

## 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:

$$W = K_w(LB^2) \quad \text{where } W = \text{fresh weight}$$

$K_w =$  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 breadth of 40mm would look like this:

$$\begin{aligned} W &= K_w(LB^2) \\ &= 0.0005474 (50 \times 40^2) \\ &= 0.0005474 (80,000) \\ &= 43.79 \text{ grams} \end{aligned}$$

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.

## 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:

$$Wl = \frac{0.15W}{31.5} \quad \text{where } Wl = \text{weight loss per day(g)} \\ W = \text{fresh weight(g)}$$

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:

<i>Fresh Wt.(g)</i>	<i>Daily Wt. loss(g)</i>
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

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.

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:

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

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):

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

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;

$$\begin{aligned} I_d &= \frac{43.79-42.19}{\frac{0.141 (43.79)}{31.5}} \\ &= \frac{1.60}{6.17} \\ &= \frac{31.5}{8.16} \end{aligned}$$

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.

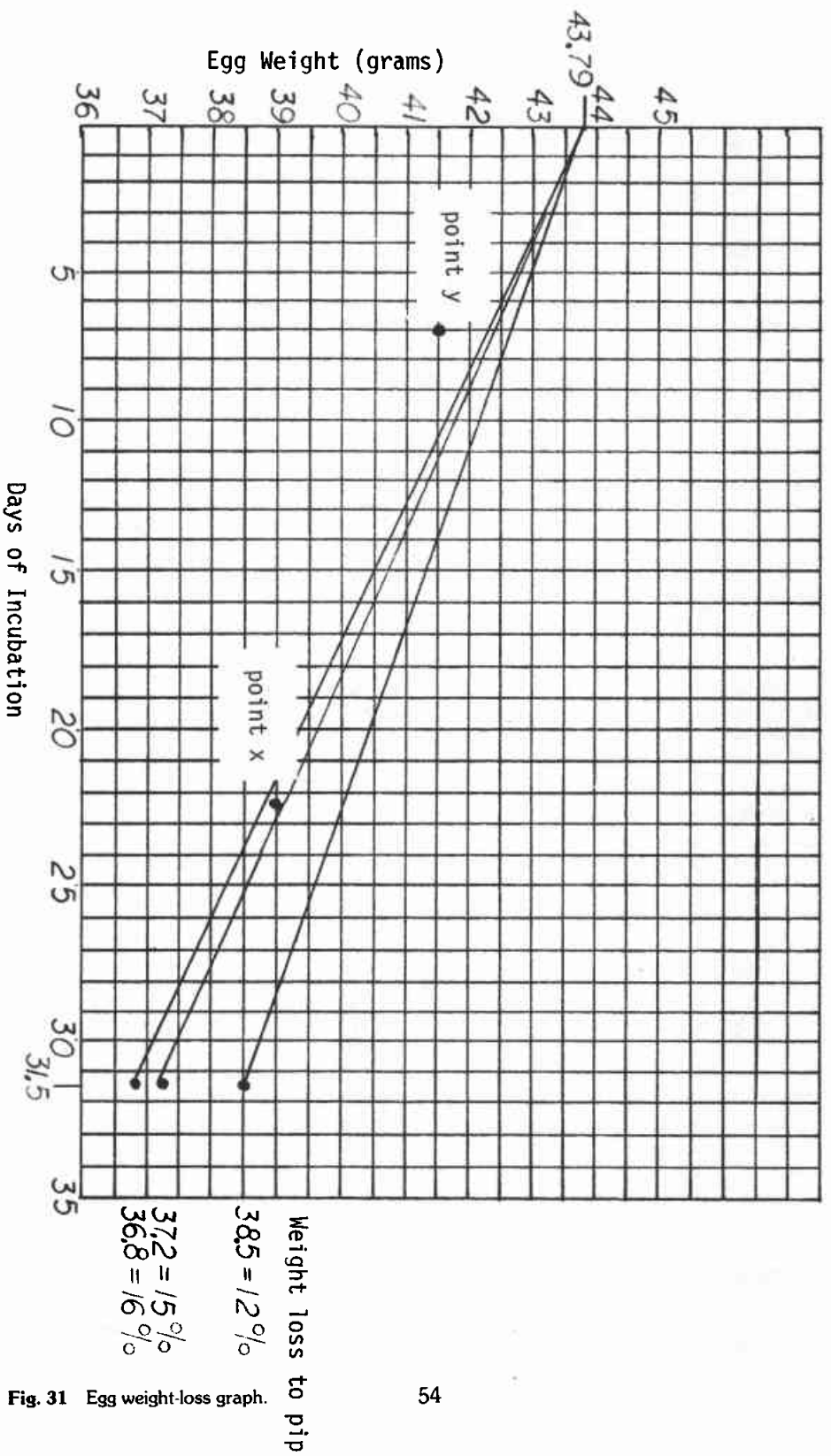


Fig. 31 Egg weight-loss graph.

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.

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 gel is a crystalline substance 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.

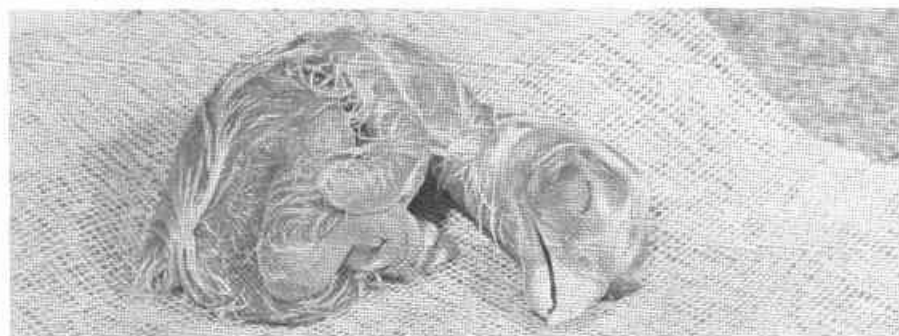
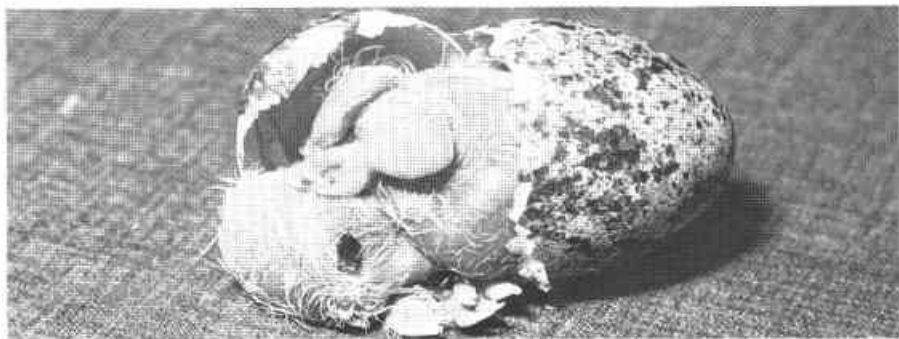
## Hatching

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.



**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.

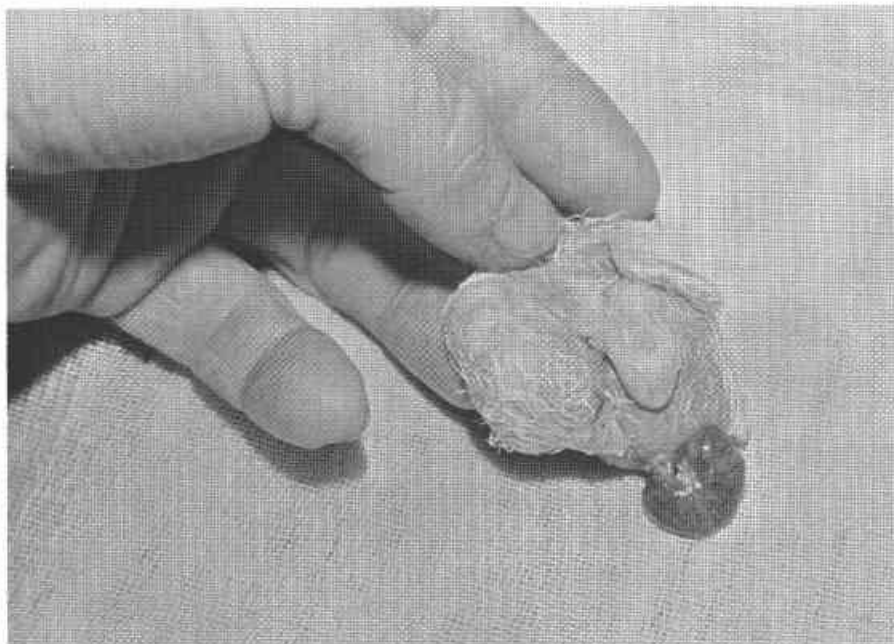
### **Problem Hatching**

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.

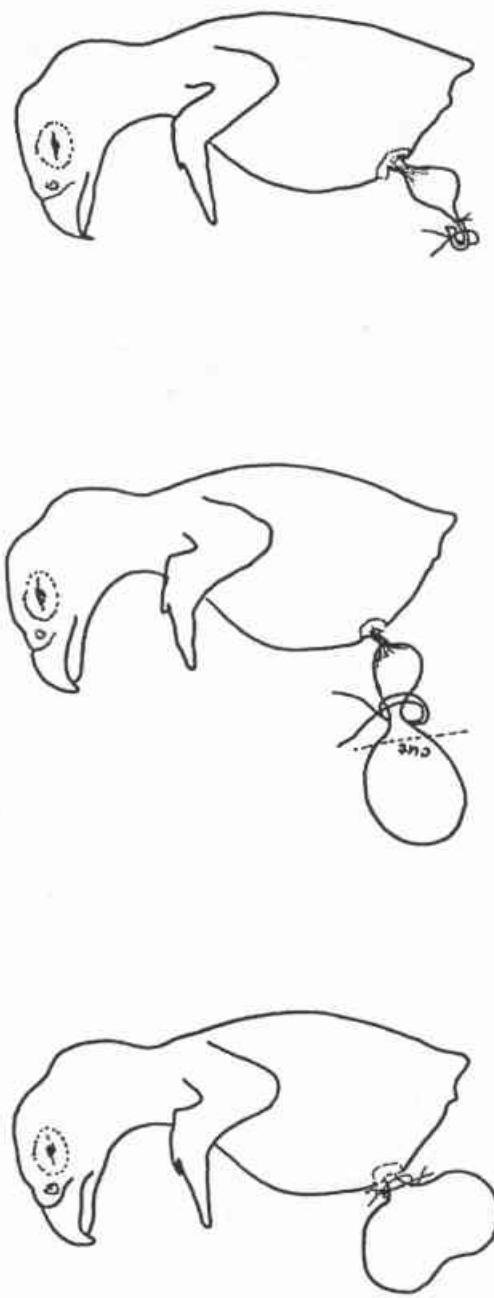
Extreme care is in order if the yolk sac is completely or partially unretracted (Fig. 33). Remove the chick from the shell very slowly. The membranes which form the yolk sac are supplied by a major blood vessel, so care must be taken to avoid rupture as that will cause bleeding and death. The yolk sac 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 sterilized 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 unretretracted yolk sac.

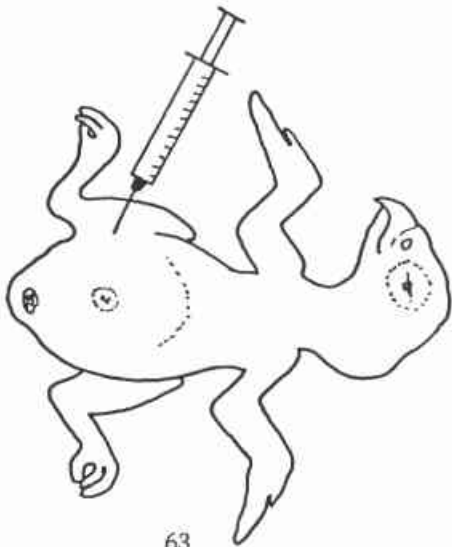
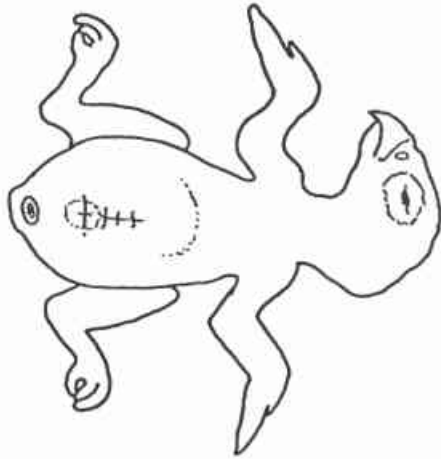
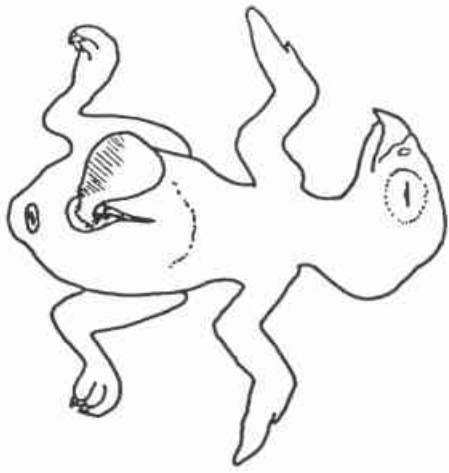
reinserted. With a swab dipped in antibiotic ointment, attempt to probe the intestine gently back into the body through the navel. Usually, the opening has closed too much to accomplish this. In that case, carefully insert the scissors into the umbilical opening and cut the ridge of tissue forming the 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 (1cc) 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



**Fig. 35** Technique for the reduction of the size of the yolk sac. Dan Konkel, 1983.

**Fig. 34** Procedure for complete yolk sac removal. 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.

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 antibiotic 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 breathe. 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 translucent 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.