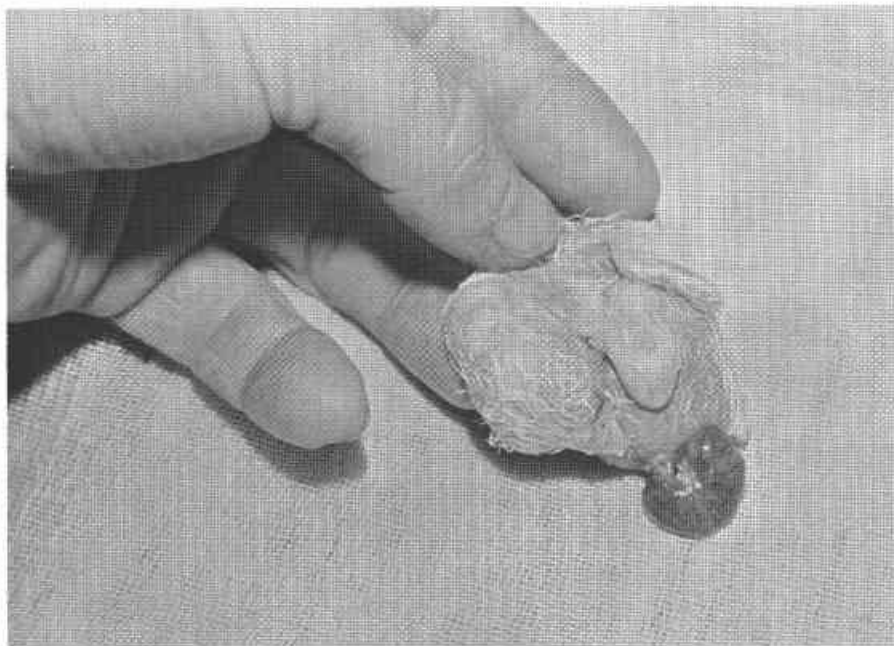
Fig. 33 Peregrine chick with unretracted yolk sac.

reinserted. With a swab dipped in antibiotic ointment, attempt to probe the intestine gently back into the body through the navel. Usually, the opening has closed too much to accomplish this. In that case, carefully insert the scissors into the umbilical opening and cut the ridge of tissue forming the navel and the skin a few millimeters toward the head (Fig. 36). Cut on the midline to minimize bleeding. Use care to cut the skin only and not the intestines within the body. Once an opening of sufficient size is created, probe the intestines into the body cavity and close the incision with a few sutures (do not use cutting edge needles). It will be necessary to hold the intestines in the body with a swab until the sutures are started, since the chick's struggles will tend to expel them. It goes without saying that it is necessary to use sterilized equipment throughout this procedure.

After the incision is closed, give the chick a subcutaneous injection of sterile, lactated Ringer's solution. These injections help supply the chick with fluid lost by removal of the yolk sac. Use a tuberculin (lcc) syringe and a 25 or 27 gauge needle. Use only new, sterile needles and syringes and swab the membrane on the Ringer's container with alcohol before inserting the needle. After filling the syringe, hold it with the needle up, and tap the sides to cause any air to rise. Remove the air by depressing the plunger. Hold the chick on its back and gently extend one leg out to the side. Notice the loose skin in the fold of the leg (the inguinal web) (Fig. 37). Carefully insert the needle just under the skin and inject one half cc to create a "water blister" in the fold of the leg. Repeat with the other one half cc in the other leg fold. Each "blister"will disappear within a few hours as the chick absorbs the fluids. Repeat the injections when the "blisters" are no longer visible. During subsequent injections some fluid may escape from holes

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Fig. 34 Procedure for complete yolk sac removal. Dan Konkel, 1983.
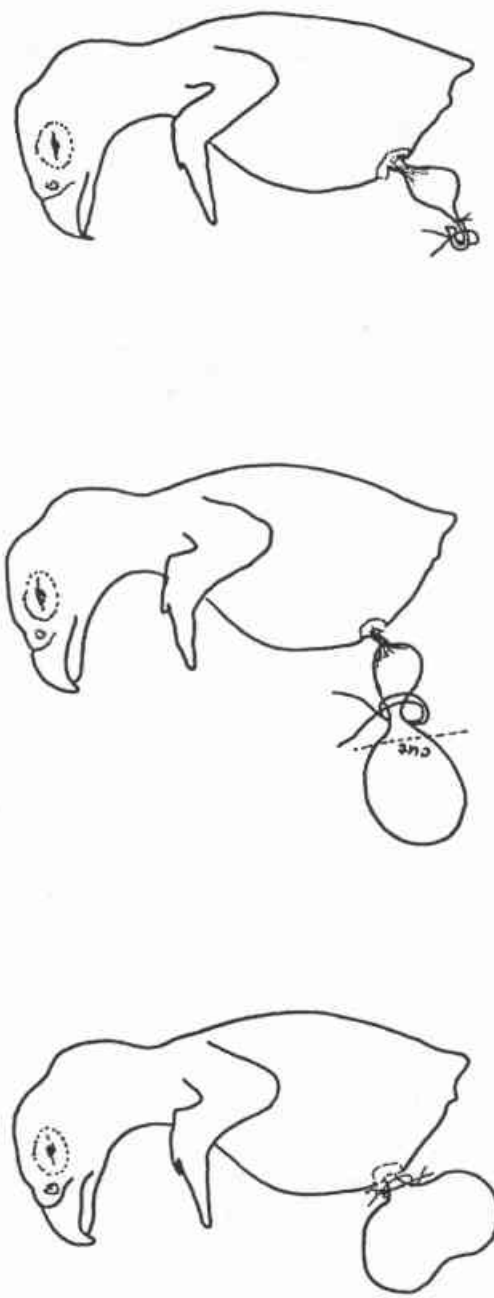
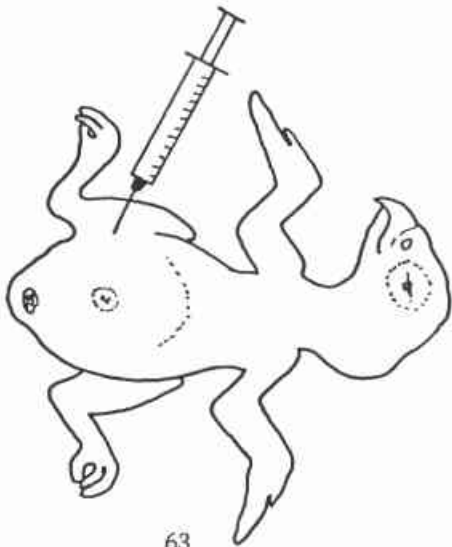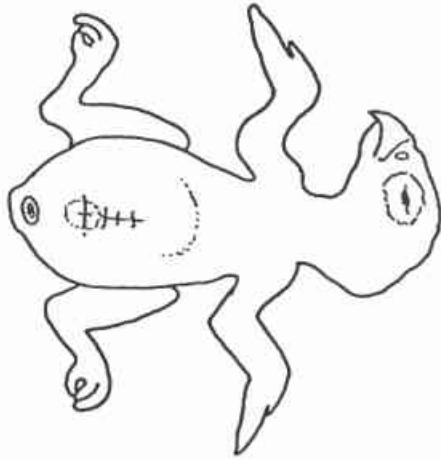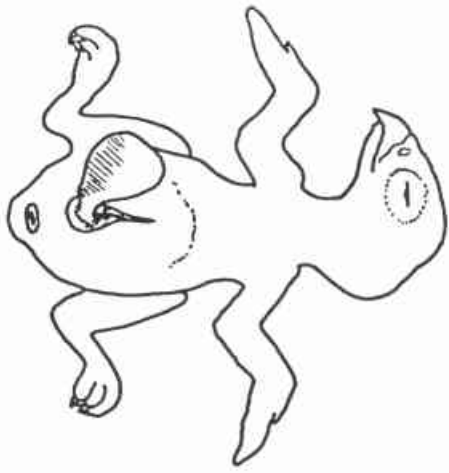Fig. 35 Technique for the reduction of the size of the yolk sac. Dan Konkel, 1983.

Fig. 36 Incision and closure for abdominal surgery. Dan Konkel, 1983.

Fig. 37 Location of the inguinal web. Primary site for injection of supplemental fluids. Dan Konkel, 1983.

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created by prior injections, though enough will be retained to serve the purpose. The technician will find it helpful to practice beforehand on day old chickens or quail. Discontinue the injections when the chick has regained its expected vigor and is eating normally. The survival rate of chicks with completely unretracted yolk sacs is low. The remedial procedures are obviously very traumatic and the loss of the yolk is seriously debilitating. Enough survive and mature, however, to make the effort worthwhile.

Yolk sacs that are only partially unretracted may be massaged into the body cavity if the unretracted portion is small enough. Lubricate the first two fingers and thumb of one hand with antibotic ointment. Gently surround the bud of yolk sac with the three fingers and compress it into the body. Once it is in, gently massage the navel with a lubricated cotton swab as this often stimulates the tissues to close. In cases where the yolk sac will not stay in place, it may be necessary to close the navel opening with one suture.

Partial unretractions that are too large to massage into the body must be tied-off and removed. Encircle the yolk sac with a loop of suture a few millimeters from the body cavity. Tighten the suture as before, taking care not to tie it so tight as to cut through the membrane. After tying, cut off that portion of the yolk sac that lies away from the knot with surgical scissors. If the remaining "stump" can be probed into the navel, then do so. If not, it will soon dry up and eventually fall off as the chick matures. The survival rate of chicks with partial unretractions is much higher than for chicks with total unretractions. One may decide to inject these chicks with lactated Ringer's a few times depending on the amount of yolk removed and their general vigor.

Embryos that do not begin their turn on their own and that need help hatching must be carefully monitored so that they are not "helped" until all the blood vessels are shut down. As a rule of thumb, pipped eggs are left to hatch undisturbed for up to 60 hours. After that point, the technician must assess the situation and decide whether or not to help the embryo to hatch. Criteria to consider include; progression of the "breakup", "lifting", and "hole" stages (described in the hatching section), the weight loss of the egg (wet or dry eggs may need help hatching depending on the severity of their condition), and disposition of the embryo as determined by its vocalizations. The experienced technician will be able to tell when an embryo is irritated or excited and when it is beginning to weaken by the sound of its vocalizations. Occasionally these criteria will indicate the need for help somewhat before the 60 hour mark.

Once it is decided that help may be necessary, carefully remove some of the shell fragments around the pip using a pair of blunt forceps. Great care must be taken not to tear the chorioallantois until all the blood vessels are shut down. Chip away in the direction of the air cell in order to keep away from the membrane. Go slowly and peer into the egg with a penlight to look for active blood vessels. In particular, look for the large vitelline vein which runs across the ventral surface of the chick. This is a major blood vessel and is easily spotted. Functioning blood vessels will appear bright red and full of blood. If the vessels are functioning, cover the hole in the shell with scotch tape to prevent the membranes from drying out, but retain a small opening so the chick can breath. Keep the beak up and in sight. Return the egg to the hatcher and wait. The egg may still hatch on its own. Check the egg frequently as the tape may interfere if natural hatching is to occur. It is safest to assume at this stage that the egg will have to be hatched by hand, so check the blood vessels often to determine

whether they are functional. Blood flow can be checked by pressing on a vessel with blunt forceps. If, when the forceps are removed, the vessel immediately refills, then obviously it is still functional. Occasionally as the shell is removed, the membranes will appear to be chalky white and no blood vessels will be visible. Carefully moisten the membranes with a swab dipped in distilled water or liquified antibiotic ointment. This treatment will make the membranes transluscent and the vessels will be visible. When the vessels finally shut down, they will be fairly transparent, with scattered places where some blood remains. At this point one can safely hatch the chick.

Most of the problems discussed thus far relate to eggs that are too wet. However, excessive weight loss can occasionally be a problem as well. An unusually large air cell at pip may be a clue that the embryo may have trouble hatching. The lack of moisture in the membranes, mucous, and fecal deposits in these eggs may cause them to be "gummy", possibly preventing the embryo from turning. Dehydrated chicks may lack muscle tone and be generally weak. These chicks will benefit greatly from subcutaneous injections of lactated Ringer's after hatching.

Another problem associated with dryness involves the shell membrane in the area of the pip. Occasionally, these membranes will dry out and stick to the beak, eyes or down of the embryo and prevent it from turning in the egg. The vocalizations of an embryo that is ready to hatch but is stuck will sound very irritated and distressed. This problem is not entirely related to total weight loss, but depends also on hatcher humidity and length of the pip to hatch interval, as well as the size of the opening in the shell. These factors determine how much dry air the membranes will be exposed to and, therefore, the degree of drying that will occur.

The most important factor to consider when assisting an embryo to hatch is determining whether and when that help is necessary. The above discussion has attempted to provide clues for the observant technician to use in this determination. The most important tool, and one that cannot be explained in writing, is the "feel" or "intuition" one develops after experiencing a large number of hatches. Those involved will find it easier over time to integrate the progression of events during pip, the vocalizations, and the weight loss into an awareness of each egg's particular situation. An egg should never be tampered with unnecessarily, but, on the other hand, be alert for signs of trouble and act when conditions indicate the need. Watch carefully for the pip and do nothing for 60 hours unless there is an obvious problem.

Brooding

We use two basic brooding systems at our facilities. These are the "still air" brooder and the "K-Pad" brooder (Burnham, 1983). Both systems work well, and the decision as to which to use hinges primarily on personal preference. The still air brooder is rather large and bulky, and requires some carpentry and electrical skills to assemble while the K-Pad components can be purchased intact. The still air brooder is less expensive unless the labor costs for assembly are included, in which case the two systems are comparably priced.

Still Air Brooder

The still air brooder (Fig. 38) is basically a box 24 x 28 x 11½ inches (61 x 71 x 29cm). Redwood is the preferable material as it will stand up to repeated washing. The front is the door which is held closed by magnetic cabinet latches and hinges to open downward. The top is one half inch plywood. A 12 x 16 inch (30x40cm) double strength glass window is installed in the top for clear and easy observation of the interior. Two round soffit vents are installed near the top on each side to ensure adequate ventilation. The heater is a 500 watt unit and is mounted on the inside back wall. The 500 watt capacity assures rapid recovery after the door is opened and heat is lost. As was the case with the incubators, safety demands a double thermostat system. The lights on the heating unit are rewired so that one serves as an indicator light, lighting when the heat is on, and the other can be controlled by a push-on-push-off switch at the brooder front for use as an observation light. A galvanized metal tray, made by any local sheetmetal shop, slides in and out on the floor of the brooder for easy access to the fledglings. Small blocks attached on the inner sides near the front prevent the tray from tipping when pulled out.

The chicks are contained in nine inch (23cm), straight sided aluminum cake pans which are nearly filled with corn cob litter. Surrounding the pan is a ten inch (25cm) diameter ring of aluminum flashing five inches (12cm) high (Fig. 38). This ring is elevated slightly above the underlying newspaper with large paper clips. In this way the chicks are contained in the pans, and when they defecate their feces hit the flashing ring and slide down onto the newspaper. This system not only keeps the chicks and their bedding very clean, but it is also easy to substitute clean rings, newspaper, etc., in order to maintain a high degree of cleanliness.

Each brooder will safely hold two of these pan/flashing assemblies. Up to four newly hatched chicks can be held in each pan, but as they reach two to three days of age the groups should be reduced to two per pan. For the first few days, the chicks are placed on a paper towel which is put on top of the corn cob litter. In this way the feces can be examined before each feeding, at which time the towel is replaced.

Be sure that the thermometer used to monitor temperature is placed at a level near the chicks (Fig. 38), since in a still air brooder the temperature will stratify; it will be hotter at the top and cooler at the bottom. There is also a slight gradient of increasing temperature from front to back in these brooders. We have found that the small alcohol thermometers that come with the "Roll-X" incubator are adequate for this application. A piece of soft cloth may be used to cover the chicks or provide a softer substrate for them to lie on, depending on their needs for comfort. Finally, a tray of water is placed in the brooder between the flashing rings and the heating unit to provide some extra humidity.
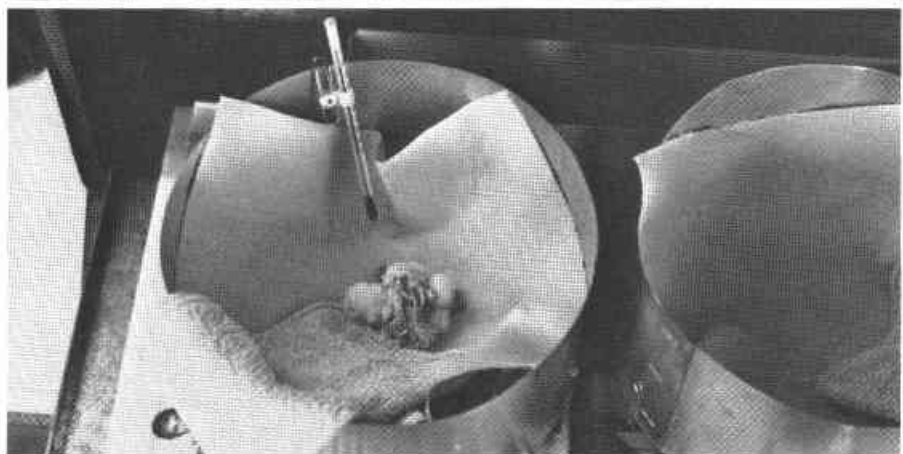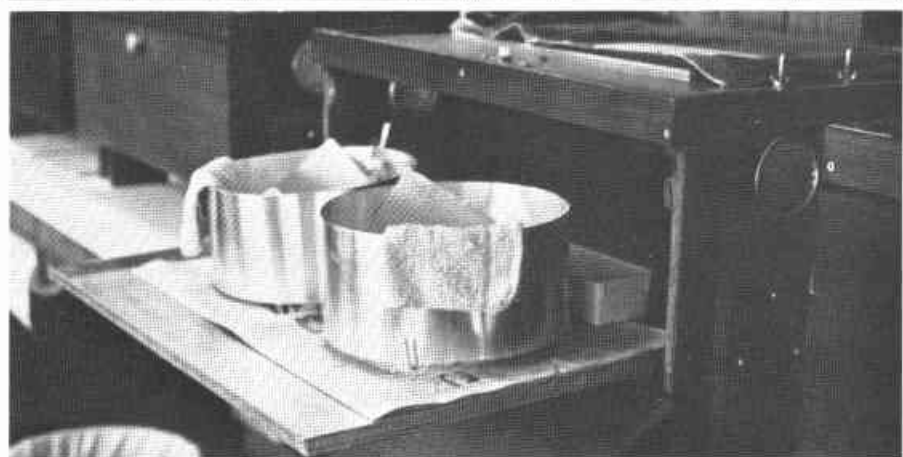
Fig. 38 Still air brooders.

Still Air Brooding Technique

After hatching, the chick is usually left in the hatcher for a short time until it dries. Even when dry, the down will remain mostly matted until the chick rubs against its brooder mates or the cloth in the brooder pan. Naturally, the down of a parent-hatched chick is soon fluffed by contact with the female's breast feathers. When dry, the chick is placed in a brooder set at 97 F (36 C). Adjust the secondary thermostat to shut off just after the primary one.

The general rule of thumb about brooding is to reduce the brooder temperature by 1 F (0.55 C) per day until the chicks can be moved from the brooder to room temperature. More important than absolute temperature, however, is the comfort of the chick(s). A comfortable chick will lie quietly sleeping with its wings loosely folded at its sides and its legs and feet tucked under its body. Occasionally, the sleeping chick will flutter its wings as if "flying in its sleep". Two or more chicks will sleep quietly touching each other, frequently in a "heap", one draped over the other in a loose bunch. A hot chick will lie with its wings stretched out and one or both legs extended to the rear. Frequently, it will complain vocally. In the extreme case, it will be seen panting. As a group, hot chicks will be noticably apart from each other. A cold chick may move around the pan with its neck arched trying to locate its mother's breast while protesting to a great degree. Two or more cold chicks will huddle together or move around the pan, complaining and in neck-arched postures. Chicks will frequently exhibit all the signs of being cold immediately after feeding. After about 15 minutes, however, they usually settle down in a comfortable position if they were comfortable before feeding.

It is advantageous to brood the chicks as cool as their comfort behavior allows as cool temperature seems to improve the condition of their down and general health. Larger or exceptionally vigorous chicks can frequently be brooded comfortably at temperatures cooler than might be expected. In virtually every case, normal, healthy chicks can be brooded cooler and are more easily made comfortable when housed with nest mates that are the same or nearly the same age (within two to three days), as opposed to housing each one alone in its own brooder pan.

As is the case for the incubators, the still air brooder should be washed with disinfectant and fumigated at regular intervals. Discard used corn cob litter and newspaper and disinfect all flashing rings, trays, etc. As with incubators, proper hygiene is important in the still air brooder, for the warm, closed environment it creates is favorable to bacterial and fungal growth.

K-pad Brooding System

The K-pad brooding system differs in principle from the still air technique in that the chick can, within limits, act upon its need for brooding by approaching or avoiding a stationary heat source. The still air brooder, as already mentioned, regulates the temperature of the chicks' entire environment. The K-pad apparatus consists of a pad through which is sent a constant flow of water. A control module regulates the water temperature and circulates it through the pad.

The system is assembled by laying the pad over a row of small jars forming a ridge in the middle of a large tub. Corn cob litter is then poured into the tub so just the elevated portion of the pad extends above the surface (Fig. 39). Fold a large towel double so that it will fit in the tub, covering the litter and pad. Adjust the control module thermostat to its highest setting of 105 F (41 C) and allow several hours for the system to equilibrate. The K-pad will not reach 105 F, however, as some heat is lost as the water is circulated from the module to the pad. The temperature actually will be about 100 F (38 C). The room temperature should be maintained at about 70 to 75 F (21 to 24 C).
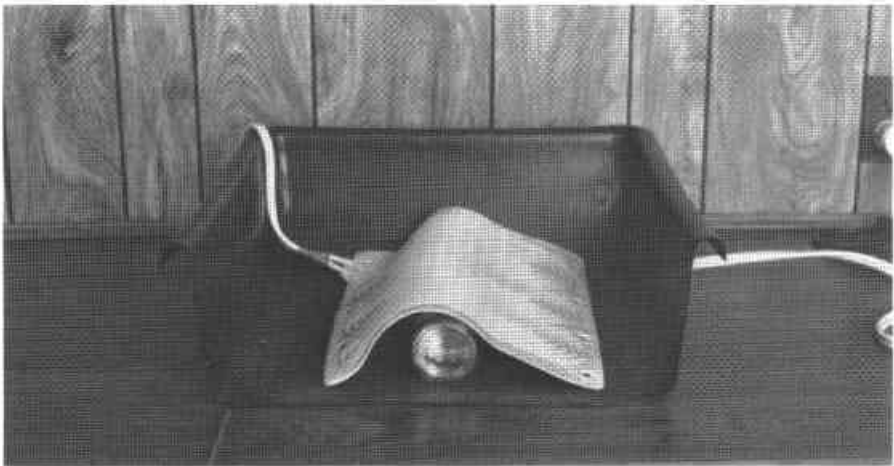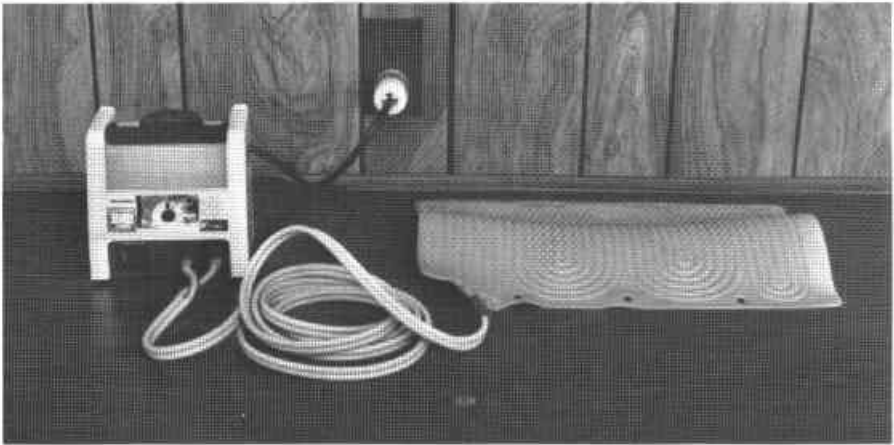

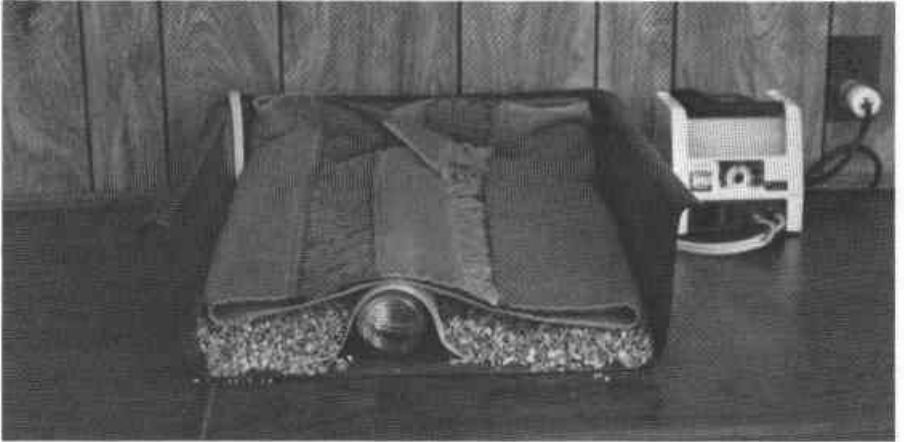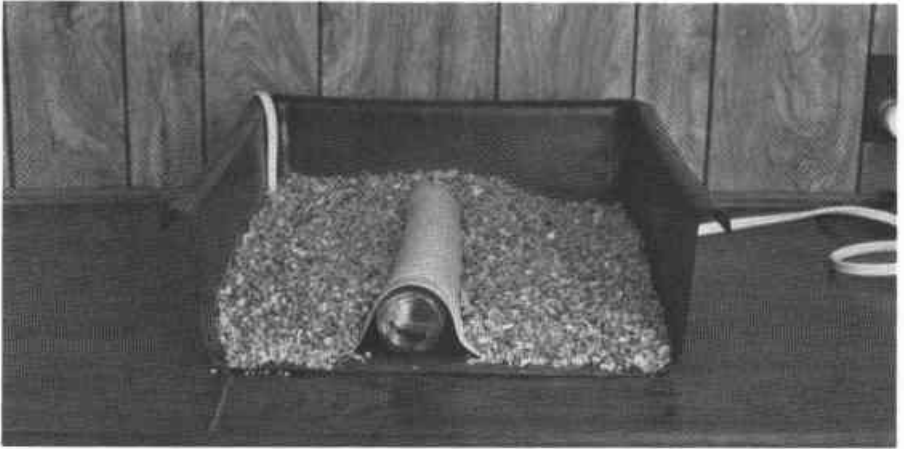**Fig. 39** K-pad brooding system. (Cut away view)

Fig. 39 K-pad brooding system. (Cut away view)

K-pad Brooding Technique

After the chick has hatched and its navel has been swabbed with 1% iodine solution, it should be placed head first against the K-pad on a four inch square piece of gauze. The gauze prevents the litter from sticking to the chick until it dries. The towel, folded as previously described, is placed directly on top of the chick. Brood the chick in this manner for about the first three days. The chick, if comfortable, will keep its head toward the K-pad and otherwise appear to be comfortable as described in the section on still air brooding technique.

By the third day, the chick will usually lie with its head turned away from the K-pad. This indicates the chick is beginning to feel too warm and is therefore retreating from the heat. Reduce the temperature by unfolding the towel so that only a single layer lies on the chick. This allows more heat to escape than is possible when it is folded double. If the chick continues to face away from the K-Pad, (about day four) drape the towel over the tub so that it is several inches above the chick. When the chick is about five days old, it will begin spending most of its time away from the K-Pad, even with the towel raised several inches. Reduce the module thermostat setting at that point to about 97 F (36 C). Remove the towel and surround the chick and K-Pad with a six inch (15cm) high ring of plexiglas or aluminum flashing. This ring will prevent the chick from voiding feces onto adjacent surfaces. The towel can be draped over the ring as needed to modify the temperature. As the chicks age, the temperature should be reduced daily to create a situation in which the chicks look and act comfortable. Reduce the temperature by lowering the module thermostat setting or repositioning the towel, or some combination thereof. It is advantageous to maintain the temperature so that the chicks are not only comfortable but also orient themselves primarily toward the K-Pad. In this way they are less likely to defecate on the K-Pad and each other.

When the chicks have reached eight days of age, it is usually only necessary to operate the module during the night and then at a thermostat setting of approximately 80 F (27 C). Supplemental heat should no longer be necessary by about day ten if the chicks are housed in a room that gets no cooler than 70 F (21 C).

The K-Pad should be removed from the K-module and washed and disinfected every second or third day. The corn cob litter should be changed as well at that time to prevent an accumulation of feces. Wash the plexiglas ring daily, as feces build up quickly on its lower edge and finally, wash and replace the towels as needed.

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Post-brooding Housing

By the time the chicks of large falcons are seven to ten days old, they should be developed enough to be removed from the brooder and housed at a room temperature of 75 F (24 C). A larger scale version of the pan/flashing ring arrangement is used to house these older chicks (Fig. 40). Plastic pans 12 inches (30cm) in diameter are nearly filled with corn cob bedding and a flashing ring 13 inches (33cm) in diameter and ten inches (25cm) high is placed around the pan. As before, the ring is supported above the underlying newspaper by paper clips. A hand towel can be draped over the flashing at times when the chicks are too cool. A soft cloth can again be used directly in the pan to cover the chicks or provide something to lie on. Normally, no more than two chicks are housed per pan.

This has proven to be a safe, efficient, and easily maintained way of housing the chicks for the period immediately after brooding. By the time the chicks outgrow this pan, some arrangements should have been made for placing them with parents prior to release, raising them for breeding, or beginning their training as "imprints" or for falconry. Youngsters to be returned to parents should be moved at or before 14 days of age to avoid problems with aggressive parent-offspring interactions.

Food Preparation

It is very important to feed young raptors the highest quality diet possible. Young chicks grow very rapidly; therefore, nutritional deficiencies can arise quickly if diet quality is not maintained. We highly recommend using freshly killed, mature, coturnix quail (*Coturnix coturnix*) to feed growing raptors, at least until the age of ten days. Coturnix quail are highly domesticated and, therefore, are fairly easy to raise in large numbers in the proper facilities. There are many pamphlets, manuals, and books available in the avicultural marketplace describing the proper husbandry of coturnix quail. In the past we have used other diets, consisting of fresh-killed chicken, or previously frozen chicken and quail, and in every case have experienced poor growth or other problems affecting the health of the **young** chicks. Chicks **older** than **ten days** can be successfully raised on other diets if the availability of quail is limited. One such diet consists of 50% **whole**, ground, six-week-old chickens (only the large feathers are excluded) and 50% lean, ground horsemeat with a vitamin/mineral supplement.

Naturally, the quail used for feeding young raptors should be healthy. When selecting individuals for butchering, discard any that are excessively thin, appear drowsy, or otherwise are not in the best of condition. Kill the quail by severing the spinal cord, gassing them with CO_2, or some other means that will not affect the food quality of the carcass. Skin the carcasses and remove the head, neck, crop, wings, feet, tail, and digestive tract. All other organs should remain. After the carcasses are prepared, grind them thoroughly in a meat grinder. Hand operated grinders are available, but electric grinders do a better job and make an unpleasant daily chore much easier, especially as the number of quail needed daily increases. Immediately after grinding, package the meat in plastic bags, covered dishes, or other sealed containers, and refrigerate.
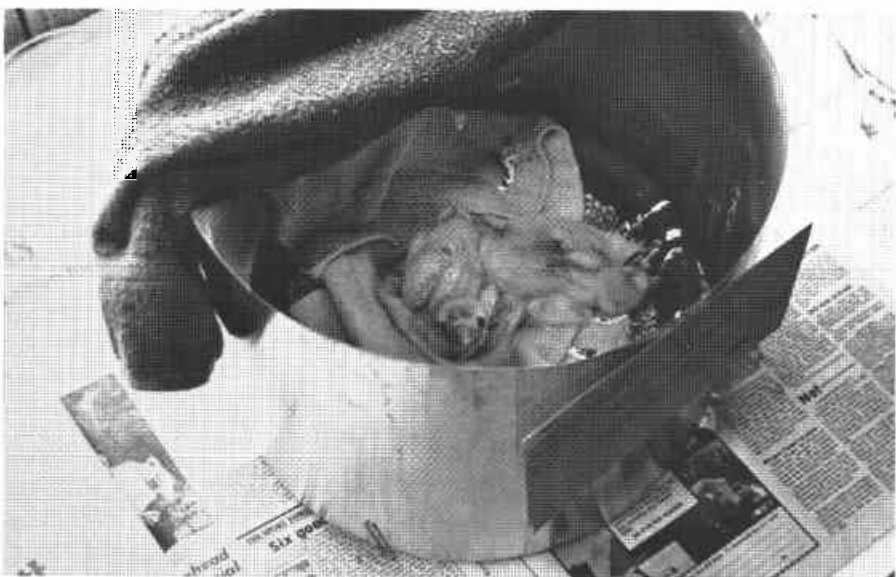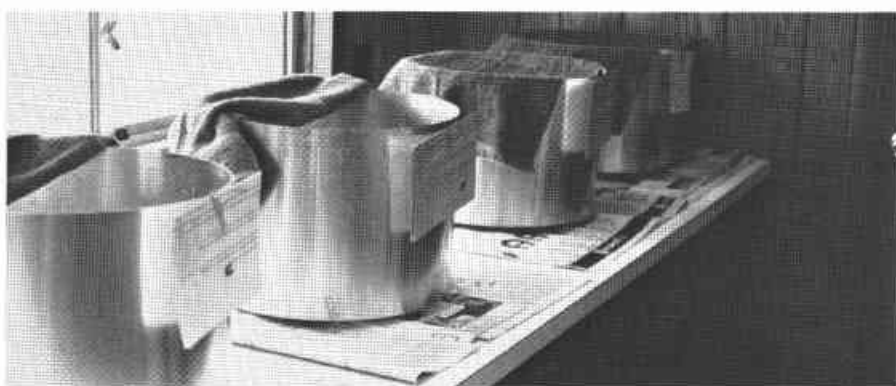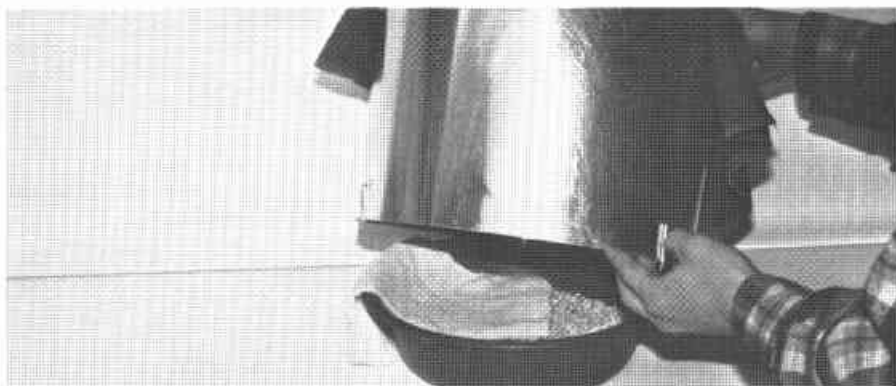
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Fig. 40 Post-brooding housing.

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When feeding time arrives, remove only the amount of food necessary for that meal. Warm the meat to room temperature in a covered dish (petri dishes work well) for 15 to 30 minutes, or place the meat in a plastic bag and dip in warm water briefly. Be careful, in this case, that the water is not so warm that it starts to discolor the meat. There is some debate whether any meat left over after feeding should be re-refrigerated. Some breeders maintain that unused portions should be discarded as a precaution against dangerous bacterial growth. On the other hand, others suggest that extra meat can be re-refrigerated safely one time. Fresh ground quail should be prepared daily; grind only the amount needed for the next 24 hours. This ensures overall freshness, as the meat will not spoil in 24 hours if refrigerated properly.

Supplemental vitamins can be added to the ground quail if desired. There is no evidence that they are necessary if the quail are prepared as previously described, however, there is also no evidence that they do any harm if administered properly. If the breeder must use some other diet, however, particularly one that is not a "whole body diet", then vitamin and mineral supplements may be desirable or necessary. A "whole body diet" in this case, means that the ground meat consists of not only muscle, but organs and bone as well. Whatever vitamin supplement is used, be sure that it contains vitamin D_3 and not D_2. Birds can only use D_3. Calcium supplementation is probably best accomplished by using bone meal which will contain the proper ratio of calcium to phosphorous.

Feeding

The young falcons are fed using a pair of blunt forceps or hemostats. Just prior to feeding, wet the ground meat with Ringer's solution (not lactated) or 0.9% saline. Both solutions should be available from veterinarians or veterinary supply houses. The 0.9% saline can be easily made at home by mixing nine grams of laboratory grade sodium chloride (NaCl) in one liter of distilled water. Store the solutions in a cool, dark place until needed. Sufficient fluids are vital to the young chicks to ensure proper digestion, so be sure each bite of food has been well moistened before feeding it.

The newly hatched chick is normally not fed its first meal until it is eight to twelve hours old. It should, at this point, be able to sit upright and beg for food. Begging can be elicited from the sleeping chick by imitating the "chup" call a female falcon uses when feeding her young. Feed the begging chick two or three BB size bites of mashed breast meat (Fig. 41). It is important that the pieces be small and soft so that they can be easily digested. The chick will continue to beg but do not feed anymore at that time. Young chicks will beg for food incessantly even when their crops and stomachs are full and they should seemingly no longer be hungry. This presumably is an instinctive behavior related to competition among siblings for a limited food supply in the aerie. It may also be related to the speed and efficiency with which a human can feed a chick as opposed to the time it takes a parent falcon to accomplish the same task. Therefore, do not be fooled into thinking that a chick should be fed until it stops begging. The newly hatched chick's digestive tract is very delicate and is just beginning to functon. Too much food might upset it and cause it to stop functioning completely. The food in the gut will then sour and spoil, and the chick may die. Gradually increase the meal size for newly hatched chicks; at three days of age they should be able to consume a full crop at each feeding. Up
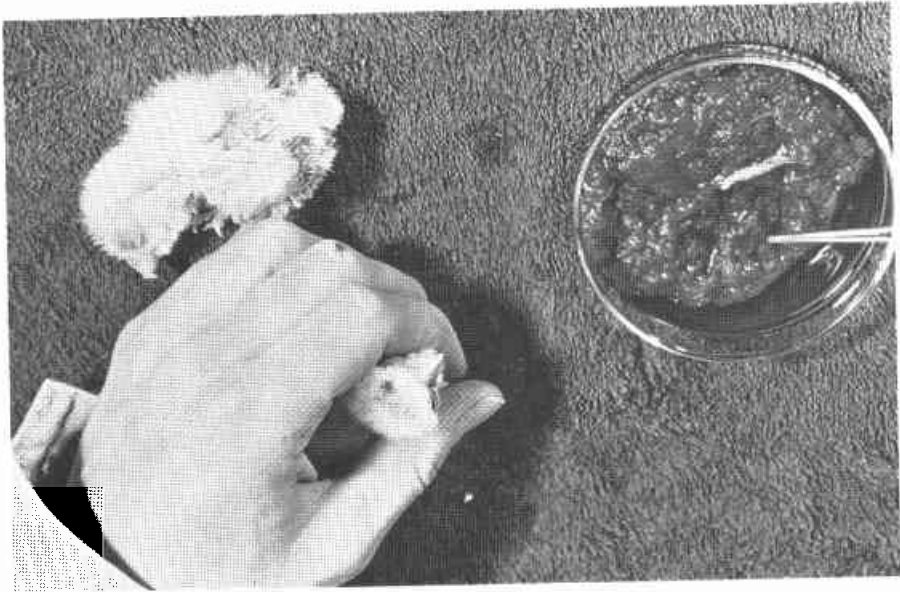
Fig. 41 Feeding day-old peregrine chicks.

to this point, the young chicks have been fed strictly the breast meat of the quail. By the middle of the second day, but certainly no later than the third day, start to feed **small** bits of bone and other organs as well. Failure to add bone to the diet by the fifth day can result in rickets, a calcium deficiency disease. When the chick begins to consume a full crop at each feeding, it should be fed the complete ground quail mixture without selectively choosing bits from it. This will ensure that it is receiving bone, meat, and other nutrients in the proper proportions. Use common sense, however, and remove a piece of meat or a bone joint that is too big for the size of the young falcon being fed. Also be aware of long, sharp bones, such as leg bones, that slip through the grinder in one piece, as these could puncture a crop or stomach.

Do not, under any circumstances, force-feed the newly hatched chick. If it does not food beg on its own, then it is not ready to eat. Recently hatched chicks can live for some time on the nutrition supplied by the remaining yolk. However, if by 12 hours of age, the chick has not begged for food, it may be generally weak and would probably benefit from an injection of lactated Ringer's, as previously described in the section on problem hatching. Fluid treatment is a common veterinary practice for all animals. It is safe when done properly, and is usually very beneficial for chicks that are weak, dehydrated, on antiobiotics, or cannot ingest liquid or food. Repeat the injection every three to four hours as necessary. A positive response is usually evident after one or two treatments, and frequently the chick is soon begging and eating normally.

Whenever feeding chicks under ten days old, it is important to check their crops and stomachs to determine the status of their previous meal. Careful attention to these details can help prevent overfeeding. Do not feed the chick again until its crop is empty. Check the stomach by facing the chick and looking at its lower abdomen. The stomach is just to the right of center. If that area

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appears dark in color, typically a dark greenish color, and/or is very hard to the touch of a finger, then a large amount of food remains in the stomach and feeding should be delayed until the stomach is soft and flaccid, and has returned to its normal light, pinkish color.

Newly hatched chicks that are receiving their first meals are not fed enough to cause very much distension of the crop or stomach. When examining them before feeding, rely primarily on the color of the stomach area. It is also helpful to examine the feces excreted since the last meal. Often they will be yellow in color, which means that the yolk material is being cycled through the gut. Soon the chick will be producing well formed black feces surrounded by white material. This indicates that the chick is digesting its food properly and that the gut is functioning as it should. The danger of overfeeding is highest in chicks up to three days old. After three days, overfeeding rarely results in death, but more commonly is seen as a sour crop. The chick will regurgitate its crop contents and will appear sick for several hours. This condition soon passes, generally within twelve hours. Do not offer the chick with a sour crop any food until it begs on its own. Any delay in recovery is reason for concern. Subcutaneous injections of lactated Ringer's may be helpful.

Young raptors are normally fed every three to five hours, except that they are not fed during an eight hour interval overnight. It may be beneficial to allow them this long interval to empty their digestive tracts more or less completely.

We give no casting material during the chick's first ten days, mostly as a matter of convenience. Feeding schedules are easier to follow if we do not have to keep track of which bird has or has not cast. It may be that the incidence of sour crop would be reduced with regular casting. When chicks begin self-feeding at just over ten days, casting is encouraged by providing some whole ground food. Five-week-old chickens with only the large feathers and crops removed are ground daily.

Problem Chicks

Occasionally a chick will exhibit splaying of the legs. This is not a serious problem and is easily corrected if immediate action is taken. Either place the chick in a small bowl or cup, in which the legs will be pushed under the body where they belong, or tie the legs together using two small bracelets and a string or rubber band. Leave about one inch (2cm) between the legs. The bracelets are to prevent constricting the blood flow to the feet. Remove the fixture after about five days. This condition indicates a problem with the surface on which the chicks are being kept.

One other thing with potentially serious consequences is food or fluid getting in the eye of a chick as it weaves back and forth at feeding time. If this should happen, rinse the eye immediately with an eye wash ("Visine" is fine and convenient to keep around) and then administer a small amount of opthalmic ointment. If left untreated there is a possibility of infection and blindness.

PHARMACOLOGICAL CONSIDERATIONS

J. David Remple, DVM   S. Kenton Riddle, DVM

Since the writing of the first *Falcon Propagation* many advances have been made in understanding the pharmacokinetics of therapeutic agents in falcons. Consequently, this second edition presents additions, deletions and dose modifications of therapeutic agents found in the original chapter. Our choices of drugs are based on effectiveness, predictability, and safety from use on thousands of raptors over the past decade. The drugs listed below are not intended to represent a complete pharmacological arsenal for falcons; rather the list is a basic starting point for the most common conditions and pathogens that the falcon breeder may encounter.

Potent, short-acting steroids such as dexamethasone are occasionally and very cautiously used to combat shock and stress. Vitamin and mineral preparations are used to supplement deficiencies, augment therapy, or act as tonics. When antibiotics are indicated their use optimally should be preceded by a culture and sensitivity test. However, owing to the rapid deterioration that can occur in birds, especially neonates, in the face of serious infection, it is often necessary to initiate therapy immediately. It is prudent to choose an antibiotic with a broad spectrum and little potential for toxicity or adverse reaction. Ticarcillin or pipercillin are good, safe first choices. The enrofloxin antibiotic, Baytril, is presently considered to be one of the safest, most effective and broad spectrum of all avian antibiotics and is an excellent "first choice" before a diagnosis is made.

Methods of administration are important. Owing to the lack of muscle mass and the delicate tissues of young chicks, oral administration, when feasible, is the most desirable. However, juvenile and adult birds are most easily and accurately medicated by intramuscular (IM) injection in the breast musculature close to the midline. This is generally painless and can be accomplished without restraint. Injections in leg musculature are painful and unpredictable as far as systemic blood levels attained. Medicating food or drinking water on a "free choice" basis should be avoided, when possible, as consumption is altered and unpredictable in the face of illness.

It is basic to avian therapy to be able to deliver fluids and drugs by the intravenous (IV) route as well as effortlessly and painlessly extract diagnostic samples of blood from a falcon's veins. The most easily accessible vein in a falcon is the medial tarsal vein which courses along the inside of the ankle joint at the junction of the feathered and scaled part of the lower leg. By wetting the feathered area with alcohol and occluding venous blood flow with slight pressure to the inside of the thigh the vein will distend and be easily visualized. Access to a vein requires two people. One holds the hooded falcon upright against their chest with the left hand and grasps the right leg of the falcon with the right hand. Slight pressure is placed on the inside of the extended leg by the holder's thumb. The syringe operator then grasps the clenched foot of the falcon with their left hand and guides the needle into the distended vein with the right hand. The holder releases the pressure to the inside of the leg, and the injection is begun. Using this technique one hand steadies the other and delicate procedures can be performed without mishap, even with an occasionally struggling falcon. For extracting blood the same procedure is used but pressure is maintained on the vein to keep it filling with blood.

Intravenous fluid replacement (see Lactated Ringers Solution below) is best accomplished in birds as several large boluses spread out over a 24 hour period. For example, a moderately dehydrated 1 Kg falcon would require 100 ml of fluids. One fourth (25 ml) would be given every six hours by fitting a large syringe with a 25 gauge needle and pushing the entire amount as fast as it will go through the end of the needle. After the needle is extracted mild pressure for a few seconds at the site will preserve the vein for repeated future use.

Widely accepted short-acting anesthetic agents are included in this chapter. Their use is common in procedures ranging from diagnostic restraint to minor surgery. The following is provided as a guide to be used by or under the direction of a veterinarian.

Table 1. Avian Drugs and Dosages (SQ = subcutaneous, IM = intramuscular, IV = intravenous, SID = once daily, BID = once every 12 hours, TID = once every 8 hours, QID = once every 6 hours.)

Generic Name	Route	*Dose	Frequency	Notes
Amikacin	IM	6 mg/Kg	TID	Especially useful against *Klebsiella* and *Pseudomonas*. Often used in conjunction with ticarcillin or pipercillin to increase potency.
Amoxicillin	Oral	150 mg/Kg	BID	Very effective against "sour crop" and bacterial diarrheas.
Amphotericin B	IV	1.5 mg/Kg	TID	Useful in conjunction with flucytosine in treating aspergillosis. Drug is very irritating if given outside a vein. Must be diluted prior to injection.
Ampicillin	Oral or IM	100 mg/Kg	BID	Similar to amoxicillin but spectrum is often less.
Baycox 2.5%	Oral	0.3 ml/Kg	SID for 2 days	Very safe and effective anticoccidial.
Calcium powder (Osteoform)	Oral	1/16 to 1/8 tsp. on food	as needed	For calcium deficiency or supplementation during egg laying, growth, or bone healing.
Chloramphenicol Succinate	IM	80 mg/Kg	TID	Broad spectrum antibiotic, occasionally used as an alternative to . . . "cillins."
Cloroquine plus Primaquine	Oral	10 mg/Kg followed by 3 doses of 5 mg/Kg	given at 0, 6, 18 & 24 hrs respectively	For treatment of malaria in susceptible species (gyrfalcons).
		10 mg/Kg	once weekly	For malarial prophylaxis during mosquito season.
Dexamethasone (Azium)	IM or IV	2 mg/Kg	once	For life-threatening shock, hemorrhage, trauma, or toxic conditions (sour crop).
Dimetridazole	Oral	0.5 ml powder in 10 ml water/Kg	SID for 5 days	For trichomoniasis.

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Doxapram	IM, IV	10 mg/Kg	once	To stimulate respiration and speed recovery from anesthesia if needed. One drop in a chick's mouth will stimulate breathing if necessary.
Doxycycline	Oral	20 mg/Kg	BID	Drug of choice for *Chlamydia*.
Enrofloxacin 5% 2.5%	IM Oral	10 mg/Kg 10 mg/Kg	BID or TID BID or TID	A new very broad spectrum antibiotic that is an excellent "first choice" before a diagnosis is available. Antibiotic of choice for *Mycoplasma*.
Fenbendazole Paste (Panacur)	Oral	0.35 ml/Kg	SID for 5 days	Very effective for *Capillaria*.
Flucytosine (Ancobon)	Oral	125 mg/Kg	TID	Drug of choice for yeast *(Candida)*. Given in conjunction with amphotericin B for aspergillosis.
Ivermectin	Oral or IM	Dilute the bovine preparation 1:4 with propylene glycol and give 0.15 ml/Kg once.		Effective against most gastointestinal worms (not tapeworms), blood sucking fleas, lice, and possibly *Serratospiculum*.
Kaopectate solution	Oral	2 ml/Kg	TID	Has a soothing effect on the gut. Used in conjunction with amoxicillin for non-specific diarrheas.
Metronidazole syrup or tabs (Flagyl)	Oral	50 mg/Kg	SID for 5 days	For trichomoniasis.
Mineral Oil	Oral	1-3 ml/Kg	once	Laxative and aid in removal of small foreign objects from the ventriculus.
Niclosamide (Yomesan)	Oral	200 mg/Kg	once on an empty stomach	For tapeworms.
Nystatin (Mycostatin)	Oral	300,000	TID units/KG	For yeast infections of the gut. Not absorbed from gut, therefore not for systemic use.
Peptobismal solution	Oral	1 ml/Kg	TID	Used in conjunction with amoxicillin for sour crop. Do not exceed dose.
Pipercillin	IM	200 mg/Kg	TID or QID	A new safe, very broad spectrum antibiotic. A good "first choice" before a diagnosis is made.
Praziquantal	Oral	1/4 tablet/Kg	once	For tapeworms and flukes.
Pyrethrin	Light external application		once	Effective against feather lice.
Spectinomycin plus Lincocin (LS-50)	IM	30 mg/Kg	TID	Broad spectrum antibiotic effective against *Mycoplasma* and *Salmonella*.
Sulfadimethoxine (Bactrovet)	Oral	50 mg/Kg the first day, followed by 25 mg/Kg each day for 7 days		For coccidiosis. Assure water is available for drinking during treatment
Ticarcillin	IM	200 ml/Kg	TID	Similar to pipercillin

Trimethoprim and Sulfamethoxazole (Tribrissen)	IM and Oral	0.15 ml/Kg Follow label instructions	BID	Broad spectrum antibiotic with potential for causing kidney damage with prolonged use. Can also be used for coccidiosis.
Tylosin	IM	30 mg/Kg	TID	For *Mycoplasma*.
Vitamins A, D$_3$, E and B Complex (Injacom)	IM	0.3 ml/KG	Once weekly	For hypovitaminosis A, D, E and various B vitamin deficiencies. Useful in avian pox, trichomoniasis, sinusitis, air sacculitis, ophthalmic disorders, anemia, and bone healing. Also used as a tonic to stimulate appetite.

* mg drug per Kg of body weight

Intravenous and Subcutaneous Rehydrating Fluids

Lactated Ringers Solution	IV (adults)	Rehydrating solutions are given to combat the dehydration that accompanies most diseases. Fluid therapy has revolutionized treatment success. The total daily dose is divided into several boluses and given (as needed) over a 24 hour period. A conservative and convenient bolus dose (given at once) in **adults** is $\underline{\text{Body Weight in grams X 0.10}}$ = ml of IV fluids to $$4$$ be given every 4 to 6 hours.
	SQ (chicks)	In chicks fluids are given subcutaneously (SQ) either under the skin of the neck or in the inguinal web. The bolus dose for **chicks** is $\underline{\text{Body weight in grams X 0.10}}$ $$5$$ = ml if SQ fluids to be given every 2 hours.
Lactated Ringers Solution plus 5% Dextrose	IV only	This solution is more isotonic for raptors and has the advantage of providing a small amount of energy from the sugar; however, it should only be given intravenously.

Short-acting Anesthetic Agents

Ketamine HC1	IV or IM	5-10 mg/Kg	The anesthetic agents ketamine and xylazine are generally combined in the same syringe. The combination increases safety while improving analgesia, relaxation and restraint. For short procedures (3-5 minutes) such as imping, the IV route is used, and the lower doses are chosen. For longer procedures
Zylazine 2%	IV or IM	1-4 mg/Kg	the higher doses are used and the IM route is chosen. Additonal increments can be given as required by the IM or IV routes. With IV the onset of action is immediate and recovery is quick. With IM the converse applies.

NUTRITION

Cal Sandfort   Ellen Dierenfeld   John Lee, DVM

Good quality food is necessary for the maintenance and reproduction of captive birds of prey. Coturnix Quail and chickens are the easiest food to raise or obtain in sufficient numbers to operate breeding facilities of any size. We have known the importance of maintaining these food items on the highest quality feed available, but little is known of the actual nutrient requirements of birds of prey or the relationship between these raptors and their diet. Hatchability problems with the falcons prompted us to begin investigations into these requirements and relationships. Since vitamin supplementation without quantitative analysis is not a substitute for good basic nutrition, we began preliminary studies into a few vitamins which influence the quality of reproduction. As our knowledge of the nutritional requirements of birds of prey increases, the base of information and standards of comparison will be developed. The following will provide the information of what is available at this time.

Multiple B Complex

Occasionally a breeder may be confronted with a chick that hatched normally or required slight assistance, but appears to become more lethargic as the hours pass. Through the years the method we used for treatment of these lethargic chicks was subcutaneous injections of Ringer's Solution to keep the chick hydrated. Unfortunately many of these problem chicks "never woke up" and died within hours after hatching.

Several years ago Dr. John Lee, Meridian, Idaho, prescribed a Vitamin B Complex for an adult Peregrine which appeared sluggish, but not necessarily sick. During the following breeding season, after hatching a "sluggish" chick we administered Multiple B Complex. The chick made a rapid recovery. This treatment was tested on other chicks by several breeders during the next few years with varying success. We currently use various brands of Vitamin B and can recommend the following methods of administration:

If the chick refuses to food beg, we administer a dosage of 0.01 cc subcutaneous in the inguinal web under the leg for newly hatched Peregrine chicks. This dosage is simpler to prepare if you dilute 0.10 cc Complex B with 0.90 cc sterile Ringer's Solution and then administer 0.10 cc of this stock solution, with additional Ringer's Solution if needed. Usually one or two injections given two to three hours apart is sufficient.

Chicks that will food beg can be given one or two drops of Complex B orally, one or two times. We often mix a drop of the vitamin B with an equal amount of water before administering it. This can improve palatability as the undiluted vitamin has a strong taste. We have also added a few drops of Multiple B Complex to the food when feeding a group of young chicks the first few times.

Vitamin B administration is a standard therapeutic treatment used by veterinarians and apparently stimulates the digestive and nervous system. For the breeder this results in an alert, hungry chick. Treatment results range from dramatic, positive improvement to no apparent effect. Though the treatment as described does not stimulate every sluggish chick, it is effective much of the time and is well worth trying.

Vitamin E

In 1987, The Peregrine Fund, in collaboration with the New York Zoological Society, undertook a study to compare the plasma and dietary vitamin E levels of wild and captive Peregrines (Dierenfeld *et al* 1989). Methods of vitamin supplementation to falcons were also tested. Initial circulating vitamin E levels in captive Peregrines (n=4) were eight times lower than the wild counterparts; 3.4 μg/ml and 26.3 μg/ml, respectively. Our current methods of vitamin E administration maintain blood levels between 16 and 29 μg/ml in the captive population.

Two methods of vitamin E supplementation are used by The Peregrine Fund. One involves a daily injection of liquid vitamin E supplement (vitamin E 40% manufactured by Nutrius, Inc., Kingsbury, CA) into the breast muscle of dead quail immediately before feeding to the falcon. The dose rate is 44 IU per quail (100 g). For large scale production, daily injections would prove very time consuming and laborious, but small programs may benefit economically from this method.

The other method employed, which works especially for large scale production, is incorporation of supplemental vitamin E into quail feed at manufacture. Vitamin E is added to provide a total diet concentration of approximately 200 IU/Kg dry matter; our current feed supplier requires a minimum order of three tons. Laboratory analysis of whole quail fed typical rations (n=5) showed that the birds contained about 1.6 μg/g vitamin E (Sherrod and Dierenfeld, unpublished data). Thus, a 100 g quail would provide 16 IU vitamin E to a falcon. Quail fed supplemented feed (n=15) contained 9.4 μg/g, supplying over 90 IU to falcons consuming them.

Levels of vitamin E in falcons as well as quail and/or quail feed, and the relationship of supplemental vitamin E to the feed, should be evaluated before altering any dietary regime. We caution against vitamin supplementation without prior knowledge of the current nutritional state of the falcons or their diet.

Biotin

The supplementation of additional Biotin into the quail by The Peregrine Fund began in 1988. Daily intake of Biotin was calculated to be only 0.8 μg per quail per day. Literature reviews indicate a daily requirement of 2 and 5 μg for chick and poults, respectively. The National Research Council (1984) reports Coturnix Quail require a 0.2-0.3 mg/Kg diet. Scott *et al (1967) in Nutrition of the Chicken* states that, "Biotin deficiency in adult laying and breeding hens causes a reduction in hatchability without adversely affecting egg production." The authors further indicated that, while liver is a rich source of Biotin, meat is a relatively poor source. Biotin occurs naturally in free and bound forms. Bound forms are probably unavailable to animals, therefore only half of the Biotin may be available from feeds. In poultry, Biotin deficiency can be produced simply by feeding Biotin deficient diets (Scott, *et al* 1967). Based on this information our quail were possibly deficient in Biotin by two- to five-fold which could undoubtedly cause our falcons to be deficient as well. In December, 1987 Biotin levels in the quail diet were increased five-fold at manufacture, resulting in a minimum intake of 4.0 μg per quail per day. We feel this change supplied the captive falcons with an adequate level of Biotin without a chance of an overdose; however, no quantitative analysis of Biotin status in either quail or falcons were conducted.

We suggest that you contact your local feed suppliers for the Biotin concentrations of individual feeds; quail diets should contain 0.2-0.3 mg/Kg Biotin, supplying between 2-5 μg Biotin per bird per day. Calculate daily intake of a quail or chicken population before adding additional Biotin.

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APPENDIX

Incubators

Lyon Electric Co., Inc.
2765 Main St.
Chula Vista, CA 92011
(619) 585-9900

Roll-X Incubators
and accessories

Incubator and Brooder Parts

Philadelphia Thermometer Co.
4401 North Sixth St.
Philadelphia, PA 19140
Tel. (215) 329-8828
FAX (215) 329-0729
Eric and Robert Engelhardt

Thermometers
Mercury Thermostat
Thermometers
Sigma Relays and Sockets
Thermometer and Thermostat
 Certification
Custom-Made Thermometers
 and Thermostats

Radio Shack
P.O. Box 2625
Ft. Worth, TX 76113
Retail stores throughout the U.S.

Relay (Part 275-217)
Relay Socket
(Part 275-220)

GQF Manufacturing Co.
P.O. Box 1552
Savannah, GA 31402
(912) 236-0651

Still-air Brooder Heating Units
Ether Wafer Thermostats
Other Accessories

Incubator Modificaitons

Willard Heck
5791 West Flying Hawk Lane
Boise, ID 83709

Incubator Fans

Pabst Mechatronic Corp.
Aquidneck Industrial Park
Newport, RI 02840
Tel. (401) 849-8810
FAX (401) 849-4640

Interfan
770 Airport Rd.
Burlingame, CA

Available through electronic parts houses. Other brands are usable but quality can vary in terms of vibration and durability.

K-Pads and Modules

Baxter Healthcare
Hospital Supply Division
1450 Waukegan Road
McGaw Park, IL 60085
(708) 473-0400

K-Module, Model K-20
K-Pad, 12.5" x 16"

Candlers

Lyon Electric Co., Inc.
2765 Main St.
Chula Vista, CA 92011
(619) 585-9900

GQF Manufacturing Co.
P.O. Box 1552
Savannah, GA 31498
Tel. (912) 236-0651
FAX (912) 234-9978

Corn Cob Litter

Andersons Industrial Products   Bed-O'Cobs
Maumee, OH 43537   Lab Animal Bedding
Delphi, IN 46923

Paxton Processing Co.   SAN-I-CEL
Paxton, IL 60957   Lab Animal Bedding

Available through pet supply stores and wholesalers.

Disinfectants

The Purdue Frederick Co.   "Betadine" surgical scrub
Norwalk, CT 06856

Ft. Dodge Laboratories, Inc.   "Nolvasan" solution
Ft. Dodge, IA 50501

Available through veterinary or medical supply houses.

Vitamins

Lambert Kay   "Avitron" liquid vitamins
Division of Carter Wallace
Cranbury, NJ 08512

Available only through pet stores or pet supply wholesalers.

D.B. Scientific   "Vitahawk" raptor vitamins
2063 Main St., Suite 406
Oakley, CA 94561

General Suppliers of Scientific and Laboratory Apparatus

Fisher Scientific
711 Forbes Ave.
Pittsburgh, PA 15219
(412) 562-8300

VWR Scientific
P.O. Box 39396
Denver, CO 80239
(303) 371-0970

Sargent-Welch Scientific Co.
7300 N. Linder Ave.
P.O. Box 1026
Skokie, IL 60077
(312) 677-0600

Curtin-Matheson Scientific, Inc.
P.O. Box 1546
Houston, TX 77001
(713) 923-1661

Hygrometers

Airguide Humidity Indicators are carried by Fisher Scientific Co. (Catalog No. 11-661)

Abbeon Cal, Inc.
123-17A Gray Ave.
Santa Barbara, CA 93101
(805) 966-0810

See general suppliers for a variety of hygrometer types.

Thermometers

Philadelphia Thermometer Co.   Thermometers
4401 N. Sixth St.   Custom-Made Thermometers
Philadelphia, PA 19140   Thermometer Certification
Tel. (215) 329-8828
FAX (215) 329-0729
Eric and Robert Engelhardt

Also general suppliers.

Scales

See general suppliers for a variety of manual and digital electronic scales.
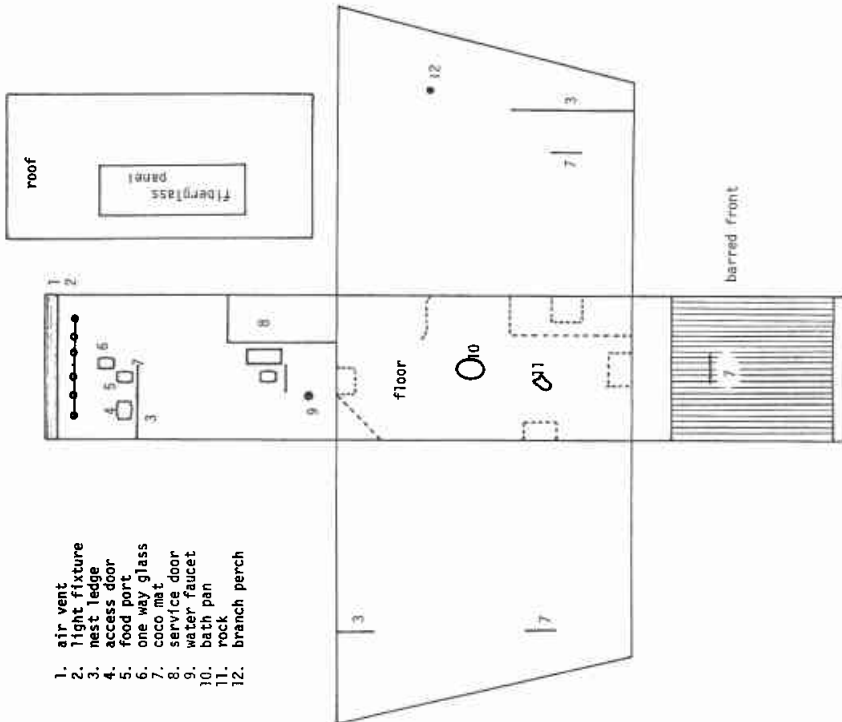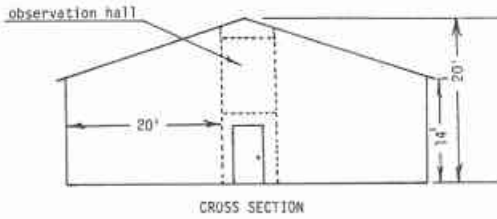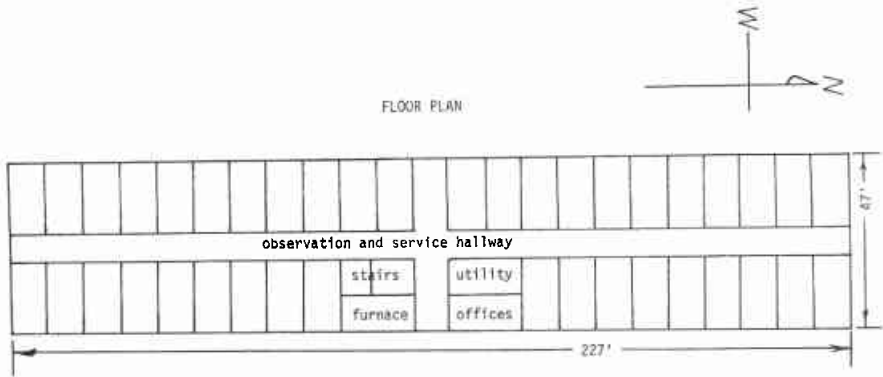
Sling Psychrometer

See general suppliers.

Silica Gel Dessicant

Fisher Scientific Co.   4 Mesh Blue Indicator
711 Forbes Ave.
Pittsburgh, PA 15219
(412) 562-8300

Power-Off Alarm

Lyon Electric Co., Inc.
2765 Main St.
Chula Vista, CA 92011
(619) 585-9900

FLOOR PLAN

observation and service hallway

| stairs | utility |
| furnace | offices |

67'

227'

observation hall

20'

20'

14'

CROSS SECTION

roof

fiberglass panel

barred front

floor

1. air vent
2. light fixture
3. nest ledge
4. access door
5. food port
6. one way glass
7. coco mat
8. service door
9. water faucet
10. bath pan
11. rock
12. branch perch

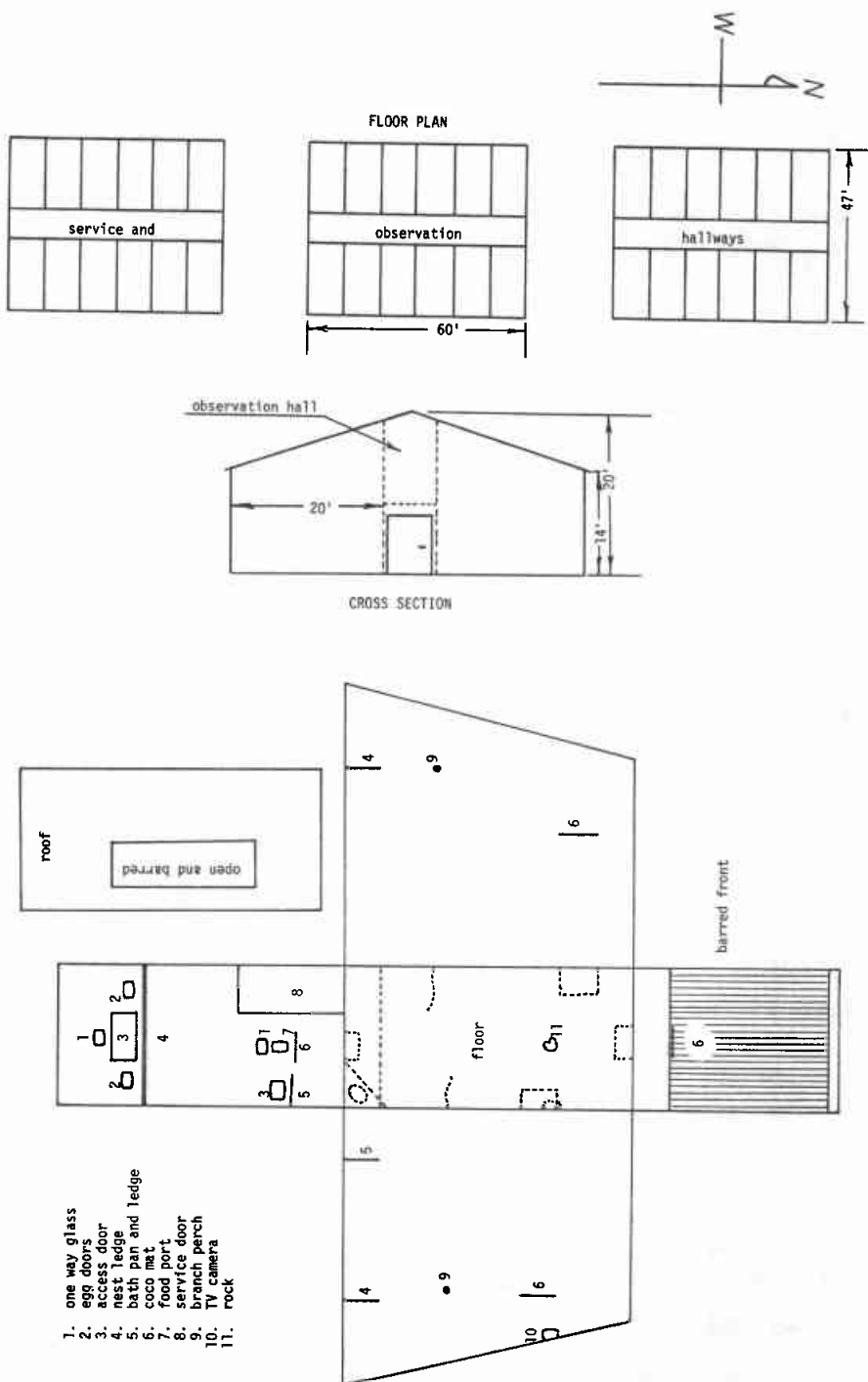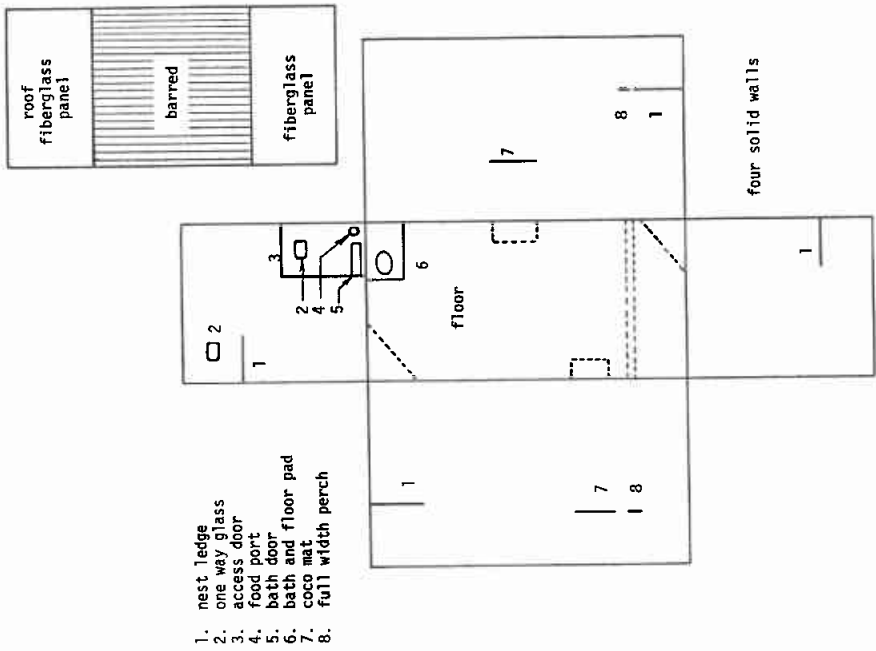**Fig. 42** Floor plan, elevations, and exploded view, Ithaca facility.

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Fig. 43 Floor plan, elevations, and exploded view, Ft. Collins facility.

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roof
fiberglass
panel

barred

fiberglass
panel

four solid walls

nest ledge
one way glass
access door
food port
bath door
bath and floor pad
coco mat
full width perch

1.
2.
3.
4.
5.
6.
7.
8.

floor

FLOOR PLAN

N

W

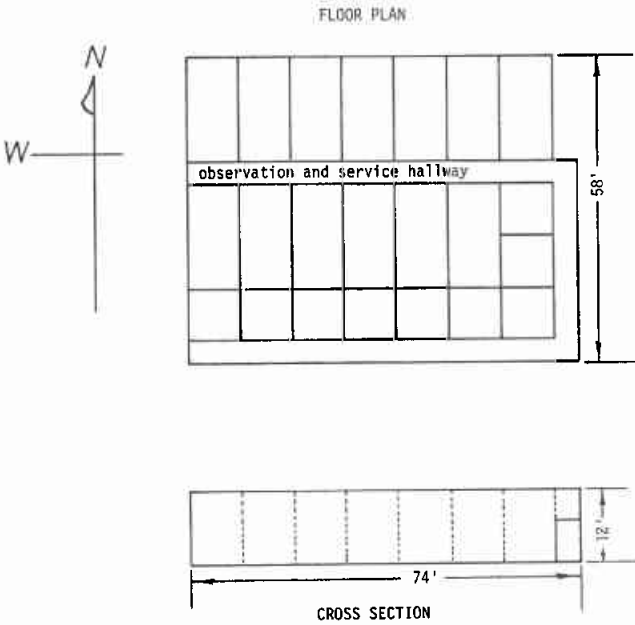observation and service hallway

58'

74'

12'

CROSS SECTION

Fig. 44 Floor plan, elevations, and exploded view, Santa Cruz facility.

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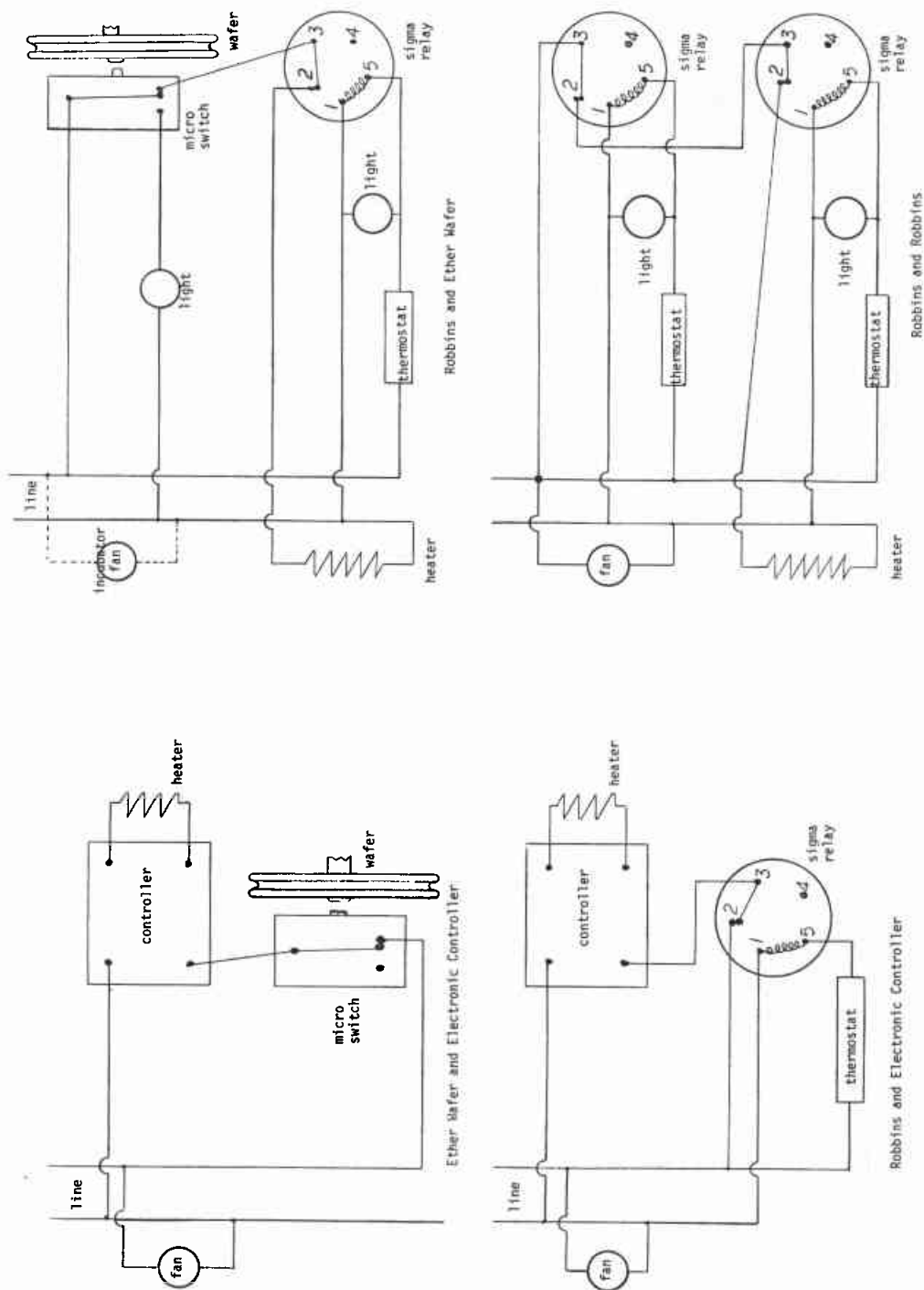
Fig. 45 Incubator modification schematics. After Burnham, 1978.

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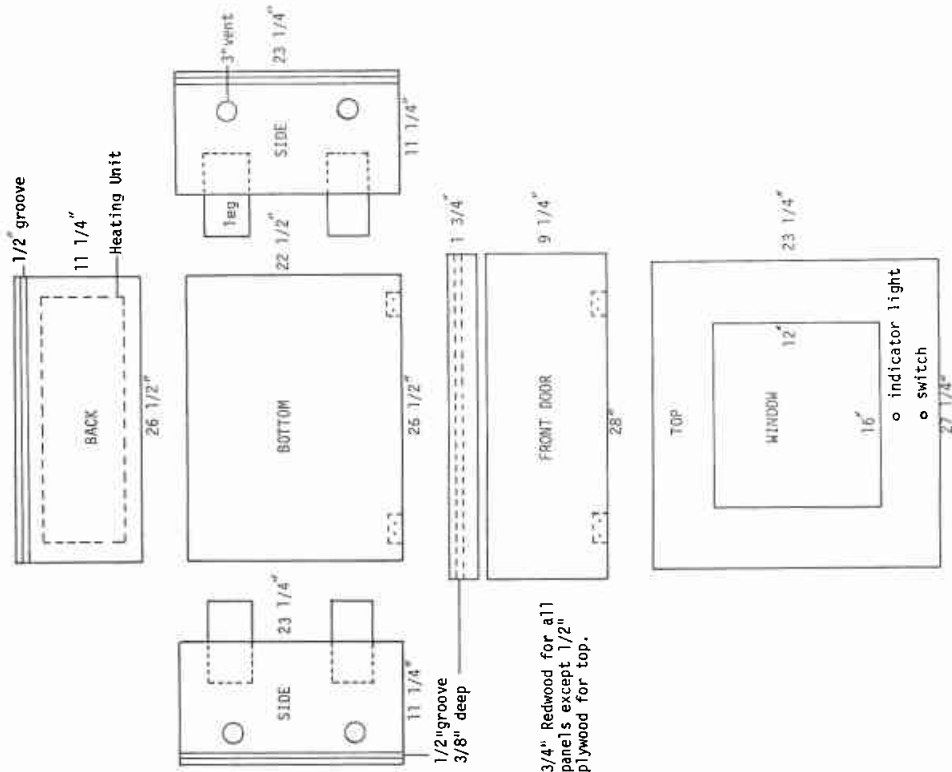
STILL-AIR BROODER PLANS

Fig. 46 Construction plans for still air brooder J. Barclay, 1983.

Materials:
disposable 1cc tuberculin syringe
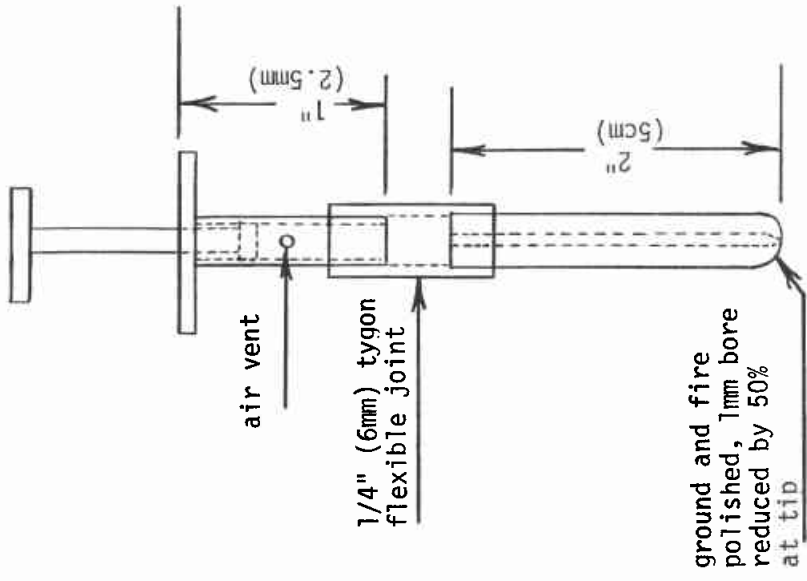1/4" (6mm) tygon tubing
7mm x 1mm bore glass tubing

air vent

1/4" (6mm) tygon flexible joint

ground and fire polished, 1mm bore reduced by 50% at tip

1" (2.5mm)

2" (5cm)

Fig. 47 Detail of insemination syringe.

Figure 48   Installation of Ten-Turn Potentiometer

Remove the original equipment potentiometer
from its four points of attachment (A,B,C,D)
with a soldering iron.

Install replacement ten turn-potentiometer
by soldering the wiper lead into hole D.
Solder the resistance lead into hole B.

POWER

INTEGRATED
CIRCUIT

B   C

A   O   D

POTENTIOMETER   ←PILOT LIGHT

HEATING COIL
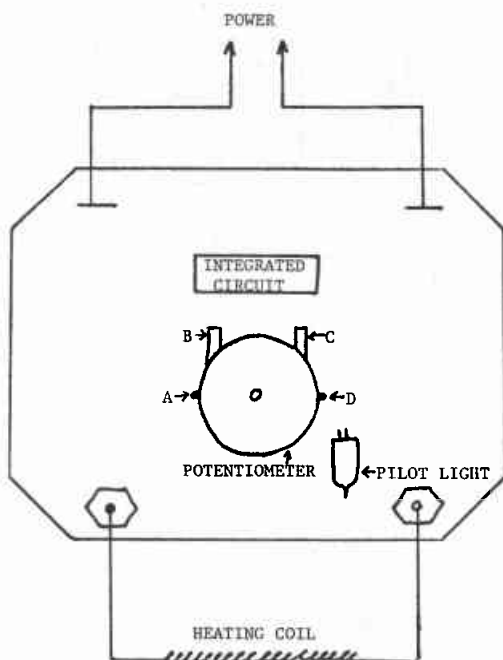
Incubators and Accessories

Incubators

We have learned only recently that Marsh Farms, the manufacturer of the "Roll-X" incubator, has been acquired by Lyon Electric Co., Inc., a poultry equipment supplier in San Diego, California (P.O. Box 81303, San Diego, Ca. 92138, phone 619-297-9000). Lyon Electric has, at the time of this printing, assured us that most of the Marsh Farms products, including the "Roll-X" incubator, will continue to be available through them once the merger is completed in December, 1985.

Solid State Temperature Controllers

When this booklet was originally published in 1983 we reported little experience with the new solid state temperature controller being supplied with the "Roll-X" incubators (page 36). At the Ithaca facility, we have now removed all

ether wafer controls and replaced them with the solid state units. They work very well; we have now used them for three seasons as the primary temperature controller with the "Robbins" system in the back-up role.

The most frequent complaint about the solid state unit as it comes from the factory seems to be that it is difficult to adjust. This is because the potentiometer normally supplied with the unit turns only about three-quarters of a turn from the lowest to the highest adjustment. Therefore, a slight movement of the knob results in a relatively large temperature change. This difficulty is eliminated by replacing the standard potentiometer with a ten-turn potentiometer of the same rating (10K ohms). With this modification, the knob must be turned ten revolutions from the lowest to the highest adjustment, so a slight movement of the knob results in a slight change in temperature.

Ten-turn potentiometers are very common in the electronics world and are easy to obtain. The incubator manufacturer supplies a unit as an option, but smaller, more compact ones are also available and can be installed privately (Figure 48).

The "Robbins" Temperature Controller

Our original discussion of incubator temperature control systems dwelled heavily on using the "Robbins" control system as provided by Robbins Incubator Company. However, since we originally published this information, Robbins Incubator Company has gone out of business. Fortunately, the components are still available through other manufacturers.

The thermostat thermometers are available through the original manufacturer, Philadlephia Thermometer and Controls (4401 North Sixth St. Philadelphia, Pa. 19140, phone 215-329-8828). The folks there are very accommodating and have been quite willing to send orders COD. When ordering refer to the six-inch thermostats with contacts one and one-half inches apart (Figure 24, page 36). Thermostats are available in one-quarter degree Fahrenheit increments.

There is a wide variety of relays that will work as replacements for the Sigma relay mentioned in our original text, but they are primarily available only through industrial supply firms. We wanted to be able to recommend an economical relay that was easily available to most people, and have for the present settled upon a unit available through Radio Shack (Part no. 275-217). This is a plug-in relay used with a socket (part no. 275-220) that can be mounted in the incubator lid as before. This relay is a double pole, double throw relay whereas the Sigma was only a single pole, single throw, but the wiring principles remain the same. Connect the thermostat thermometer circuit across the relay coil terminals (#7 and #9 on the radio Shack relay). The heating coil power circuit should be connected to the "normally on" switch terminals (#1 and #5, refer also to page 92). If desired, jumper wires can be installed to connect terminals 5 to 6 and 1 to 2 on the socket. This will spread the electrical load between both poles (switches) of the double pole relay, possibly increasing relay life.
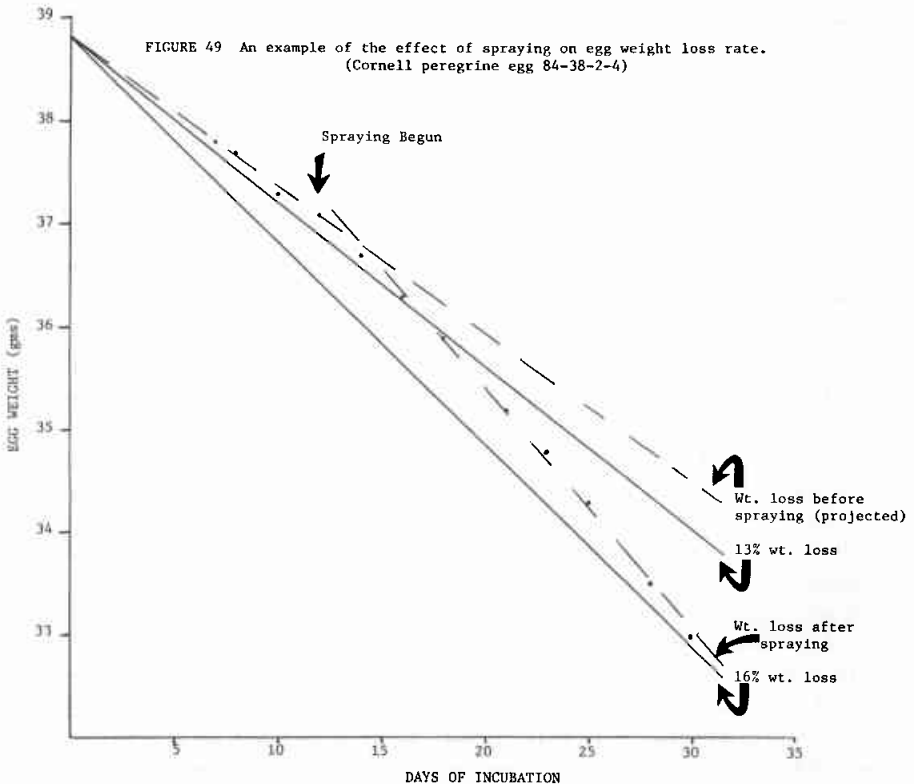
According to the factory, the thermostat thermometer is only rated to han-

dle three milliamps of current. When used with a Sigma relay (coil resistance 5000 ohms) however, it is forced to handle a load of 24 milliamps. Our incubators have run for many seasons in this configuration without failure of the thermostats. However, in order to prevent larger current loads through the thermostat, we recommend using relays with a coil resistance of at least 4500 ohms. As further protection, we have been recently installing a metal oxide varistor (MOV) across the terminals of the relay coil. This device diverts voltage spikes which could prove harmful to the thermostat.

The only remaining part necessary to complete the original "Robbins" system is the clips that hold the thermostat thermometer. These are simply fuse clips which should be available at any electronic parts store.

Spraying Eggs

The discussion of "Problem Eggs" (page 56) briefly mentioned a technique used to accelerate egg weight loss that involved spraying the eggs with sterile, distilled water several times per day. We are now able to say that it does work. Most eggs on which we have tried this technique exhibited variable increases in weight loss. The exact mechanism is not clear, and while it seems illogical to add water to an incubator wherein you want eggs to lose more weight (page

FIGURE 49   An example of the effect of spraying on egg weight loss rate.
(Cornell peregrine egg 84-38-2-4)

Spraying Begun

Wt. loss before spraying (projected)

13% wt. loss

Wt. loss after spraying

16% wt. loss

EGG WEIGHT (gms)

DAYS OF INCUBATION

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53), the technique has nonetheless worked well for us and other private breeders. This technique has the added advantage of being less troublesome than using silica gel which must be removed from the incubator, oven-dried, and replaced daily.

Eggs to be sprayed are normally placed in a separate incubator so as not to disturb the environment of those not requiring treatment. The eggs are wetted using sterile distilled water applied with a hand-held, trigger-type sprayer. We simply raise the incubator lid, spray the eggs with two-three bursts of spray or until well wetted, then close the incubator. The eggs should be sprayed at least six times per day to affect an increase in rate of weight loss. Eggs sprayed four times or less were not affected. Try to spray the eggs at somewhat equal intervals throughout the day; for example, every four hours.

Once the egg has started to achieve a daily weight loss that will permit it to reach the target of 13-16% weight loss to pip, spraying can be discontinued and the egg placed in a dry incubator. Reweigh the egg in 24 hours to double-check its weight loss rate (Figure 49).

The rate of weight loss for some eggs that have been sprayed for a week or more will sometimes begin to level out and may even decline in some cases. Discontinue spraying these eggs and place them in a dry incubator for 24 hours, then reweigh. At this point the egg may lose weight faster than in the dry incubator and sometimes, will lose weight so rapidly that additionally humidity (in the form of dishes of water, see page 37) will be required.

Problem Hatching

The section "Problem Hatching" (page 60) discusses procedures to use when a chick hatches with a fully or partially unretracted yolk sac. It was mentioned (page 64) that partially unretracted yolk sacs can sometimes be massaged back into the body cavity *if the unretracted portion is small enough*. We would emphasize this last phrase, as attempting to replace too large a bud of unretracted yolk can be dangerous. If attempts are made to reinsert more yolk sac than the body cavity can easily handle, then the possibility is increased that the yolk sac may rupture. Two problems can then result. The chick may drown if the leaking yolk enters the air sacs or, if yolk leaks into the body cavity, it may not be resorbed and might serve as a source of infection resulting in peritonitus.

There are no hard and fast rules for judging when to remove a bud of unretracted yolk. Common sense will have to play a leading role; assess the relative sizes of the yolk and the chick; if the yolk will not fit easily or "comfortably" within the chick, then refer to the surgical procedure on page 64 and remove the excess yolk sac.

Food and Feeding

Our original comments on feeding captive falcons (page 11) mentioned that, at the Ithaca facility, we used a combination of frozen chickens and quail to feed our breeding adults. While this seems to be a perfectly adequate mainte-

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nance diet during the non-breeding season, we now believe that the dietary needs of breeding adult falcons are best met by providing them with the highest quality live or freshly-killed quail at least four days per week.

During the 1983 breeding season at the Ithaca facility, quail were largely unavailable. As a result, adults were maintained entirely on frozen chicken with vitamin supplements. Production was very poor that year; egg fertility was low, hatchability was only 65%, and many of the chicks that hatched and survived required considerable "nursing".

During the 1984 season, we altered our feeding regime to include freshly-killed quail for the breeding adults at least three times per week. Our production that year improved dramatically; fertility rose, hatchability jumped to 86%, and the chicks hatched without incident and required no extraordinary care. In 1985 we provided freshly-killed or live quail seven days per week during the breeding season, and recorded production slightly higher than 1984. The introduction of live quail that season also seemed to heighten the enthusiasm of the breeding pairs and increase the intensity of courtship behavior, particularly in the males.

Much of the change we have seen is not revealed in the statistics, but has to do with the vigor and vitality of the chicks. The hatching eggs require much less "help" (page 60) at hatching and the chicks are more vigorous; they show a strong begging response very soon after hatching and most mature without the problems experienced in the past.

While we do not have controlled experimental data to support this anecdotal evidence, we cannot identify any other factor which could account for the improvement in production for both young and old breeders over these past two years. We intend to continue providing fresh quail to our breeders from early February until the end of the breeding season. In addition, since a whole, fresh quail, properly maintained on high quality feed should contain a proper balance of all the vitamins and nutrients, we no longer use the vitamin supplements discussed on page 12.

Regarding the feeding of newly hatched chicks (page 72), we continue to believe that freshly-killed quail is the best diet and have not altered that procedure.

Incubator Fans

The section **Incubator Maintenance** (page 40) includes some discussion of high quality replacement fans for the Roll-X incubator. It was mentioned that fans rated at 100 cfm (cubic feet per minute) should be used to replace the stock C-frame fans. While we continue to use 100 cfm fans in many of our machines, we have found that there can be advantages to using lower volume fans in some incubators.

Fans rated at 75 cfm are used in many of our Roll-Xs. These fans run more quietly and with less vibration due to their slower running speed and reduced static pressure. Eggs that require very humid incubators to maintain proper weight loss can benefit from a lower fan volume as reduced air flow reduces the rate of moisture evaporation from the egg.

Further in the same vein, we use fans rated at 50 cfm in our hatchers. These

fans run very quietly and produce a very slow movement of air. Consequently, with less air movement we seem to have fewer dried membranes at the pip site. The level of circulation, however, is sufficient not only to maintain proper hatcher conditions, but also to quickly recover the hatcher environment after the lid is opened.

Most manufacturers offer fans of various capacities, and they are typically available from electronics parts stores. As the different capacities are manufactured in the standard size that fits Roll-X machines (see page 40), changing fans for different applications is simply a matter of removing the baffle plate in the incubator lid and exchanging fan units.