The Egg—Development, Incubation, and Hatching

BEA ORENDORFF
WILD BIRD RESCUE INC.
BUTLER, KY

INTRODUCTION

Much of the information in this paper was obtained from the poultry industry, because that is where most of the research is currently conducted. However, the same principles apply to wild birds. Egg size, number of eggs per clutch, color, frequency of egg-laying, and shape are inherited. Regardless of a bird's age, the number of eggs it lays, their size, shape, shell color, texture, and strength can be affected by a variety of things including environmental stress, improper nutrition, medications, vaccinations, parasites, and disease.

Size—Egg size can vary greatly from one order of birds to another, as well as within families. Small birds generally lay eggs that are heavier in proportion to their body weight than those of larger birds. Some birds that have precocial young lay eggs that are relatively larger than the eggs of similarly-sized birds with altricial young. This is because precocial eggs contain more nutritive material and require longer to hatch but the young hatch more developed.

Number—Most passerine species lay two or three clutches of eggs per season, while birds of prey and precocial birds lay one because the young are dependant on their parents for a longer period of time than young songbirds.

It is believed that the number of eggs in a clutch has been determined by natural selection to the largest number of fledged young that a pair of birds is capable of producing in relation to the food supply available (Terres 1980). Romanoff (1949) states that the number of eggs depends on the amount of danger to which the species is exposed. Some birds have larger clutches in the first nest of the season, and a smaller number in the second or third.

Most birds are determinate egg-layers—they lay a certain number of eggs in a clutch, and will not lay more even if one or more eggs are removed from the nest. Other birds are indeterminate egg-layers—they will continue to lay eggs to replace those removed from the nest. For example, most ducks and geese are indeterminate egg layers as are some passerines and woodpeckers. The domestic chicken falls in the latter category (Romanoff 1949).

Color—Egg color is inherited and again, there are variations within families. In colored eggs, after the egg shell is formed, pigments (whose source is hemoglobin) are deposited during shell formation as a uniform ground color. After the shell is complete, other pigment may be added as spots, streaks, or blotches (Romanoff 1949). Typically, cavity nesters lay white or lightly speckled eggs, and birds that nest in open nests lay colored or heavily streaked or splotched eggs.

Frequency of laying—Frequency of laying varies as well. Most passerines, woodpeckers, ducks, and geese lay one egg every 24 hours. Birds that lay every 38 to 48 hours are usually the larger birds, such as waterbirds, birds of prey, and some geese. Swifts and hummingbirds also fall into this latter category (Terres 1980).

Shape—Egg shape depends on the species, as well as the limitations of the oviduct. Eggs can be oval, round, conical, or elliptical. However, within species the eggs are alike.

DEVELOPMENT

A female's reproductive system consists of one functional ovary and passageway or oviduct. A female chick embryo actually starts out with two ovaries, but the right one atrophies. Only the left one continues to develop and become functional (Marquand 1978).

Fertilization occurs about 24 hours before the egg is laid. The functioning left ovary consists of

Bea Orendorff has been a licensed avain rehabilitator since 1981 and the co-founder and past president of KWRA and OWRA. She is the editor of **Wildlife Rehabilitation Bulletin**, as well as the editor of **Wildlife Rehabilitation** (NWRA 2003 symposium proceedings). Bea is also a former member of the NWRA Board of Directors (1991–2004) and the 1997 recipient of the NWRA Significant Achievement Award.

a clump of undeveloped yolks or ova located just beneath the hen's backbone, approximately halfway between the neck and tail. As each egg cell is released from the ovary with the yolk, it is fertilized at the top of the oviduct. Then four layers of albumen (egg white) are deposited as the egg travels toward the infundibulum. Next, the egg acquires the first of its shell membranes moving down the infundibulum where it will spend 80 percent of the total time, and will acquire its outer shell and color. The total process takes about 24 hours (Brown 1985).

The avian egg contains all the essentials for life, including all eight of the essential amino acids, and the food supply that is needed by the chick until it hatches. The shell is porous to connect the inside and outside of the shell. The pores permit the exchange of gases and the loss of water. Carbon dioxide, oxygen, and other atmospheric gases can move through the pores. IMPORTANT: When handling eggs, always wear gloves.

Attached to the shell are two membranes, the inner and outer shell membranes. They protect the egg from bacterial invasion and help prevent rapid evaporation of moisture from the egg. An air cell forms between the inner and outer membranes because the egg is the same temperature as the hen's body temperature when it is laid. As the egg cools to room temperature, its contents shrink slightly. Air is drawn through the pores and forms an air cell at the larger end of the egg. During storage or incubation, the air cell increases in size. Close to the hatching time, the chick pushes its head through the inner membrane into the air cell to draw its first breath of air (Marquand 1978).

Other main parts of the egg are the albumen (egg white) and the yolk. The egg yolk contains all the fat, cholestero, and almost half of the protein, all the egg's vitamins A, D, and E, and zinc, most of the egg's phosphorus, manganese, iron, copper, iodine, and calcium. The egg white (albumen) contains about two thirds of the egg's liquid weight, most of the egg's protein, niacin, riboflavin, magnesium, potassium, sodium, and sulfur. Much of the calcium that is needed comes from the shell.

Incubation

Prior to incubation, all cells in the embryo look the same, and have the same function. However, that changes during the first four days of incubation. As cell division continues, the cells become different types of tissues and organs. Some cells develop into the circulatory system, others into the brain, and still others into muscles. In chickens, the first four days are a time of dramatic change. Mistakes sometimes occur in this process. If it is a serious mistake, the defect is lethal and the embryo dies. In the incubation process, these mistakes cause "early deads." If the biological mistake is not serious, the embryo may continue to develop longer before dying, or it may survive with a congenital defect.

Transporting eggs to your facility must be done with the minimum of rough handling as it may damage not only the egg shell, but may also disturb the arrangement of the egg contents. Jarring may separate the shell membrane from the egg membrane resulting in the formation of a "loose" air cell, consisting of several air bubbles (Romanoff 1960).

Dirty egg shells, cracks, or dents may allow contaminants to enter the egg. If the eggs are dirty, carefully wash them in a mild, warm soapy solution. If they are dented or cracked, cover the affected area with a thin coat of nail polish or Elmer's glue. Fertile eggs should be incubated within seven days after they are laid. The number of eggs that hatch begins to decrease if held too long. If it is necessary to hold the eggs before incubation, keep them at a temperature of 50 to 65°F. Refrigerator temperatures (around 45°F) will kill the embryo. The embryo may resume development if the temperature is above 75°F.

Successful incubation depends on maintaining favorable conditions for hatching fertile eggs (Figure 1). Four factors of major importance are temperature, humidity, ventilation, and turning. The incubation temperature of naturally incubated eggs is controlled by the hen who adjusts the egg's temperature by the amount of time she spends on the eggs.

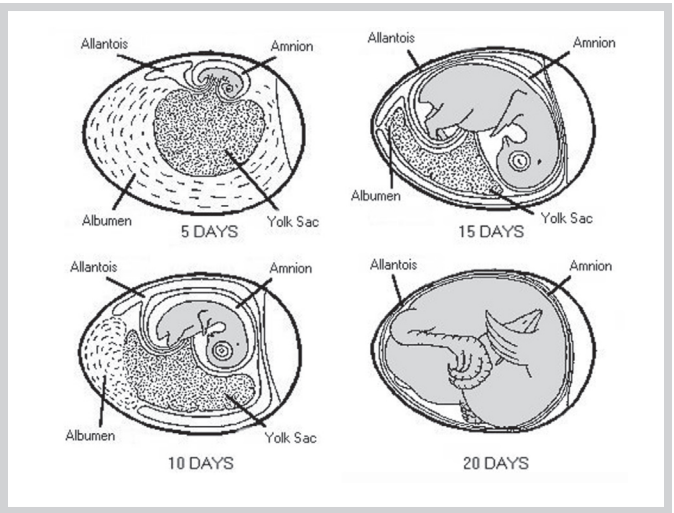

Figure 1. Embryonic development (Miss. State University 2003).

In artificially incubated eggs, we must ensure that all variants are accurate and within range to achieve high hatchability rates. Any degree of variability within each of these factors may decrease hatchability. Commercial incubators are automated to control all these factors. In small incubators, some of these factors must be controlled manually.

Commercial, air-circulated heat incubators are highly recommended and preferred by the author. These incubators have a fan to move the air around so that the temperature stays uniform around all the eggs' surfaces.

In a rehabilitation setting, if several people will be involved with the incubation project, it is best to keep a written record. When the hatch is completed, the chicks, shells, and unhatched eggs should be removed and the interior wiped clean with a soapy sponge. It should be permitted to air dry for several days before using it again or putting it in storage.

Temperature—The incubation temperature requirements for hatching eggs is surprisingly uniform. The eggs of almost all wild species can be incubated at the same incubation temperature.

The recommended temperature within an artificial incubator depends upon the type of incubator being used. If the incubator has a fan for air circulation, the temperature must be maintained at 99.5°F. Incubators without an air circulation system require a higher temperature—102°F. The reason for different temperatures is that circulating air warms all parts of the egg shell while still air temperatures are warmer at the top of the egg than at the bottom. Therefore, increasing the temperature at the top of the egg will compensate for the egg's cooler parts. The same average egg temperature of 100°F can be maintained (for the entire egg) if the higher temperature of 102°F exists at the egg's uppermost point.

Temperature must be closely watched, and the thermometer should be at the same level as the eggs. Do not allow the thermometer's bulb to touch the eggs or incubator. Do not allow temperatures to exceed these recommendations, even for only a short period of time. Although it is not recommended, slightly lower temperatures will not kill the chick embryos, but can increase incubation time, and produce weakened chicks. Temperatures only a degree or two above the recommended temperatures can kill chicks within 15 to 30 minutes, depending on how high the temperature is and the stage of development of the chick embryo.

Humidity and Ventilation—There is some confusion as to how the measurement of humidity is expressed. Most people refer to the level of humidity in terms of degrees Fahrenheit (wet-bulb) rather than percent relative humidity. The two terms are interconvertible and actual humidity depends upon the temperature as measured with a dry-bulb thermometer.

Rarely is the humidity too high in properly ventilated still-air incubators. The water-pan area should be equivalent to one-half or more of the floor surface area. Increased ventilation during the last few days of incubation and hatching may necessitate the addition of another pan of water or a wet sponge. Humidity is maintained by increasing the exposed water surface area.

The amount of moisture that is in the air is the relative humidity. It is usually measured by a wet-bulb thermometer. Function depends on the cooling caused by evaporating water. A thermometer is covered by a cloth sleeve that extends into a container of water. At a given temperature, high humidity causes water evaporation and cooling of the thermometer; therefore, the wet-bulb thermometer reading is similar to that of the dry-bulb thermometer. If the humidity is low, much evaporation occurs, resulting in a lowering of wet-bulb temperature; therefore, the wet-bulb temperature is much lower than the dry-bulb temperature.

Humidity must be regulated to prevent unnecessary loss of egg moisture. It must be maintained at 58 to 60 percent or 84 to 86°F wet bulb temperature for the first 18 days for chicken eggs and 68 percent and 91°F wet bulb temperature for the last three days. Too much or too little humidity in the incubator will cause hatching problems and the death of embryos.

If an incubator has too little moisture, the amount can be increased by increasing the area of water available for evaporation. A bigger pan can be used, or sponges can be placed in the water. The air flow through the incubator might also be decreased. Some air exchange between the inside and outside of the incubator should occur continuously to replace oxygen used by the developing embryos. When that need is met, air exchange can be managed according to heat and humidity requirements. More air flow tends to lower incubator temperature and humidity.

Ventilation is also very important during the incubation process. While the embryo is developing, oxygen enters the egg through the shell and carbon dioxide escapes in the same manner. During hatching, the chicks require an increased supply of fresh oxygen. As embryos grow, the incubator air vents are gradually opened wider to satisfy increased embryonic oxy-

gen demand. Care must be taken to maintain humidity during the hatching period. Unobstructed ventilation holes, both above and below the eggs, are essential for proper air exchange.

Turning—In commercial incubation, eggs are placed in flats, and the flats are automatically tilted back and forth every hour. The purpose of turning is to prevent the developing embryo from sticking to the shell.

In small incubators that do not have an automatic turner, it is recommended that eggs are turned at least three times a day, five times is better. Eggs must always be turned an odd number of times per day so that no one side of the egg is down for two consecutive nights, the period during which the eggs will stay unturned. This will ensure that the embryo does not rest on the same side, and risk becoming deformed. Don't forget to wear gloves when turning the eggs.

The author always marks the opposite sides of each egg with a soft pencil, not a pen or marker—a circle on one side and an X on the opposite side—to help keep track of which side is down every night. Eggs should not be turned the last three days before hatching because, during that time, the embryo positions itself so it can break into the air space at the large end of the egg, in preparation for the actual hatching. Of course this may not always be possible if eggs have already been partially incubated by the time they are received into rehabilitation.

Candling

Rehabilitators usually do not know whether eggs they receive have already been incubated by the parent bird; candling them can help determine the stage of development (Figure 2). It is safe to assume that eggs are fertile unless they have undergone severe temperature fluctuations. Few wild bird eggs are infertile—fertility is usually very high because wild birds must be healthy to develop eggs.

Assuming an egg was laid on the day it is received, the first blood vessels, meandering along the inside of the egg shell, should be visible in three days (Figure 3). Candling at later stages of incubation should show the embryo growing and filling up the space inside the egg. By day eight or nine, the chick may be startled by the light, and its movement can be easily observed. If the embryo is about to hatch, it is possible to see its beak poking within the air space. If development does not occur within three days of admission, the eggs may not be fertile, or there may be serious incubation problems.

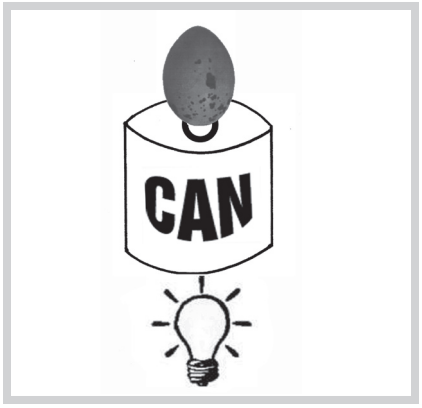

Figure 2. Egg candler.

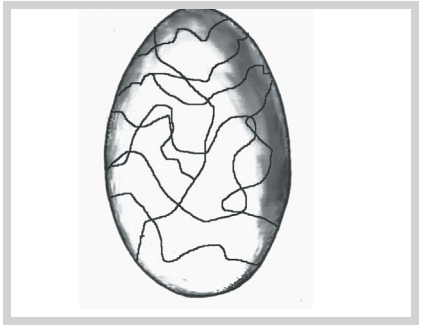

Figure 3. Fertile egg in the third day of development–blood vessels are visible.

Hatching

Depending on the species and assuming everything is normal, three days before hatching several major events occur. The chick pokes its beak through the inner membrane into the air cell, then begins to breathe, and rests for a time. It can be heard making faint peeping sounds, if placed next to one's ear. The allantois, which has served as its lungs, begins to dry up. The last step before the chick breaks out of its shell is to absorb the remaining yolk into its abdomen through the navel.

The normal hatching position is with the head in the large end of the egg, under the right wing, with the legs drawn up toward the head. Using its egg tooth and the enlarged muscles on the back of the neck, the chick punches a small hole in its shell (pipping). Simultaneously, the blood vessels circling the inside of the egg shell start drying up. The chick then continues the process all the way around the shell. When the circle is almost complete, the large end of the egg can break away easily. Sometimes, the chick may rest for a while, partially in and out of the egg shell, before proceeding with the final push (with its legs) out of the shell. At this point, the chick is exhausted and rests while the navel openings heal and its down dries. The egg tooth falls off a few days after hatching. In passerines and other small species, this happens around day three after hatching.

Hatching Problems (Table 1)

If embryos develop to the pipping stage, or the first shell-cracking at hatching, they are normally healthy enough to hatch unless incubation problems prevent it. Problems are usually caused by either poor ventilation or improper humidity.

Air exchange—The air exchange requirement within an incubator is greatest during the last day of incubation. The embryo's oxygen requirements continually increase during development, and particularly when breathing, using the respiratory system just before hatching. People frequently restrict the incubator's vents at this time in an attempt to boost incubator humidity. Instead of helping the chick hatch, the chick is suffocated from lack of ventilation. Never decrease ventilation at hatching in an attempt to increase humidity. Increase humidity by other methods.

Position—If the head is positioned in the small end of the egg, the chick's chances of survival are reduced by as much as fifty percent. Just as a wrong position in humans makes birth difficult, so does the wrong position in birds make hatching more difficult, if not impossible. In the wild that rarely happens, but when it does, such chicks perish. In a rehabilitation facility, we don't always know the stage of the egg's development, nor is it always possible to see the chick in the egg, even with candling. Eggs that were incubated by ignorant people may have been jarred, over- or under-heated, contaminated, or the humidity may have been too high or too low. Deaths can be produced from too much humidity during the entire incubation period or from too little humidity during the hatching period. All these factors can affect the embryo's development and position within the egg.

In the author's experience, most chicks, that are turned towards the wrong end of the egg at hatching time, have not survived the process or, even if helped to hatch, died shortly afterwards. Those that did survive, often were weak, and although they were coaxed along, usually died within days.

Hatching assistance—Chicks that have trouble completing the hatching process may be assisted. Keep in mind that the entire process, from the first crack in the shell to the chick actually hatching, can take several hours or even days. In songbirds the process takes just a few hours. If the shell is pipped and there is movement but progress after one to two hours has ceased, two to three tiny pieces of the shell can be removed with a clean pair of tweezers. If bleeding occurs, the chick is not ready to hatch—the blood vessels have not dried up. Removing these small shell pieces should signal the blood vessels to start drying up. Timing is critical at this stage—removing too much of the shell too soon can cause the chick to die.

The chick should now be allowed to rest for one to two hours. If during that time no progress is made, another few small shell pieces should be removed. If the inner membrane is intact, a small hole should be punched into it with a sterile needle to allow the chick access to fresh air. If the humidity was allowed to decrease after the chick pipped the shell, the membranes within the shell can dry and stick to the chick. This prevents the chick from turning inside the shell and stops the hatching process. The chick eventually dies. If the membranes around the shell opening appear dried and shrunken, the opening should be misted lightly (so as not to drown the chick) with a water mister.

After the chick has hatched, it must be allowed to rest, dry, and demonstrate that it is viable. In

Table 1. Hatching Problems (Mississippi State University 2003).

Symptoms	Probable Cause	Corrective Measure
Embryos dead at early stages	Improper temperatures	Follow recommended incubation temperatures.
	Improper egg turning	Turn at least 3 times daily.
	Improper ventilation	Increase ventilation rate in incubator and/or room, but avoid drafts.
Pipped eggs not hatching	Insufficient moisture	Increase humidity during the hatching period.
	Improper ventilation	Increase ventilation rate in incubator and/or room, but avoid drafts.
Embryos sticking to shell	Low humidity (especially during hatching)	Increase incubation humidity by increasing water evaporation. Embryos dried too much.
	Excessive ventilation rate	Reduce ventilation. Maintain minimum air exchange to prevent suffocation of embryos.
Crippled chicks	Improper temperatures (usually high)	Follow recommended incubation temperatures.
	Low incubation humidity	Increase incubation humidity by increasing water evaporation. Embryos dried too much.
	Improper egg position or turning	Turn eggs at least 3 times daily. Do not turn eggs within 3 days of hatching.
Mushy chicks	Low temperature / poor ventilation	Follow recommended incubation temperatures. Increase ventilation but avoid drafts.

waterfowl, viability is demonstrated if, within a few hours after the down has dried and is fluffy, the chick is standing, moving around (even though it is wobbly), and pecking. In songbirds, the chick should be able to raise its head and gape for food.

Artificially incubated eggs in our profession usually suffer from complications. Eggs that require hatching assistance in a rehabilitation facility does not mean that the chicks within were already weak and might not have survived the hatching process, had they been incubated naturally. Rehabilitators usually receive eggs that have been chilled or badly jarred during transport to the facility, or kept for a number of days before they are turned in. People often think egg incubation is a fun, family project.

Unfortunately, despite a rehabilitator's best efforts, many chicks will not survive the hatching process because of what they went through from the time they were taken from their nest. So, please keep in mind that after you have spent all this time incubating the eggs, perhaps even assisted their hatching, you may end up euthanizing them.

Ethics

- Should we incubate and hatch eggs?
- Should we do it as a learning experience?
- Should we take the biologist's approach—an egg removed from the wild is lost to nature, therefore dead, and we should dispose of it?
- Should we take the humanitarian approach—the chick in this egg deserves a chance and it was not its fault that someone took it out of its nest, or cut its nest down, and we should do whatever it takes to give it life?
- Should we incubate and hatch only threatened or endangered species?
- Are we meddling in nature when we incubate and hatch eggs of any wild bird species?

Glossary (Cornell University website)

Allantois—A sac connected to the embryo's abdomen making respiration by the embryo possible; it also stores excretions, absorbs albumen used for food by the embryo, and absorbs calcium from the egg shell for the structural needs of the embryo.

Amnion—A transparent sac, filled with colorless fluid, surrounding the embryo; the amnion and amniotic fluid protect the developing embryo from shock and permit it to exercise.

Broody hen—A hen that through hormonal changes has undergone marked changes in behavior and physiology, including cessation of laying and development of the maternal instincts. A hen that wants to sit on eggs to hatch them and to brood chicks.

Egg tooth—A tiny, sharp, horny projection on the end of the chick's beak used to peck holes in the shell.

Chorion—A membrane that surrounds both the yolk sac and the amnion; it has no apparent initial function but later fuses with the allantois to form the chorio-allantois membrane.

Extra embryonic membranes—Membranes outside the embryo's body that make respiration, nutrition, and secretion possible and provide protection; they include the yolk sac, amnion, allantois, and chorion.

Hatchability—The quality or state of being hatchable.

Pip—To break through or peck holes in the shell by the chick.

Literature Cited

Brown, A. F. 1985. *The Incubation Book.* World Pheasant Association. Surrey, England: Spur Publications Co.

Cornell University website (www.cornell.edu). 2003.

Marquand, J. 1978. *The Avian Embryo.* Ohio State University Extension, Bulletin 633.

Mississippi State University website (www.msstate.edu). 2003.

Romanoff, A. L., and A. J. Romanoff. 1949. *The Avian Egg.* New York, NY: J. Wiley and Sons.

Romanoff, A. L. 1960. *The Avian Embryo, Structural and Functional Development.* New York, NY: The MacMillan Co.

Terres, J. K. 1980. *Audubon Society Encyclopedia of North American Birds.* New York, NY: Alfred P. Knopf.

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