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Beginning of LIFE

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Virginia Cooperative Extension

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VIRGINIA STATE UNIVERSITY

Beginning of LIFE

Revised by Curtis Novak, Assistant Professor and Extension Specialist, Department of Animal and Poultry Sciences, Virginia Tech

Catalina Troche, Research Specialist, Department of Animal and Poultry Sciences, Virginia Tech

www.ext.vt.edu

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Foreword

This publication is a reference for leaders and teachers of the 4-H school-enrichment project entitled "Beginning of Life." 4-H projects offer a number of resource materials and educational methods to supplement the school, community, and home environments to support positive youth development. As you involve your young people in this program, introduce it as a Virginia 4-H program. A number of other 4-H projects covering a broad range of topics are also available through your local Virginia Cooperative Extension (VCE) office.

The purpose of all 4-H programs is to develop youth through the involvement of their parents and volunteers who organize and conduct learning experiences in a variety of settings. 4-H is concerned with the four-fold development of each individual, symbolized by the 4-H emblem. This emblem is a green four-leaf clover with a white H on each leaf.

The four H's stand for Head, Heart, Hands, and Health. As a teacher-leader you can help you students develop their:

Heads – by teaching youths how to learn, think, make decisions, and obtain new knowledge.

Hearts – by teaching youths how to work with others, develop values and attitudes, accept social responsibilities, and develop pride in accomplishment.

Hands – by teaching youths new skills and how to improve those they possess, how to be leaders, and how to work cooperatively with others.

Health – by teaching youths how to care for their health and well-being, and those of others, by developing practices that will enhance social, mental, and physical health.

You will find the 4-H project a stimulating educational experience for you and your students. Perhaps the youths will want to pursue other projects available through 4-H. Please refer any interested youths to the 4-H Extension agent in your county or city.

Introduction

The "Beginning of Life" 4-H project is designed to help youth obtain a better understanding of life and embryonic development. This publication will help you – the teacher, the project leader, or the individual doing an independent study – become more familiar with the details of embryonic development and the "Beginning of Life" project. This manual will provide you with enough information to demonstrate the basic processes of development. It is important for you to be able to explain what is happening and why it is happening as an embryo develops.

The bird egg is an excellent educational subject for the study of embryology. First, unlike most animals, the embryonic development of the birds takes place within the egg and outside of the body of the female. Second, the egg is small and readily available. Third, the incubation period is short enough to maintain the interest of even the youngest student.

Extension professionals, teachers, and youth should feel free to contact the poultry science faculty at Virginia Tech with specific questions that may arise. However, it is important that youth understand that part of science projects and research is learning to strengthen their library skills. This means that they need to learn how to research available reference material as they proceed with their science projects.

SOLs:

Math: 3.1, 3.8, 3.15, 3.15, 3.16, 3.17, 4.1, 4.5, 4.11, 4.12, 4.19, 5.1, 5.3, 5.11, 5.12, 6.1, 6.9, 6.10

Science: 3.1, 3.8, 4.1, 4.4, 4.5, 5.1, 5.5, 6.1

English: 3.2, 4.2, 5.1, 5.3, 5.7, 5.8, 6.1

Visual Arts: K.16, 1.5, 1.9

History and Social Sciences: 2.1

This Project should

- Teach responsibility and caring for a living thing.
- Teach respect for life and the value of living things.
- Emphasize a "hands-on" experience with living things.
- Help youth grasp developmental processes and stages of growth.
- Introduce and explain the topic of reproduction to youth.
- Introduce youth to scientific processes and other areas of science.

Everyone involved in this detailed experiment of incubating the eggs project will be fascinated by the wonders of the "Beginning of Life."

A special note about this material: This manual will use the chicken as the basis for discussion. However, with only slight variations, it could be used for any bird; in fact, the coturnix quail is often used.

Planning and Scheduling the Project

Planning is crucial to the success of the "Beginning of Life" project. This section is designed as a check list to help you plan the project activities in an orderly and timely manner. As you complete each part of the planning process, check it off with a pencil so you know what has been finished. Using a pencil allows you to erase the checks at the completion of the project and lets you use the same list for a number of years. Complete the following planning activities to help ensure a successful project.

Six Months Before You Plan to Start the Project

_____ Plan the exact dates during which you wish to do this project, which is usually used as a supplement to a specific curriculum like biology, human sexuality, human development, or other related topic. It is extremely important that you understand that this is a continuous project for a 25-day period. Plan the project between holidays. It is usually best to plan to set your eggs on a Wednesday. This allows you to prepare on Monday and Tuesday and ensures that the chicks will not hatch on a weekend.

Dates of the embryology project: ____/_____/____ to ____/____/____.

Contact your local Virginia Cooperative Extension office and be aware of any possible requirements for enrollment or egg procurement.

_____ **Before you begin the project, consider what will be done with the chickens that are hatched.** If possible, line up someone who has experience in keeping chickens and is willing to take them. Do not hatch chicks and then abandon them or give them to someone who is unable to care for them properly. Remember that Virginia state law requires chicks to be given in groups of six.

_____ Order the eggs you will need as soon as possible. To ensure egg availability, order the eggs at least one to three months in advance of the day that you need them. For a basic observation and hatching project, 12 eggs per incubator are adequate. If you are planning to do an experiment, additional eggs may be required. Most private breeding farms that supply fertile eggs require notice at least a month in advance. Be certain that the arrival of the eggs coincides with the starting date of your project.

_____ Secure an incubator at least a month before the start of the project and be sure it is in proper working condition.

_____ Prepare lesson plans and order any materials you need to support the program.

Additional Resource Materials

Plan any activities you wish to incorporate into the project well in advance so that any materials you may need can be secured before the project begins. Once you have obtained all of the needed materials, you are ready to implement a successful project.

The following is a checklist of materials needed, where to obtain them, and the time frame required to secure them.

A. Incubator (consider an incubator with a large viewing area such as the "Picture Window Hovabator," which is recommended. Fans are recommended. Automatic turners are not recommended.):

- Purchase from local feed and seed store.
- Order from supply company (see VCE Small Flock Fact Sheet #22 "List of Companies Which Deal in Small Incubators").
- Some local VCE offices have incubators available for loan.

Time Frame: Order two months prior to start of project.

B. Fertile Eggs:

- In some cases, chicken and coturnix quail eggs can be obtained through your local VCE agent.
- Many times fertile eggs can be obtained from local farmers of hobbyists.
- Chicken eggs can be purchased from:

  Brickland Breeder Farms
  Rte. 1, Box 312-B
  Kenbridge, VA 23944
  (Attention: Victoria Martin)

- Quail eggs can be purchased from:

  G.Q.F.
  P.O. Box 1552
  Savannah, GA 31498
  Telephone (912) 236-0651

Time Frame: Order at least one to three months prior to start of project.

C. Resource Materials Available Through Your VCE 4-H Agent:

- Literature – contact your local VCE office for additional resource and supplemental literature for this and other projects.
- Internet. You can locate Curtis L. Novak at Virginia Tech by connecting to *http://www.apsc.vt.edu/Faculty/Novak/Novak.html*
- The specific page for "Beginning of Life" at *http://www.ext.vt.edu/resources/4h/4hpubs/availonline.html*

Time Frame: Order one month prior to start of project.

D. Other Educational Aids:

Carolina Biological Supply
2700 York Rd.
Burlington, NC 27212
(800) 334-5551

Wards Natural Science, Inc.
5100 West Henrietta Rd.
P.O. Box 92912
Rochester, NY 14692-9012
(800) 962-2660

Time Frame: Order educational aids at least one month prior to start of project.

E. Feed, Feeders, and Waterers:

- Obtain from local pet stores or feed-and-seed farm-supply stores.

Time Frame: One week prior to expected hatch date.

F. "Development of The Chicken Embryo" Jamesway Incubator Company:

- Excellent color poster that follows the development of the embryo from the development of the egg to hatch.

Time Frame: Contact Jamesway Incubator Company for availability and pricing.

Contact: Jamesway Incubator Company
1105-C Technology Drive
Indian Trail, NC 28079
(704) 821-3168
(800) 438-8077
http://www.jamesway.com/

Starting the Project

_____ Set up and start running the incubator 48 hours before eggs are to arrive.

_____ Prepare the students for the project at least a day before the project begins. Help them understand the principles of incubation and embryology. Discuss what you wish to accomplish and what role they will play in reaching the goals of the project. This includes preparing calendars and other project resources.

_____ Bring the eggs to room temperature at least two hours before putting them in the incubator.

_____ Mark the eggs with "X" and "O" on opposite sides to aid in daily turning.

_____ Set the eggs in the incubator.

_____ Turn the eggs three times daily.

_____ Keep water pans full at all times. Always add water that is warm to the touch.

_____ Keep daily records of all activities involving the eggs (i.e., turning, temperature, water added, and candling). These records are extremely helpful for trouble-shooting causes of poor hatches.

_____ Candle the eggs every three days to check progress.

_____ Stop turning eggs three days prior to expected hatch.

_____ Prepare brooding area two days prior to expected hatch.

_____ Remove the chicks from the incubator and place them in a warm brooder within 4 to 6 hours after they hatch.

_____ Remove and discard all unhatched eggs within 48 hours after the first chicks' hatch, then disconnect incubator power.

_____ Clean and disinfect the incubator as soon as the power is disconnected. If dirt dries to the surface, it will be difficult to remove.

_____ Let the incubator dry out. Then store in a safe, cool, and dry place.

About the Chicken

History

The domestication of the chicken dates back to 2000 B.C. The domestic chickens' ancestry can be traced back to four species of wild jungle fowl from Southeast Asia. However, the Red jungle fowl (*Gallus gallus* or *Gallus bankiva*) is the most commonly found wild species in the world today and is considered the main ancestor of the domestic chicken. The chicken belongs to the genus *Gallus* of the family *Phasianidae*. Domestic chickens are simply classified as *Gallus domesticus*.

The sport of cockfighting had tremendous influence, not only in the domestication of the chicken, but also on the distribution of fowl through out the world. After centuries of selection and breeding for numerous extremes, chickens now exist in many colors, sizes, and shapes. There are more than 350 combinations of physical features known today. In 1873, the American Poultry Association was organized for the purposes of adopting standards of excellence and establishing a way of classifying the various breeds.

Although the purebred poultry industry served as the foundation for the development of the commercial industry, the two industries soon developed very different types of domestic fowl. While the purebred exhibition industry continued to select and breed fowl for standard conformations and plumage colors, the commercial industry developed specialized hybrids for meat and egg production. Today, the two industries are very different: The purebred fowl of today are basically the same as they were 100 years ago and are mainly raised as a hobby; whereas the commercial poultry industry has developed into a science which produces highly nutritious meat and eggs with extreme efficiency.

Breeds and Varieties

The breeds and varieties of chickens are so numerous that it would be impossible to discuss all of them in detail at this time. However, a basic knowledge of how to identify and classify fowl may be helpful. Domestic fowl are divided into classes, breeds and varieties.

Class: A grouping of breeds according to the geographic area of their origin or to similar characteristics.

Breed: An established group of individuals with similar physical features (i.e., body shape or type, skin color, number of toes, feathered or non-feathered legs) that when mated with others of its own kind produce offspring that have the same characteristics. The Plymouth Rock breed is a good example.

Variety: A sub-division of a breed. Differentiating characteristics include plumage color and pattern, comb type, and the presence of beards or muffs. For example, the Plymouth Rock breed is available in many colors – Barred, White Buff, Partridge, Silver Penciled, etc. In each, the physical shape and features are the same but the feather color and pattern differ, which constitutes each as a separate variety.

Some of the more common breeds and varieties of domestic chickens include:

A. **New Hampshire Red** – has yellow skin, lays brown-shelled eggs, and has orange-red adult plumage. This is a dual-purpose breed, which means it has been selected for both a meaty body and to produce eggs.

B. **Rhode Island Red** – is similar to New Hampshire Red except it is usually a better layer and the Rhode Island Red has deep-red adult plumage. The chicks of Rhode Island Reds are brown in color.

C. **Barred Plymouth Rock** – is a dual-purpose chicken that has gray and white striped plumage. The chicks are easily identified by the black fluff with a white spot on the tops of their heads. This breed was developed in America during the 19th century.

D. **Cochin** – is mainly raised as an ornamental fowl, but the females are frequently used to naturally incubate and brood the chicks of other fowl. The Cochin's origin is traced to China but the big, fluffy balls of feathers as we know them today were further developed in America. The Cochin has feathered shanks and extremely loose, soft feathers that give it its fluffy appearance.

E. **Cornish** – was developed as the ultimate meat bird and has contributed to build the vast broiler industry of the world. The Cornish originated in England.

F. **Leghorn** – is the grandparent of the modern white-egg industry. Originating in Italy, the Leghorn has a large single comb and is flighty by nature. Most chicks hatched from white shelled eggs will be white Leghorn-type chickens.

G. **Polish** – is another unusual and beautiful breed. It has a crest or hat of feathers on top of its head.

H. **Frizzle** – has a genetic modification that causes the feathers to curl back towards the bird's head instead of lying naturally.

I. **Naked Neck** – has a bare neck; feathers are totally absent. This single gene trait affects the arrangement and number of tracts over the chicken's body.

J. **Silkie** – is a blue skinned chicken used for ornamental purposes. This breed appears to have hair instead of feathers. This is a genetic trait that affects the barbules of the feathers so the feather does not keep its normal texture and appearance. The barbules are small hook-like structures that hold the barbs of the feather in place.

K. **Araucana** – was discovered in South America and is nicknamed the Easter egg chicken because of the blue and green eggs it lays. This is again a genetic modification in which a blue cuticle is applied to the egg. When introduced to the brown-egg layers, the result is an olive-green shell; introduced to white-egg layers, the result is a blue shell.

L. **Bantam** – is the miniature of the poultry world. The word "bantam" is the term used to classify the over 350 breeds and varieties of true-breeding miniature chickens. There are bantams of almost every breed of large chicken, but there are some types for which there is no large counterpart. Bantams are purebreds raised for exhibition and hobby. Their small size and numerous shapes, colors, and personalities give them a broad appeal to people who live in urban areas.

Commercial Poultry

Over the years, traditional breeds have lost their commercial importance and crossbreeds and hybrid strains have been developed into the modern chicken.

In the modern *Egg Industry*, the birds are hybrid White Leghorns or sex-linked hybrids that resemble New Hampshire Reds and Barred Plymouth Rocks. Sex-linking is where a plumage trait, like slow feathering or a certain color pattern, is linked to the sex chromosome so that there is a distinct physical difference between the sexes of day-old chicks. This saves time and money separating the females for production. Today's egg producing hens can lay over 300 eggs per year; this is over twice the average of 150 eggs per year in 1947.

The modern *Broiler Industry* has developed a hybrid that is unlike any other breed. Twenty years ago, it took 14 weeks to achieve a 5-pound market weight. Today's broiler can achieve a 4-pound market weight in 6 weeks. These advances are the result of scientific progress in genetic, nutritional, and environmental research.

The modern *Turkey Industry* has developed a hybrid white turkey that is larger and faster-growing than purebred or wild turkeys. The modern hybrid turkeys are so large they can no longer breed naturally. All modern turkeys are artificially inseminated. Artificial insemination allows selective breeding of the sexes so that breeders can raise fewer males and achieve higher rates of hatchability.

Biology of the Fowl

Let's take a look at the internal and external biology of the chicken. The chicken is an interesting creature when observed from a biological standpoint. The chicken has a comb, which is unique. It has a high rate of metabolism, is a rapid breather and digests its food relatively quickly. The body temperature varies, but averages around 106ºF. Let's start with the terms for the chicken's exterior features.

Interesting Facts About The Exterior Features Of The Chicken (see Figure 1)

The ***Comb*** of a chicken functions as its cooling system. Chickens do not sweat like humans.
The chicken cools itself by circulating its blood throughout its comb and wattles. The comb in ascent operates like the radiator in a car. There are seven different types of combs in chickens. The four most common types of combs are shown in Figure 2.

The ***Earlobe*** color can tell you what color egg the chicken will lay. If the chicken has a white earlobe, it will lay a white-shelled egg. If it has a red earlobe, it will lay a brown-shelled egg. There is one exception to this rule: Aracuanas lay blue- and green-shelled eggs.

By observing the ***Hackle*** (neck) and ***Saddle*** (back) feathers of an adult chicken, you can determine its sex. Male hackle and saddle feathers come to a distinctly pointed tip and are more shinny. Female hackle and saddle feathers have rounded ends. The

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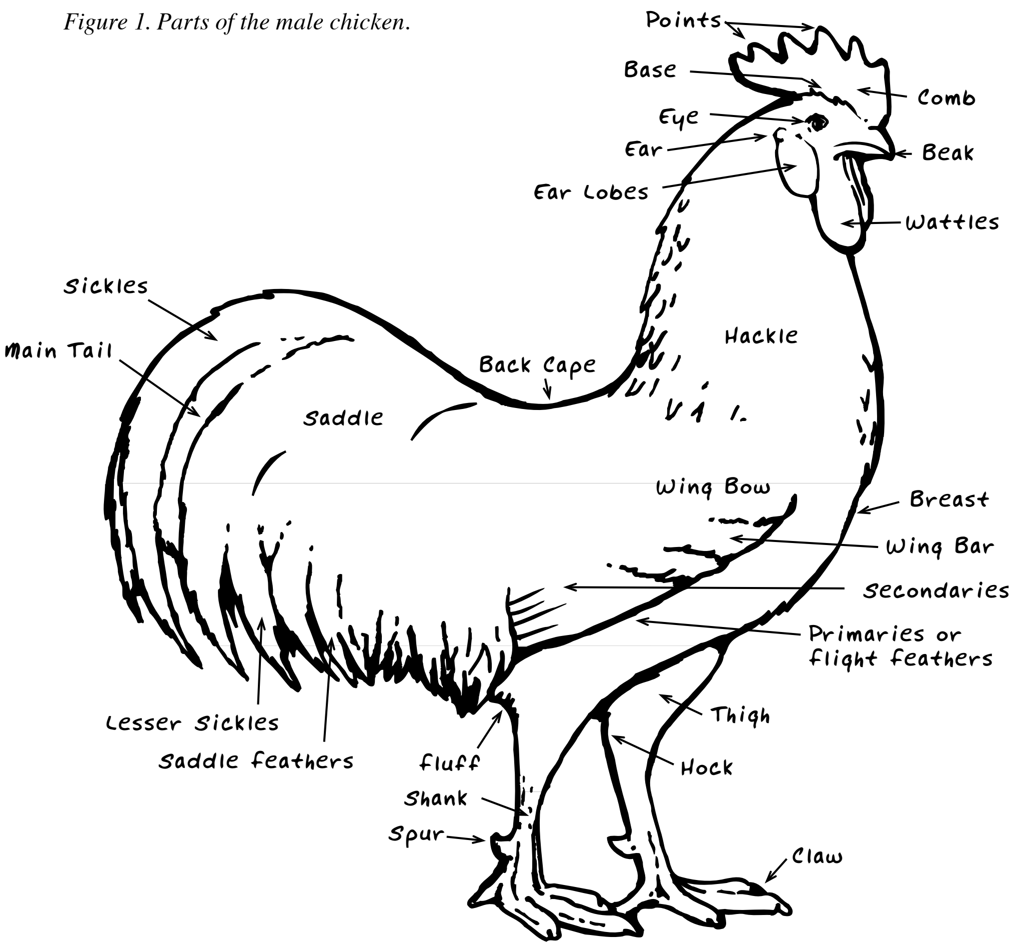
Figure 1. Parts of the male chicken.



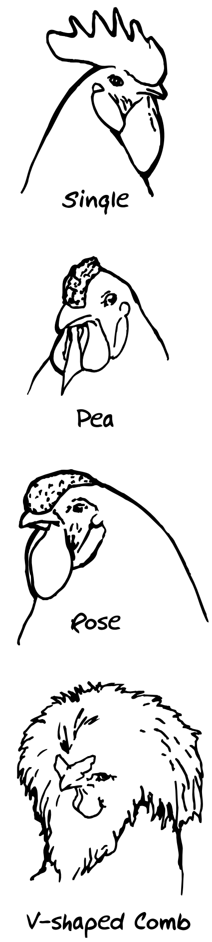


Figure 2. Four comb types.

breeds of "Seabright" and "Campine" are the only exceptions. In these two "hen-feathered" breeds, the feathers are alike in both sexes.

Feathers basically serve as the bird's protection. They can insulate the bird from the cold, protect the bird's skin from getting wet, and can help the bird fly or glide to safety. Although feathers cover most of a bird's body, they all grow from certain defined areas of the bird's skin called "feather tracts." The first indications of feather tracts appear during the fifth day of embryonic development when the feather *papillae* appear. *Papillae* is Latin for "pimples" and that is what they look like on a developing embryo.

The ***Skeleton*** of the fowl is compact, lightweight, and strong. Birds have many hollow bones that are connected to the respiratory system; these are the bones of the skull, humerus, clavicle, heel, and lumbar and sacral vertebrae. Another interesting feature of chicken bones is called medullar bone. This type of bone fills the narrow cavities in the long bones of the chicken and provides a readily available source of calcium for eggshell formation when calcium intake is not sufficient. Medullar bone is found in the tibia, femur, pubic bones, sternum, ribs, ulna, toes, and scapula. (see Figure 3).

Chicken Digestive System

The chicken has a simple digestive system, with few to no microorganisms living in the digestive system to help digest food as in ruminants such as cattle. Chickens, much like humans, depend on enzymes to aid in breaking down food so it can be absorbed.

The beak of the bird replaces the mouth and lips. The crop is a pouch formed to serve as a storage area for the food until it can be passed along for digestion in the gizzard and intestines. The proventriculus is the true stomach of the bird, from which hydrochloric acid and pepsin (an enzyme) are secreted to aid in digestion. The gizzard is the oval organ composed of two pairs of thick red muscles. These muscles are extremely strong and are used to grind or crush the

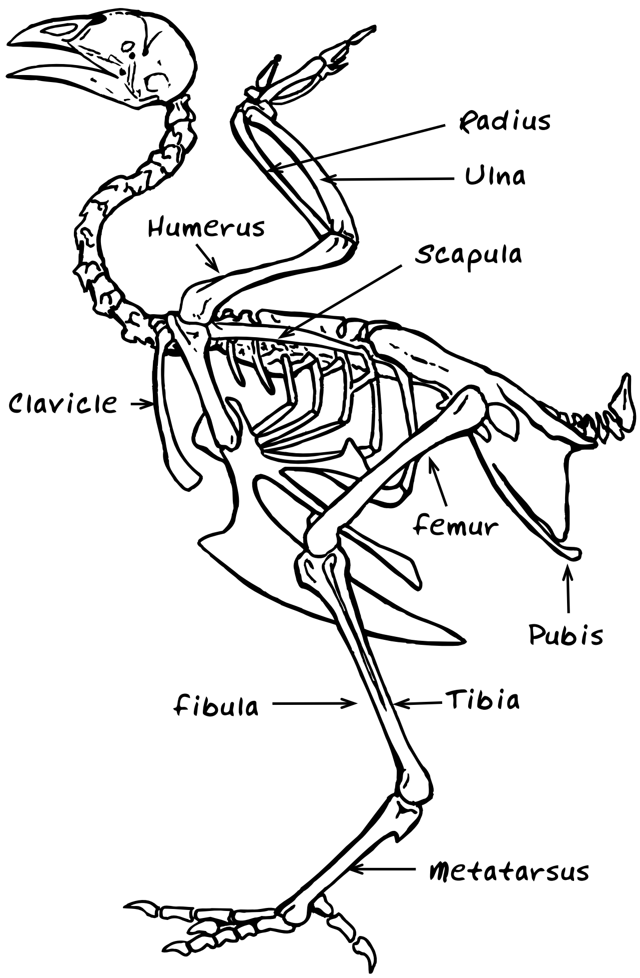


Figure 3. The skeleton of a fowl.

food particles. This process is aided by the presence of grit and gravel picked up by the bird. The digestion and absorption of food take place primarily in the small intestine. It usually take about 2.5 hours for food to pass through the digestive tract from beak to cloaca.

The Reproductive System and Fertilization

The Rooster

The male fowl has two testes that are situated along its back. These never descend into an external scrotum, as do those of other farm animals. Some male chickens are "caponized" or castrated (surgical removal of the testes) to make them fatten more readily. The operation is relatively simple and requires no stitches to close the incision.

A **testis** consists of a large number of very slender, much-convoluted ducts, from the linings of which the sperm are given off. These ducts appear in groups separated by delicate membranes that extend inward from a parent membrane that surrounds the testis. They all lead eventually to the ductus deferens, a tube that conducts the sperm to a small papilla; together, the two papilla serve as an intermittent organ. They are located on the rear wall of the cloaca.

The rooster responds to light in the same manner as does the hen. Increasing day length causes release of hormones from the pituitary. This in turn causes enlargement of the testes, androgen secretions and semen production, and stimulates mating behavior. Males used by breeders need to be lighted properly for maximum fertility and should not be lighted to stimulate gonad development until they will be used. The male should be lighted two weeks prior to the females for best fertility of the first eggs.

The Hen

The reproductive system of the female chicken is in two parts: the ovary and oviduct. Unlike most female animals, which have two functioning ovaries, the chicken usually has only one. The right ovary stops developing when the female chick hatches, but the left one continues to mature.

The ovary is a cluster of sacs attached to the hen's back about midway between the neck and the tail. It is fully formed when the chicken hatches and contains several thousand tiny ova, each ovum within its own follicle. As the female reaches maturity, these ova develop a few at a time into yolks.

The oviduct is a tube-like organ lying along the backbone between the ovary and the tail. In a mature hen it is approximately 25 to 27 inches long. The yolk is completely formed in the ovary. When a yolk is fully developed, its follicle ruptures, releasing it from the ovary. It then enters the infundibulum, the entrance of the oviduct (see Figure 1 on page P-10).

All of the other parts of the egg are added to the yolk as it passes through the oviduct. The chalazae, albumen, shell membranes, and shell are formed around the yolk to make the complete egg, which is then laid (see Figure 5.) This complete cycle usually requires a little more than 24 hours.

About 30 minutes after the egg is laid, another yolk is released and the process repeats itself (see Table 1.)

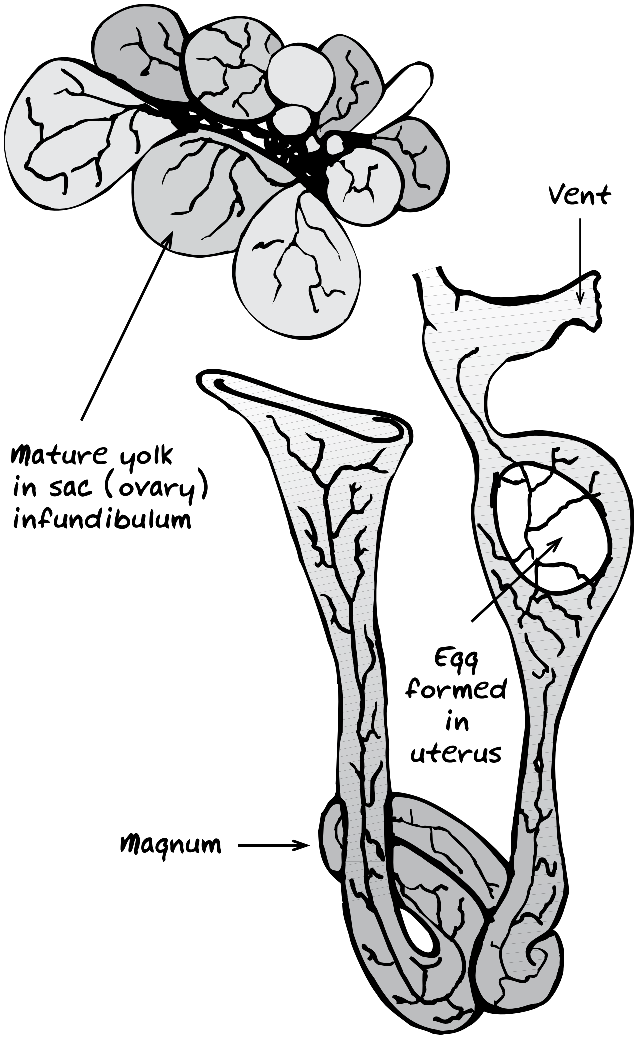


Figure 4. Reproductive organs of the hen.

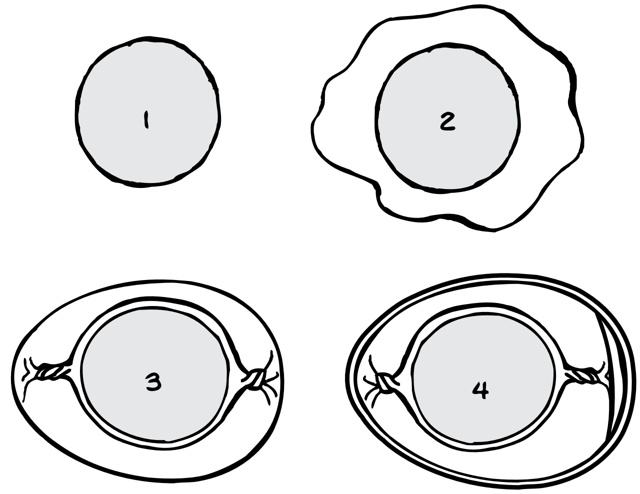


Figure 5. Order of egg formation in hen's oviduct.

How Eggs are Fertilized

Many people wonder how and why eggs grow the way they do. You might wonder why eggs from the supermarket don't grow and hatch when incubated. The male chicken or rooster makes the difference. Each sex, the rooster and hen, contributes something to the egg. The rooster provides sperm. The hen provides an ova. When a rooster mates with a hen (see Figure 6), he deposits spermatozoa in the oviduct. These sperm, containing male germ cells, travel the length of the oviduct, and are stored in the infundibulum. On the surface of every egg yolk there can be seen a tiny, whitish spot called the blastodisc. This contains a single female cell. If sperm is present when a yolk enters the infundibulum, a single sperm penetrates the blastodisc, fertilizing it and the blastodisc becomes a blastoderm. Technically, the

Table 1. Egg Development

Parts of Oviduct	Length of Part	Time Spent There	Function of Part
Infundibulum	2 inches	15 min	Picks up yolk, egg fertilized
Magnum	13 inches	3 hours	Albumen laid down
Isthmus	4 inches	1.25 hours	Shell membrane laid down, shape of egg determined
Uterus	4.2 inches	20.75 hours	Shell formed pigment of cuticle laid down
Vagina and Cloaca	4 inches	-	Egg passes through as it is laid

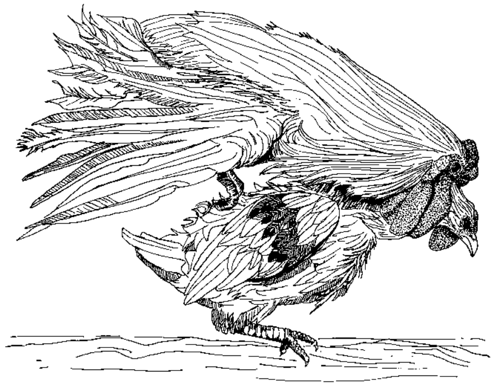


Figure 6. Rooster Mounting Hen

(Embryology 4-H Manual I, North Carolina Extension)

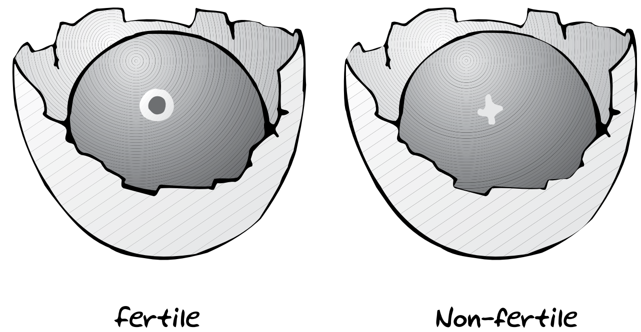


Figure 8. Fertile and non-fertile eggs.

blastoderm is the true egg. Shortly after fertilization, the blastoderm begins to divide into 2, 4, 8 and more cells. The first stages of embryonic development have begun and continue until the egg is laid. Development then subsides until the egg is incubated. When sperm and ova unite, this process is called fertilization (see Figure 7). After fertilization, the eggs can develop and become a chick. Only fertilized eggs grow into chicks.

The rooster must be present for an egg to be fertilized. The eggs that you buy at the supermarket are from hens that are raised without a rooster being present. Roosters are not necessary at egg farms

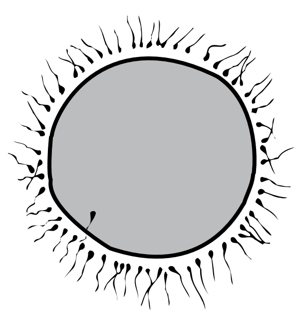


Figure 7. Sperm unites with the egg.

where eggs are produced to be consumed by people and not used for incubation. Eggs for incubation are grown at special farms called breeder farms where roosters are present with the hens.

The next time you break open an egg, look for the germinal disc. You will see that supermarket eggs are infertile (see Figure 8.)

The Avian Egg

The avian egg is a marvel of nature's architecture. A highly complex reproductive cell, it is essentially a very small center of life, a world of its own.

Scientifically speaking, an egg (ovum) is the reproductive cell produced by the female. It remains a single cell until the single cell (nucleus) of the male sperm fertilizes it. Once fertilized, the egg has a full complement of chromosomes and genes to start developing.

The fertilized cell (zygote) then rapidly divides into 2 cells, 4, 8, 16, 32, 64, and so on, until the faint outline of a developing embryo and a network of blood vessels surrounding the yolk and other nutrients can be seen.

What is normally called "an egg" (the chicken egg, for example) is a much more complex structure designed to nourish and protect the embryo growing from the zygote. A vigorous healthy chick can be hatched from each fertile egg. The egg needs only a warm humid environment while the embryo is maturing.

As we know it, the egg is the single most complete food known to man. Versatile and nutritious, it is used every day in the preparation of the most common and the most fanciful meals.

Although human nutritional requirements are not the same as those of the chick, they are similar in so many respects that the egg has become a convenient, economical source of many of the essential proteins, minerals, and vitamins necessary to our good health.

The Parts of the Egg

Looking at the egg from the outside we see the shell, which is a hard, protective covering composed primarily of calcium carbonate. The shell is porous and the pores at the large end are more numerous than those at the small end (There are about 7,000 pores in a chicken egg shell.) This permits the transfer of gases through the shell. Carbon dioxide and moisture are given off through the pores and are replaced by atmospheric gases, including oxygen (see Figures 4 and 5 on page 8.)

Immediately beneath the shell are two membranes, the outer and inner shell membranes. These membranes protect the contents of the egg from bacterial invasion and prevent rapid evaporation of liquid from the egg.

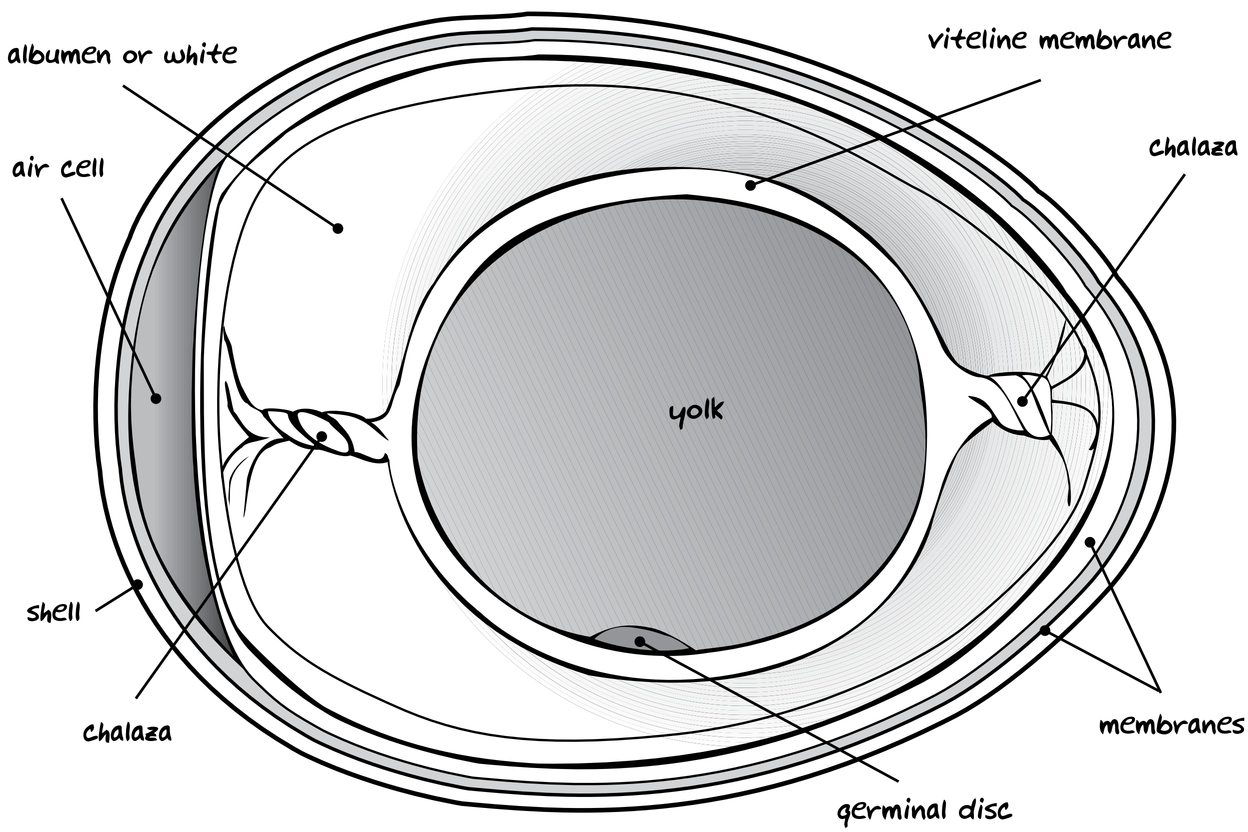
Because the body temperature of a hen is approximately 106°F, eggs are very warm at the time they are laid. The temperature of the air is usually much lower than 106°F, and the egg cools to the temperature of its surroundings. As cooling takes place, the contents of the egg contract more than the shell of the egg does. This creates a vacuum, and air is drawn through the pores in the large end of the shell. As a result, an air cell forms at the large end of the egg. The air cell serves as a tiny shock absorber during early embryonic development, and on the 20 th day of incubation the chick pokes its beak through the shell membranes into the air cell (which by this time has enlarged greatly) and draws its first breath of air from this space.

While the embryo is growing, the shell membranes surround and contain the white, or albumen, of the egg. The albumen provides the liquid medium in which the embryo develops, but it also contains a large amount of the protein necessary for proper development.

In a fresh egg, one can see two white cords attached to the yolk sac. These two cords, called chalazae, are made of twisted strands of mucin fibers that are a special form of protein. The chalazae hold the yolk in the center of the egg.

The yolk contains large amounts of carbohydrate, fat, and protein. The egg white (albumen) is almost pure high-quality protein. The yolk is also a reservoir of the vitamins and minerals that are essential for normal growth (see Table 1 on page 8). These substances combine with the oxygen taken in through

Figure 9. Parts of the eggs



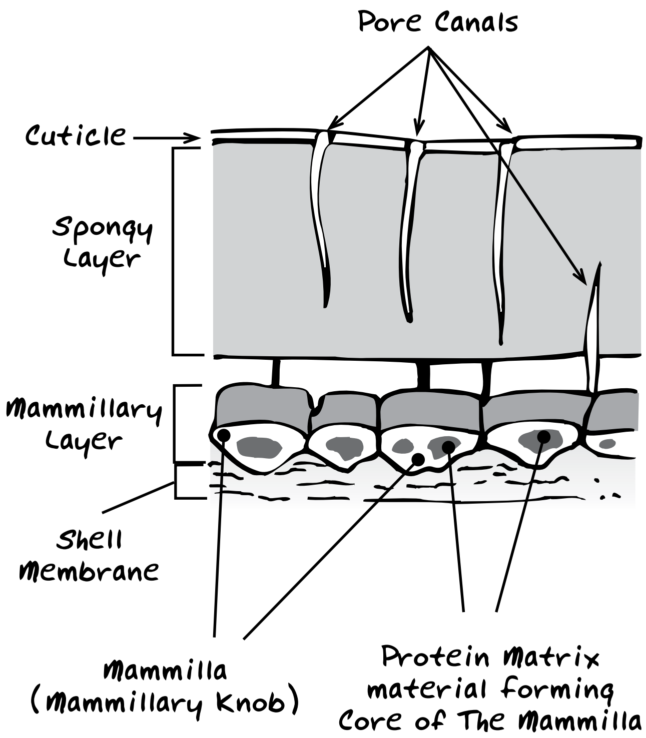


Figure 10. Magnified radial section through the shell

the pores of the shell and provide an abundant source of metabolic energy for the embryo. By-products of this process are carbon dioxide and water. The embryo uses water to replace moisture lost through evaporation. Carbon dioxide is transpired through the pores of the shell. Calcium is absorbed from the yolk and shell to make its bony structure, or skeleton.

Selection and Care of Hatching Eggs

Obtaining Hatching Eggs

Obtaining fertile eggs may present a problem, especially if you live in an urban area. Most of the eggs sold in grocery stores are not fertile and cannot be used for incubation. Fertile eggs can usually be obtained from hatcheries or poultry breeding farms. Some large hospitals may also be able to provide them. Contact your local Extension office for suggestions.

When you obtain fertile eggs from a source which does not routinely hatch its own eggs, you may want to test the eggs in an incubator to ensure that good

Table 2. Nutritional Value of Eggs

Nutrition Information Per Serving
Serving Size = 2 U.S. Large Eggs (108 g edible portion)

Servings Per Carton	6	Fat (Percentage of Calories-68%)	12g
Calories	160	Polyunsaturated	1g
Protein	13 g	Saturated	4g
Carbohydrates	1 g	Sodium	140g

Serving Size = 2 U.S. Large Eggs (108 g edible portion)

Protein	30	Iron	10	Iodine	35
Vitamin A	10	Vitamin D	15	Zinc	10
Vitamin C	*	Vitamin E	6	Pantothenic Acid	15
Thiamin	6	Vitamin B6	6	Copper	4
Riboflavin	20	Folic Acid	15	Magnesium	4
Niacin	*	Vitamin B12	15	Calcium	6
Phosphorous	20				

fertility and hatchability can be obtained before you use the eggs as part of the class project. Laying hens raised with a male does not guarantee fertility or hatchability. You are also strongly encouraged to use chicken or coturnix quail eggs to hatch in the classroom. Duck, goose, pheasant, and other species of fowl are much more difficult to hatch in classroom incubators. Duck and goose eggs often rot and may explode in the incubator.

Before you begin the project, consider what will be done with the chickens that are hatched. If possible, line up someone who has experience in keeping chickens and is willing to take them. Do not hatch chicks and then abandon them or give them to someone who is unable to care for them properly. Remember that Virginia state law requires chicks to be given in groups of six.

When you have located a source of fertile eggs, pick them up yourself if possible, rather than having them shipped or mailed. It is difficult for hatcheries, the postal service and transportation companies to properly handle small orders of eggs.

Culling and Caring for Eggs Prior to Incubation

Culling fertile eggs prior to setting them in an incubator can increase hatchability. Fertile eggs from a commercial hatchery are usually already sorted; however, it is usually wise to check your eggs before setting them. Cracked eggs, thin-shelled eggs and double-yolked eggs hatch very poorly. These eggs should be removed before incubating.

Proper care of fertile eggs prior to incubation is essential for success. The eggs should be collected within 4 hours from when they were laid. Never wash the eggs unless absolutely necessary. Then use water warmer than the egg so the egg sweats and releases the dirt. If you use cold water, the egg will contract and pull the dirt and bacteria deeper into its pores. It is always best to set to fertile eggs in a prepared incubator as soon as you get them.

Science of Incubation

Incubation means maintaining conditions favorable for developing and hatching fertile eggs. Still-air incubators do not provide mechanical circulation of air. Forced-air incubators are equipped with electric fans. Optimum operating temperatures differ slightly.

Four factors are of major importance in incubating eggs artificially: temperature, humidity, ventilation, and turning. Of these factors, temperature is the most critical. However, humidity tends to be overlooked and causes many of the hatching problems encountered by teachers. Extensive research has shown that the optimum incubator temperature is 100°F, relative humidity is 60 percent, concentration of oxygen 21 percent, carbon dioxide 0.5 percent, and air movement past the eggs is at 12 cubic feet per minute.

Temperature

An incubator should be operated in a location free from drafts and direct sunlight. An incubator should also be operated for several hours with water placed in a pan to stabilize its internal atmosphere before fertile eggs are set. During the warm-up period the temperature should be adjusted to hold a constant 101°F for still air, 100°F for forced air. To obtain reliable readings, the bulb of the thermometer should be at the same height as the tops of the eggs and away from the source of heat. Using two thermometers is a good idea to ensure you are getting an accurate reading.

Incubator temperature should be maintained between 100° and 101°F. The acceptable range is 97° to 102°F. High mortality is seen if the temperature drops below 96°F or rises above 103°F for a number of hours. If the temperature stays at either extreme for several days, the egg may not hatch. Overheating is more critical than underheating. Running the

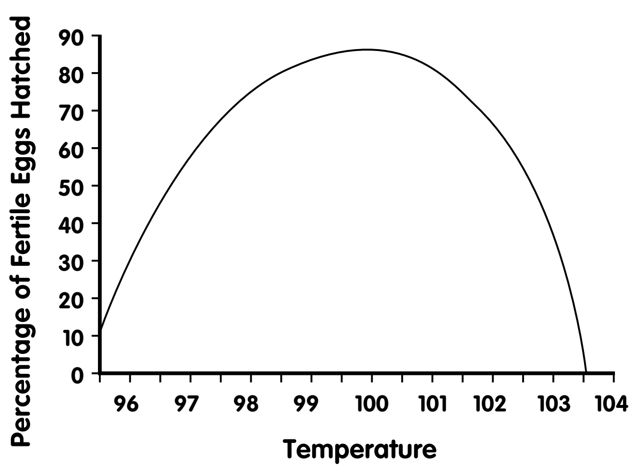


Figure 6. The effects of incubation temperature on percentage of fertile eggs hatched. Relative humidity 60 percent, Oxygen 12 percent, CO_2 below 0.5 percent.

(From Egg to Chick , Northeast States Cooperative Service)

incubator at 105°F for 15 minutes will seriously affect the embryos, but running it at 95°F for 3 or 4 hours will only slow their metabolic rate (see figure 6 above).

Do not make the mistake of overheating the eggs. Many times, when the eggs remain clear and show no development, it is due to excessive heat during the first 48 to 72 hours. Do not adjust the heat upward during the first 48 hours. This practice cooks many eggs. The eggs will take time to warm to incubator temperature and many times the incubator temperature will drop below 98°F for the first 6 to 8 hours or until the eggs warm to 100°F.

Humidity

The relative humidity of the air within an incubator for the first 18 days should be 60 percent. During the last 3 days (the hatching period) the relative humidity should be nearer to 65 – 70 percent. Too much moisture in the incubator prevents normal evaporation and results in a decreased hatch, but excessive moisture is seldom a problem in small incubators. Too little moisture results in excessive evaporation, causing chicks to sometimes stick to the shell and hatch crippled.

Table 4 (Relative Humidity, below) will enable you to calculate relative humidity using readings from a wet-bulb thermometer and a dry-bulb thermometer.

During the hatching period, using an atomizer to spray a small amount of water into the ventilating holes may increase the humidity in the incubator (this is especially helpful when duck or goose eggs are being hatched.) An 8-inch pie tin or petri dish containing water and placed on the tray of eggs should provide adequate moisture. The relative humidity in the incubator can also be varied by changing the size of the water pan or by putting a sponge in the pan to increase the evaporating surface. The pan should be checked regularly while the incubator is in use to be sure that there is always an adequate amount of water.

Table 4. Relative Humidity

Incubator Temperature	Wet Bulb Readings					
100°F	81.3	83.3	85.3	87.3	89	90.7
101°F	82.2	84.2	86.2	88.2	90.0	91.7
102°F	83.0	85.0	87.0	89.0	91.0	92.7
Percent Relative Humidity	45%	50%	55%	60%	65%	70%

(From Egg to Chick, *Northeast States Cooperative Service*)

Whenever you add water to an incubator, it should be about the same temperature as the incubator so you do not stress the eggs or the incubator. A good test is to add water just warm to the touch.

In the latter stages of incubation (from the 19th day on), condensation on the glass indicates the presence of sufficient moisture. However, the condensation is also related to the temperature of the room where the incubator is being operated. There will be more condensation on the glass if the room is cold, so be sure the temperature in the incubator remains steady.

Using a wet-bulb thermometer is a good learning experience for determining relative humidity. The wet-bulb thermometer measures the evaporative cooling event. If the wet and dry bulb read the same temperature, you would have 100 percent humidity. The more evaporation taking place, the lower the temperature reading on the wet-bulb thermometer and the larger the spread will be between the wet- and dry-bulb reading.

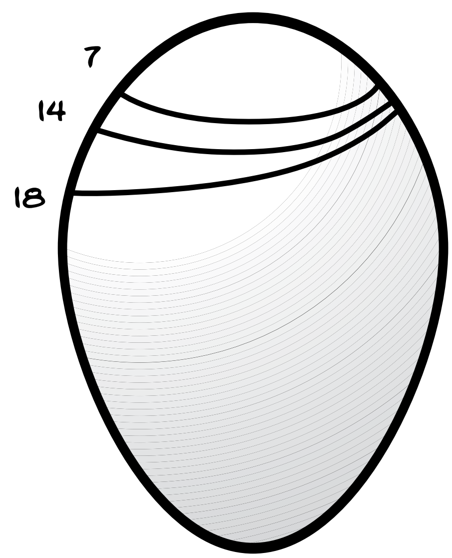


Figure 8: Diagram showing the air cell on the 7th, 14th, and 18th days of incubation

(From Egg to Chick, Northeast States Cooperative Service)

*18 U.S.C. 707

To make a wet-bulb thermometer, just add a cotton wick to the end of a thermometer. Then place the tail of the wick in water. The cotton then absorbs the water. As the water evaporates from the cotton it causes a cooling effect on the thermometer.

It is also possible to determine whether there is too much or too little humidity in the incubator by candling the eggs and comparing the size of the air cell with the diagram in Figure 8 below.

Ventilation

The best hatching results are obtained with normal atmospheric air, which usually contains 21 percent oxygen. It is difficult to provide too much oxygen, but a deficiency is possible. Make sure that the ventilation holes are open to allow a normal exchange of air.

This is critical on home-made incubators. It is possible to suffocate the eggs and chicks in air-tight containers.

Turning

Turning the eggs during the incubation period prevents the blastoderm from migrating through the albumen and sticking to the shell membrane. Chicken eggs should be turned three to five times daily from the 2nd to the 18th day. Do not turn the eggs during the last 3 days!

To insure proper turning, mark each end of the egg with a pencil. Put an "X" on one side and an "O" on the opposite side.

Place the eggs on the welded wire platform horizontally, in a single layer, with the end marked "X" on top. When the eggs are turned all the "X's" will be on the bottom and the "O's" on top. At the next turning, the "X's" will be in view, and so on.

When incubators are used in schools, it may be difficult to turn the eggs on the weekend. If the eggs are not turned, the hatch may be somewhat slower, so it is recommended that the eggs be turned at least once daily on weekends. In some schools, the temperature is reduced on weekends and holidays, and it may be advisable to make an insulation cover for your incubator by placing a large cardboard box over the incubator.

Except for the 19th through the 21st day, it is safe to move the incubator with the eggs in it. Some teachers take the incubator with its eggs home on weekends. Rolling and cracking of the eggs can be prevented during the move by packing the eggs in a carton. The incubator should be wrapped in a heavy blanket and placed in a warm vehicle to maintain the temperature of the eggs, and the trip should not take more than half an hour.

After the 18th day, do not open or move the incubator until the hatch is completed because the chicks are in a hatching position in the eggs and because a desirable hatching humidity must be maintained.

How the Chicken Incubates Eggs Naturally

In nature, the female bird selects the nest site and lays a clutch of eggs (usually 8 to 13 eggs), one egg per day. Once she has a clutch of eggs, she begins sitting on the eggs full-time, leaving only for food and water.

The hen's body temperature is 105° to 106°F. When the hen sits on the eggs, this heats the eggs to 100° to 101°F. The hen turns the eggs on a regular basis by using her beak to scoop under the egg and roll it towards her. The humidity comes from the environment, the bird's body, and any moisture the female transfers back to the nest on her feathers. Brooding hens often leave their nests to feed at dawn or dusk when dew is present on the grass.

As you can see, science has simply developed mechanical boxes that supply the fertile eggs with the same environment as the hen.

Incubating the Eggs for This Project

Types of Incubators

This program has used five main styles of incubators over the years. Always follow the manufacturer's instructions for best results.

1. *Lyon Electric "Transparent Hen."* These incubators are excellent if they are properly maintained. However, the wafer thermostats, plastic shells and heat coils are no longer available to replace those that are damaged. If the plastic sides are damaged or the temperature control hole cover is missing, you will not be able to hold steady temperatures or humidity. Once the heater coil, thermostat, or plastic sides are damaged, you may be better off replacing rather than repairing this incubator.

2. *Turn – X Incubators*. These incubators are still available in many model types, but are more expensive than most others available. They hold 18 chicken eggs and they easily maintain good humidity levels. These must be kept clean since the entire bottom serves as the water source. They are relatively reliable. Some teachers have found the electronic circuit board to be troublesome. The forced-air style is an advantage.

3. *Round Metal Hova-bator Style*. These are be coming less common. However, parts are still available. Disadvantages are the lack of visibility of the eggs and what is happening inside.

4. *Round Styrofoam Hova-bators*. Parts are easy to replace and find. Proper humidity is hard to obtain and maintain without adding extra water pans. Visibility can be a problem. These are fairly low-priced incubators.

5. *Square Styrofoam Hova-bators*. All parts are easy to replace and find. It is advisable to get the model with the clear plastic top. This model makes the eggs and chicks extremely visible. Buying a model with a fan also helps regulate humidity and temperature. Adding an extra water tray may increase humidity. These are probably the most economical incubators available.

Automatic turners have their advantages and disadvantages. The main advantage is that they turn eggs during the time in which is inconvenient for you to turn the eggs – on weekends and snow days, for example – yet there are disadvantages as well. By using an automatic turner, you eliminate the youth's responsibility for turning and caring for the eggs during the week. Those using automatic turners often don't add water as often and tend to miss problems such as losses in temperature or other incubator problems. Some automatic turners don't turn the eggs properly and can result in lower hatches also. Mark the eggs to make sure the turner is doing the job you expect.

Incubator Set-Up and Operation

Proper set-up and operation of your incubator is critical to the success of the "Beginning of Life" project. To help you with this critical portion of the project, a "Must" schedule and "Do Not" list are provided. Also see Table 2 on page 11 if you have questions. If you follow these instructions you will have a successful project

Embryology "Must" Schedule

A. Plan dates to run the project. Avoid holidays. Wednesday is usually the best day to set the eggs. This eliminates any chance of eggs hatching on weekends.

B. Set up the incubator. Make sure it operates correctly for at least 24 hours before you set the eggs.

   1. Set-up the incubator in a room that stays above 60°F.
   2. Adjust the incubator so it holds the desired temperature. In still-air units (without fans), adjust the temperature to 100.5°F. In forced-air units (with fans), adjust the temperature to 99.5°F. Always adjust the thermostat so the heat source comes on when the temperature drops below the desired temperature.
   3. Use two (2) thermometers to ensure an accurate temperature reading.

DO NOT set the incubator next to or on top of a heat register or in a sunny window.

DO NOT set the incubator in a drafty location (i.e., near an air conditioner, a fan blower, or an open hallway).

C. Make a calendar for the project.

   1. Have a place to mark when the eggs are turned.
   2. Have a place to enter the daily dry- and wet-bulb temperature.
   3. Have enough space to write down daily observations.

D. Prepare the eggs for setting.

   1. Place eggs at room temperature for two (2) hours before setting.
   2. Candle the eggs for cracks. **DO NOT** set cracked eggs.
   3. Remove any excessive dirt from the eggs.
   4. Number the eggs and mark each egg with an "X" on one side and an "O" on the other side. Use a pencil. Do not use a permanent or toxic ink pen.
   5. Set the eggs in the incubator with all the "X" sides up. Turn the eggs daily. All eggs should be turned three times daily. You must turn them at least once a day on weekends. Be sure eggs are turned gently; rough turning for the first 10 days can be fatal.

*18 U.S.C. 707

6. Record temperatures each time before you turn the eggs.
7. Keep the water trays full. Use water warm to the touch. **DO NOT** add cold or hot water. Add water when you turn the eggs and when water gets low.
8. Only open the incubator to turn the eggs and to add water, or to set the eggs at the beginning of the project.
9. Candle eggs every 4 to 6 days to check progress. Remove any eggs that are clear or contain dead embryos.
10. Stop turning the eggs three days before the hatch date. For chicken eggs, stop turning them on the 18th day.
11. Prepare for brooding three (3) days before the hatch date. You want everything prepared before the chicks hatch.
12. Remove chicks from the incubator and place in the brooder within 4 to 6 hours after hatching. If your incubator has good levels of humidity the chicks may not dry in the incubator. They will dry once moved to the brooder.

"DO NOT" List

DO NOT store or transport fertile eggs in temperatures above 70°F or below 35°F, if possible. Do not store eggs for more than seven (7) days.

DO NOT expect the incubator to be in perfect operating condition the day you plan to set the eggs. Set it up and check it well in advance.

DO NOT open the incubator more than necessary.

DO NOT let the eggs go more than 24 hours without turning.

DO NOT let the water tray become low or dry

DO NOT add hot or cold water to incubator. Add only water that is warm to the touch.

DO NOT turn the eggs after the 18th day for chickens.

DO NOT help the chicks out of their shells at hatching time. This usually causes more problems than it is worth. Most will die or be crippled if helped out.

Sanitation of Incubator and Equipment

After the hatch has been completed, the incubator box and tray should be brushed clean of all debris and dust. The cleaned surfaces should be wiped thoroughly with a cloth dampened in quaternary ammonium, household bleach, or other disinfectant. Follow the directions of the manufacturer carefully.

A. After using, clean the incubator properly and immediately.
   1. Remove all loose shells and dry matter.
   2. Clean the egg tray and water pans.
      a. Soak in warm water with mild bleach or disinfectant, if necessary.
      b. Scrub off all adhering dirt with brush.
   3. Wipe plastic clean with soft cloth and glass cleaner.
   4. Clean bottom of incubator.
      a. DO NOT use chemical cleaners. Some chemical cleaners will melt Styrofoam. Many plastic and foam bottoms will absorb the chemicals, which may kill the embryos in the future.
      b. Soak in warm 25 percent bleach/water solution and wipe clean with a cloth.
      c. You can scrub most plastic bottoms with a brush.
   5. Cleaning the heating element and other electrical units.
      a. DO NOT touch or get the element wet.
      b. Brush wafers gently with a soft brush to remove the dust.

B. Store the incubator in a protective carton.

C. Store the incubator in a cool, dry location.

D. Prevent excessive movement. Each time the incubator is moved, it increases the chance of the element or wafers being damaged.

Incubation Periods of Other Species

One of the miracles of nature is the transformation of the egg into the chick. In a brief three weeks of incubation, a fully developed chick grows from a single cell and emerges from a seemingly lifeless egg.

Not all avian eggs hatch in 21 days. The Japanese quail needs 17 days; the pigeon 18 to 20 days. The

Table 3. Incubation Period and Incubator Operation for Eggs of Domestic Birds

Requirements	Chickens	Guinea, Peafowl, Turkey	Goose and Duck	Muscovy Duck	Pheasant	Bobwhite Quail	Coturnix Quail
Incubation Period (days)	21	28	28	35	24-28	23-24	17
Still-air operating temp (°F – dry bulb)	100.5	100.5	100.5	100.5	100.5	100.5	100.5
Forced-air operating temp (°F – wet bulb)	99.5	99.5	99.5	99.5	99.5	99.5	99.5
Humidity (°F – wet bulb)	85-87	83-85	84-86	84-86	86-88	84-86	84-86
Do not turn eggs after	Day 18	Day 25	Day 25	Day 31	Day 21	Day 21	Day 15
Humidity during last 3 days of incubation (°F – wet bulb)	90-94	90-94	90-94	90-94	90-94	90-94	90-94

(Incubating Eggs of Domestic Birds, Clemson University Extension)

swan and the ostrich need 42 days of incubation before hatching. The duckbill platypus is the only mammal that lays eggs, and they have an incubation period of 12 days. Never incubate the eggs of wild birds; these chicks will not live without their mother's care if they do hatch. Table 4 shows comparative incubation information for 13 domestic birds.

Troubleshooting

Maximum hatchability requires fresh eggs from well-bred and properly managed flocks. However, egg care and incubation are even more critical.

What follows is an analysis of common problems seen during this type of project, and a discussion of the possible causes and how they may be corrected.

Problem #1: Eggs clear – no blood rings, no embryonic development.

Causes:

1. Eggs infertile.
2. Eggs damaged by being either badly chilled or overheated.
3. Eggs held too long or held under improper conditions.

Correction:

1. Keep eggs under proper temperature and humidity conditions and set within seven days after date laid.
2. Get eggs from another source.

Problem #2: Eggs candling clear but showing blood ring or very small embryo on breaking.

Causes:

1. Badly chilled eggs or eggs overheated or held at too high a temperature.
2. Improper incubator temperature at earliest stage of incubation.
3. Eggs held too long or held under improper conditions of temperature and humidity.

Correction:

1. Protect eggs against freezing temperatures, gather eggs often, cool properly and quickly; hold eggs under conditions recommended by breeder.
2. Check accuracy of thermometer. Operate incubator at proper temperature.
3. Keep eggs under proper temperature and humidity conditions and set them within seven days after date laid.

Problem #3: Early dead embryos one to six days into incubation.

Causes:

1. Temperature too high or too low in incubator.
2. Lack of ventilation.
3. Improper turning of eggs.

Correction:

1. Check accuracy of thermometer. Operate incubator at proper temperature.
2. Provide adequate ventilation of the incubator room and proper openings of the incubator ventilators. Do not recirculate air. Supply 100 percent fresh, tempered air.
3. Turn eggs at regular intervals 3 times daily.

Problem #4: Any considerable number of embryos dead from the sixth through the sixteenth days of incubation (normally this is a period of relatively low embryonic death).

Causes:

1. Incubator temperature too high.
2. Infected embryos – either by infection from hens or, especially, by external microbial contamination through shell.
3. Lack of ventilation.

Correction:

1. Check accuracy of thermometer. Operate incubator at proper temperature.
2. Provide adequate ventilation of the incubator room and proper openings of the incubator ventilators.

Problem #5: Chicks fully formed, but dead without pipping. May have considerable quantities of unabsorbed yolk.

Causes:

1. Low average humidity in incubator.
2. See probable causes in problem #3 above.
3. Chilled eggs.

Correction:

1. Maintain proper humidity throughout incubation cycle.
2. Gather eggs quickly, cool properly, and hold under proper conditions.

Problem #6: Eggs pipped, but chicks dead in shell.

Causes:

1. Low average humidity.
2. Inadequate ventilation.
3. Excessive high temperature for a short period.
4. Low average temperature.

Correction:

1. Maintain proper humidity levels through incubator cycle.
2. Provide adequate ventilation of the incubator room and proper openings of the incubator ventilators.
3. Guard against temperature surge.
4. Maintain proper temperature throughout incubation cycle.

Problem #7: Sticky chicks – chicks smeared with egg contents.

Causes:

1. Low average temperature.
2. Average humidity too high.
3. Inadequate ventilation.

Correction:

1. Maintain proper humidity levels throughout incubation cycle.
2. Provide adequate ventilation of the incubator room and proper openings of the incubator ventilators.
3. Guard against temperature surge.
4. Maintain proper temperature throughout incubation cycle.

Problem #8: Dry sticks – shell sticking to chicks.

Causes:

1. Eggs dried down too much.
2. Low humidity at hatching time.
3. Improper egg turning.

Correction:

1. Maintain proper humidity levels during egg-holding period and throughout incubation cycle. Do not over-ventilate.
2. Proper humidity levels throughout incubation cycle.
3. Turn eggs hourly or at least at regular intervals eight times daily.

Problem #9: Chicks hatching too early with bloody navels.

Causes:

1. Temperature too high.

Correction:

1. Maintain proper temperature levels throughout incubation cycle.

Problem #10: Large, soft-bodied, mushy chicks dead on trays with bad odor.

Causes:

1. Low average temperature.
2. Poor ventilation in incubator.
3. Humidity too high during incubation.

Correction:

1. Maintain proper temperature throughout incubation cycle.
2. Provide proper ventilation of the incubator room and proper opening of the incubator ventilators.
3. Maintain proper humidity levels throughout incubation cycle.

Problem #11: Short down on chicks or eyelids stuck closed with down.

Causes:

1. High temperature.
2. Low humidity.
3. Excessive ventilation in the incubator at hatching time.
4. Holding chicks in incubator too long after they hatch.

Correction:

1. Maintain proper temperature levels throughout incubation cycle.
2. Maintain proper humidity levels throughout incubation cycle.
3. Reduce opening of incubator ventilators. Do not restrict so far as to permit animal heat to push temperature above safe level.
4. Remove chicks as soon as they are fluffed and ready.

Problem #12: Delayed hatch – eggs not starting to pip until 21st day or later.

Causes:

1. Average temperature too low in the incubator.
2. Eggs held too long.

Correction:

1. Maintain correct temperature levels throughout incubation cycle.
2. Before placing them in the incubator, try not to hold eggs more than seven days and then only if holding conditions are ideal.

Problem #13: Malformed chicks in poor hatch, usually associated with an excessive number of chicks dead in shell, with a high incidence of malpositions.

Causes:

1. Eggs held too long before setting, even under good conditions, or eggs held any length of time at improper levels of temperature and/or humidity.
2. Eggs chilled before setting.
3. Improper turning or setting.
4. Inadequate ventilation.
5. Abnormally high or abnormally low incubator temperature.
6. Insufficient moisture.
7. Damage to eggs in shipment caused by jarring or shipping them with large end down.
8. Eggs from poor quality stock.

Correction:

1. Try not to hold eggs more than seven days if at all possible, and then only if holding conditions are ideal.
2. Gather eggs quickly, cool properly before casing, and hold under proper conditions.
3. Provide adequate ventilation of the incubator room and proper openings of the incubator ventilators. Do not recirculate air. Supply 100 percent fresh, tempered air.
4. Maintain proper temperature levels throughout the incubation cycle.
5. Maintain proper humidity levels throughout the incubation cycle
6. Hatching eggs must be shipped in good quality, well-protected egg cases or equivalent, with small end down. Avoid rough handling.

Chick Embryo Development

Where Chick Life Begins

The development of the chick begins in the single cell formed by the union of two parental cells, the egg and sperm, in the process known as fertilization. In birds, fertilization occurs in the infundibulum about 24 hours before the egg is laid.

The newly formed single cell begins to divide into 2, then 4, 8, 16, 32, and so on. At the time of laying, hundreds of cells are grouped in a small, white spot (germinal disc) that is easily seen on the surface of the yolk. This spot in a fertilized, freshly laid egg is the beginning of the chick (see Figure 3 on page 7).

When the egg is laid and cools, division of the cells ceases. Cooling the egg to room (40°F to 75°F) temperature does not result in the death of the embryo. It may resume its development after several days of rest if it is again heated by the hen or in an incubator.

Development During Incubation

As soon as the egg is heated again, the cluster of cells in the blastoderm begins to multiply by successive division. The first cells formed are all alike. Then, as the division of cells progresses, some differences begin to appear.

These differences become more and more pronounced. Gradually the various cells acquire specific characteristics of structure and cell groupings or layers. These cell groupings are called the ectoderm, mesoderm, and endoderm. These three layers of cells constitute the materials out of which the various organs and systems of the body are to be developed.

From the ectoderm, the skin, feathers, beak, claws, nervous system, lens and retina of the eye, and linings of the mouth and vent are developed. The mesoderm develops into the bone, muscle, blood, and the reproductive and excretory organs. The endoderm produces the linings of the digestive tract and the secretory and respiratory organs.

Development from a single cell to a pipping chick is a continuous, orderly process. It involves many changes from apparently simple to new, complex structures. From the structures arise all the organs and tissues of the living chick.

Physiological Processes within the Egg

Many elaborate physiological processes take place during the transformation of the embryo from egg to chick. These processes are respiration, excretion, nutrition, and protection.

For the embryo to develop without any anatomical connection to the hen's body, nature has provided membranes outside the embryo's body to enable the embryo to use all parts of the egg for growth and development. These "extra-embryonic" membranes are the yolk sac, amnion, chorion, and allantois.

The yolk sac is a layer of tissue growing over the surface of the yolk. Its walls are lined with a special tissue that digests and absorbs the yolk material to provide sustenance for the embryo. Yolk material does not pass through the yolk stalk to the embryo even though a narrow opening in the stalk is still in evidence at the end of the incubation period. As embryonic development continues, the yolk sac is engulfed within the embryo and is completely absorbed at hatching. At this time, enough nutritive material remains to adequately maintain the chick for up to two days.

The amnion is a transparent sac filled with a colorless fluid that serves as a protective cushion during embryonic development. This amniotic fluid also permits the developing embryo to exercise. The embryo is free to change its shape and position while the amniotic fluid equalizes the external pressure. Specialized muscles also develop in the amnion, which by smooth, rhythmic contractions gently agitate the amniotic fluid. The slow and gentle rocking movement apparently aids in keeping the growing parts free from one another, thereby preventing adhesions and resultant malformations.

The chorion serves as a container for both the amnion and yolk sac. Initially, the chorion has no apparent function but later the allantois fuses with it to form the choric-allantoic membrane. This brings the capillaries of the allantois into direct contact with the shell membrane, allowing calcium absorption from the shell.

The allantois has four functions. (1) It serves as an embryonic respiratory organ. (2) It receives the excretions of the embryonic kidneys. (3) It absorbs albumen, which serves as a nutrient (protein) for the embryo. (4) It absorbs calcium from the shell for the structural needs of the embryo. The allantois differs

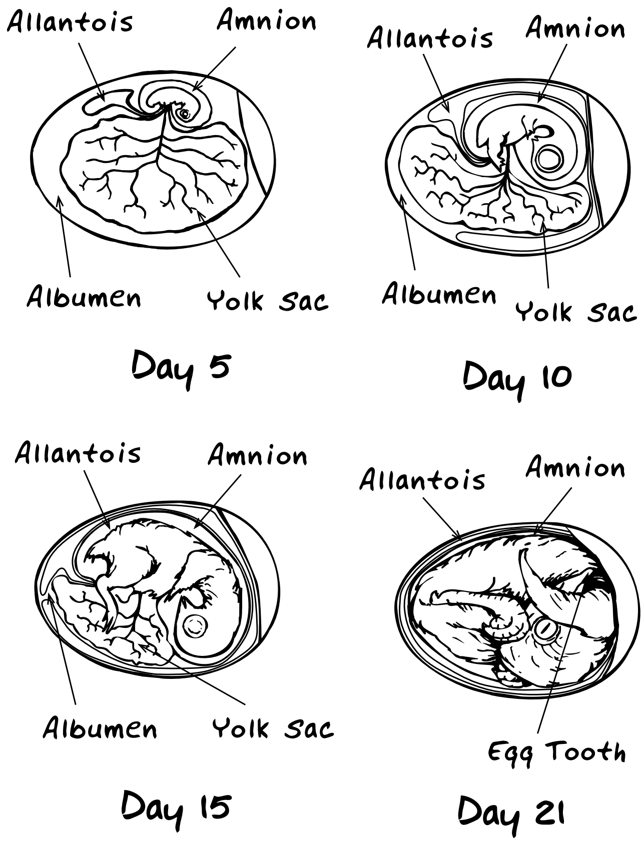


Figure 14. Successive changes in the position of the embryo and its membranes.

from the amnion and chorion in that it arises within the body of the embryo. In fact, its proximal portion remains intra-embryonic through the development.

Functions of the Embryonic Blood Vessels

During the incubation period of the chick, there are two sets of embryonic blood vessels. One set, the vitelline vessels, is concerned with carrying the yolk materials to the growing embryo. The other set, the allantoic vessels, is chiefly concerned with respiration and with carrying waste products from the embryo to the allantois. When the chick is hatched, these embryonic blood vessels cease to function (see Figure 10 on page 11).

Hatching

Several changes take place between the 18th and 21st days. The abdominal wall surrounds the residual yolk sac on the 19th and 20th days of incubation. The chick draws what remains of the yolk into its body and "takes its lunch with it" (so to speak) when it hatches. Thus, the chick really doesn't need to be fed for the first day or two after it hatches.

Fluid decreases in the amnion. The chick's head is under its right wing with the tip of the beak pointed at the air cell. The large neck muscle contracts and forces the egg tooth through the air cell, and the chick takes its first breath of air. This is referred to as internal pipping. At this time, you may hear the chick peeping inside the shell.

On the 21st day, the chick finishes its escape from the shell. The egg tooth, a sharp, horny structure located near the top of the beak, makes the initial break in the shell. This is referred to as external pipping.

The hatching process can last for 4 to 12 hours before the chick completely emerges from the shell. As the chick's head rotates from under the wing, the egg tooth pips the shell and continues to break the shell in a nearly perfect circle from the inside until it is able to push the top off the egg.

The chick, as it appears upon freeing itself from the shell, is wet and very tired. For the next several hours it will lie sill and rest. A few hours later the chick, now dry and fluffy, will become extremely active and the egg tooth will dry and fall off.

The following outline will give you the exact order to development of the embryo on a daily basis.

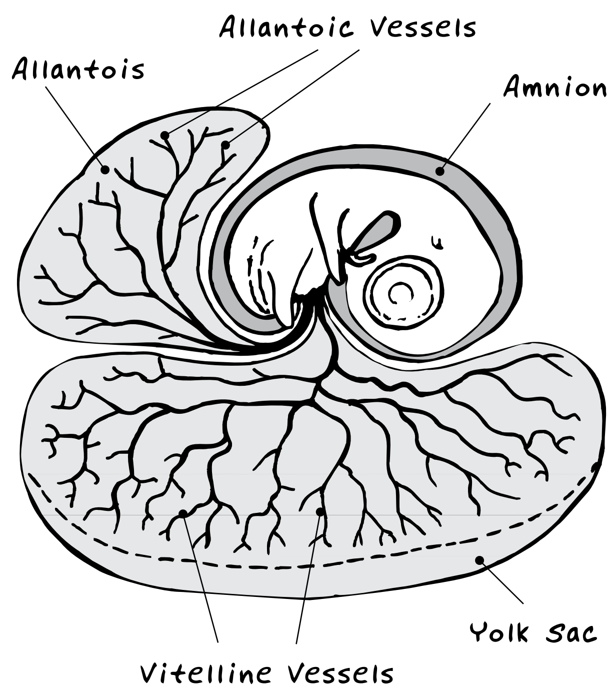


Figure 15. 7-day embryo with its embryonic membranes and blood vessels.

Daily Embryonic Development

Before Egg Laying

1. Fertilization
2. Division and growth of living cells
3. Segregation of cells into groups of special functions (gastrulation)

Between Laying and Incubation

1. Virtually no growth. Stage of inactive embryonic life.

During Incubation (see Figure 17 on page 24)

Day One:

1. Development of area pellucida and area opaca of blastoderm
2. Major developments visible under microscope:

   18 hours: Appearance of alimentary tract

   19 hours: Beginning of brain crease

   20 hours: appearance of vertebral column

   21 hours: Beginning of formation of brain and nervous system

   22 hours: Beginning of formation of head

   23 hours: Appearance of blood island

   24 hours: Beginning of formation of eyes

Day Two:

1. Embryo begins to turn on left side
2. Blood vessels appear in the yolk sac
3. Major developments visible under microscope:

   25 hours: Beginning of formation of veins and heart

   30 hours: Second, third, and fourth vesicles of the brain clearly defined, as is the heart, which now starts to beat.

   35 hours: Beginning of formation of ear pits

   36 hours: First sign of amnion

   46 hours: Formation of throat

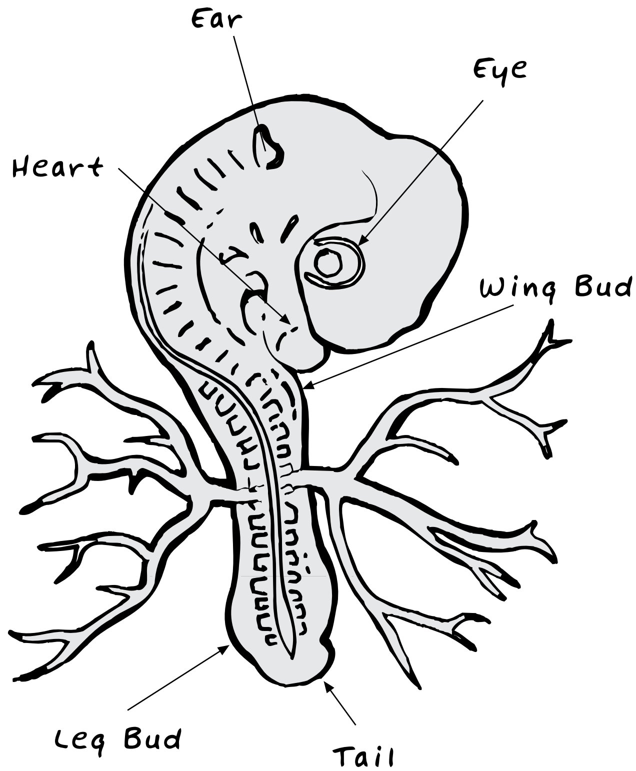


Figure 16. 3-day embryo

Day Three: (see Figure 17 on page 24)

1. Beginning of formation of nose, wings, legs, and allantois
2. Amnion completely surrounds embryo

Day Four:

1. Beginning of formation of tongue
2. Embryo completely separate from yolk sac and turned on left side
3. Allantois breaks through amnion

Day Five:

1. Proventriculus and gizzard formed
2. Formulation of reproductive organs – sex division

Day Six:

1. Beginning of formation of beak and egg-tooth
2. Main division of legs and wings
3. Voluntary movement begins

Day Seven:

1. Indications of digits in legs and wings
2. Abdomen more prominent due to development of viscera

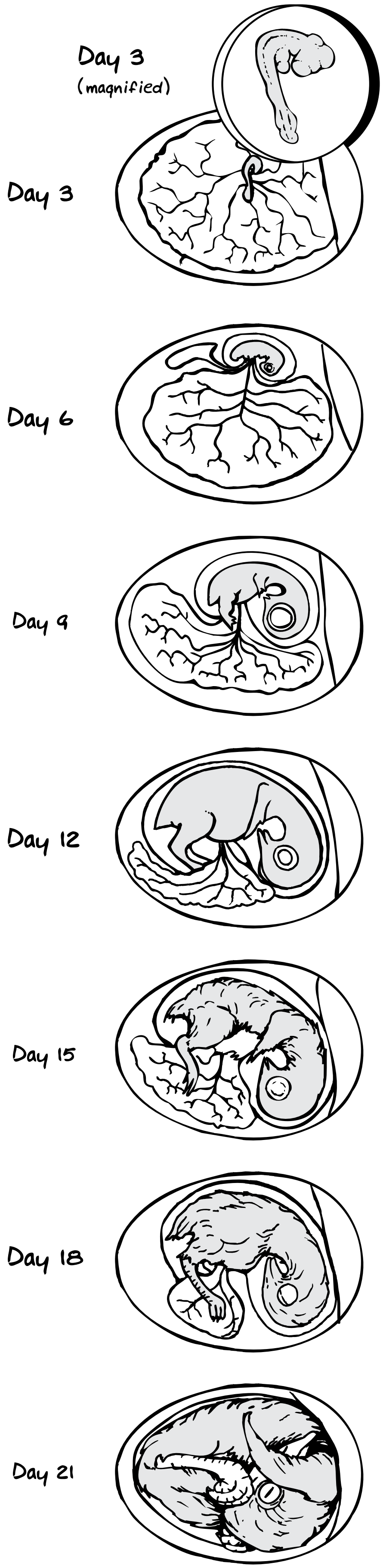


Figure 17. Stages of development

Day Eight:

1. Beginning of formation of feathers

Day Nine:

1. Embryo begins to look bird-like
2. Mouth opening appears

Day Ten:

1. Beak starts to harden
2. Skin pores visible to naked eye
3. Digits completely separated

Day Eleven:

1. Days ten to twelve tend to run together. No different changes visible on this day

Day Twelve:

1. Toes fully formed
2. First few visible feathers

Day Thirteen:

1. Appearance of scales and claws
2. Body fairly well covered with feathers

Day Fourteen:

1. Embryo turns its head toward blunt end of egg

Day Fifteen:

1. Small intestines taken into body

Day Sixteen:

1. Scales, claws, and beak becoming firm and horny
2. Embryo fully covered with feathers
3. Albumen nearly gone and yolk increasingly important as nutrient

Day Seventeen:

1. Beak turns toward air cell, amniotic fluid decreases, and embryo begins preparation for hatching

Day Eighteen:

1. Growth of embryo nearly complete

Day Nineteen:

1. Yolk sac drawn into body cavity through umbilicus
2. Embryo occupies most of space within egg except air cell

Day Twenty:

1. Yolk sac completely draws into body cavity
2. Embryo becomes chick, breaks amnion, and starts breathing air in air cell
3. Allantois ceases to function and starts to dry up

Day Twenty-one:

1. CHICK HATCHES (see Figure 18 below)

Look for the egg tooth at the tip of the newly hatched chick. Although used only for a single event in the life of the chick, as a tool to crash through the shell, the egg tooth has served its critical purpose well. Its usefulness over, it will be lost within 36 to 48 hours.

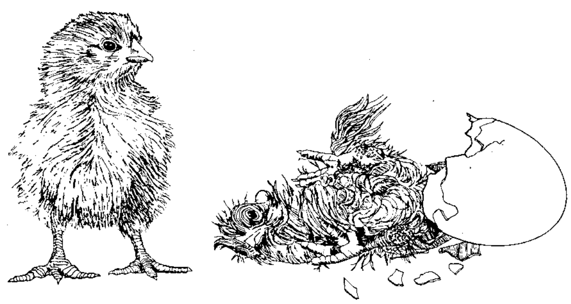


Figure 18. Chick hatches.
(Artwork from North Carolina Extension Service.)

Observing the Developing Embryo

It is advisable to observe the development of the embryo. The following two methods are most commonly used. The candling method doesn't affect the hatching of the eggs, but the shell-window method normally results in the death of the embryo after 10 to 14 days of development. There is a third method, which is NOT recommended: Open one egg each day during the incubation period in order to observe in detail the development of the embryo. With this method, 20-30 additional eggs are needed to complete observations. The advantage of the shell window over the breaking-out of embryos daily is that a single "window-embryo" will survive for days if cared for properly.

Candling Eggs with an Overhead Projector

Candling the eggs is an important part of the "Beginning of Life" project. Candling serves three very important functions. First, by candling the eggs before they are set you can eliminate any cracked eggs from being set. Cracked eggs will not hatch. Second, candling helps determine which eggs are fertile. Third, by candling the eggs every few days you can observe the growth and development of the embryo without breaking the egg open.

How to Construct Your Own Overhead Egg Candler

Materials Needed:

1. Overhead projector (with light source coming from below glass plate)
2. One 1 foot x 1 foot piece of cardboard
3. One small box (at least 3 by 4 inches and 1 inch deep)

Procedure: (see Figure 19 on page 26)

1. Cut an oval hole approximately 3 inches by 2 inches in the center of the sheet of cardboard.
2. Cut the same size (3 inches by 2 inches) oval hole in one side of the small box.
3. Cut an egg-shaped hole in the opposite side of the small box. Make the holes slightly smaller than the size of a small egg. An egg-shaped oval of about 1 3/4 inches by 1 inch works best. This hole is to hold the egg in place so the embryo can be observed without excessive handling.
4. Fasten the box to the cardboard base (with the egg shaped hole up) so that the holes are lined up. Use a strong wrapping tape to fasten them together

Now you are ready to candle and observe the live embryos in their natural environment. To properly candle the egg, set the candler on an overhead projector. Place the overhead projector on the floor or on a low table top. Darken the room, the darker the room the better to view. Remove a fertile egg from the incubator and place it on the hole of the candler. With the egg on its side, gently rotate the egg until you get the best view of the embryo.

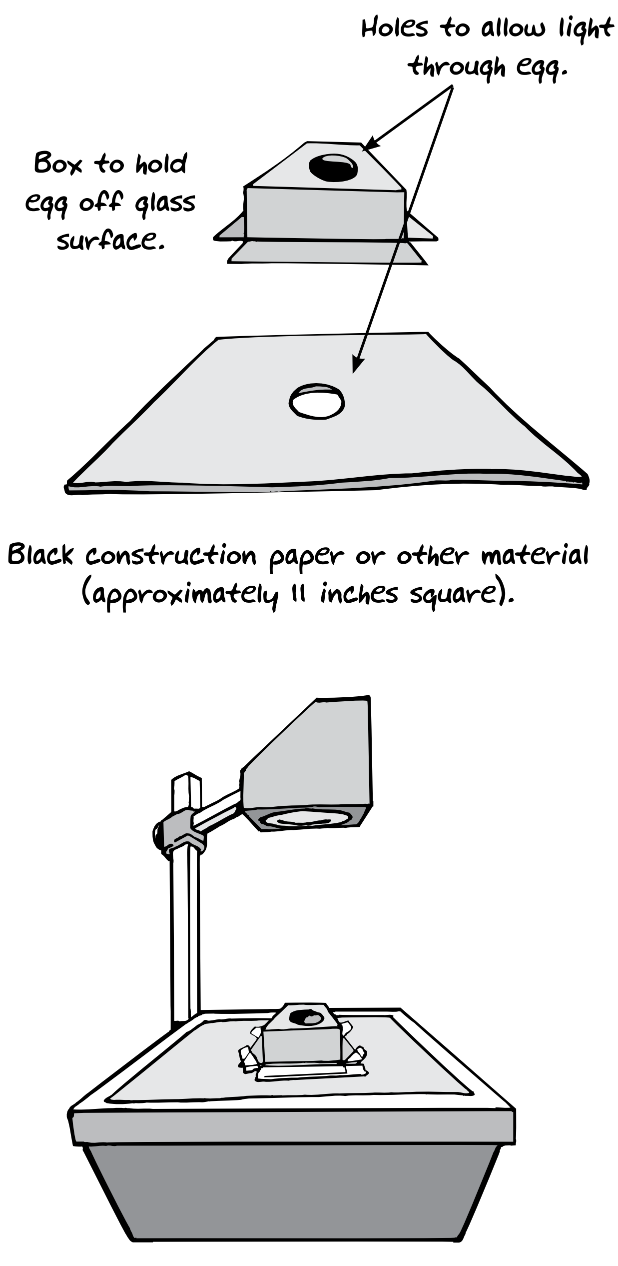


Figure 19. Overhead projector egg candler.

Some Recommended Activities Include:

1. Candle a fresh refrigerated egg and another egg that has been kept at room temperature for 3 to 5 days. Identify the air cell and yolk. Look for cracks. Gently crack an egg to see what the crack looks like.
2. Observe a 48-hour embryo, 3-day embryo, 6-day embryo, 9-day embryo, 12-day embryo, 18-day embryo, and a 19-day old embryo.

The Shell-Window Method

Removing part of the shell of an egg provides another way to study embryo development. In embryos more than two days old, most of the development can be seen if the shell is removed from the air-cell end of the egg.

Materials needed:

- Fertile eggs
- Tweezers or forceps
- Scissors
- Water pan and water
- Egg carton
- Eye dropper

The major obstacle after assembling the necessary equipment is to open the shell without damaging the embryo and its membrane. This is not as difficult as it appears. Here is a step-by-step explanation of how to open fertile, incubated eggs for embryo observation:

Step One:

Carefully crack the shell at the air-cell (broad) end of the egg. Do not puncture the inner shell membrane.

Step Two:

Cut or peel off the shell covering the air cell. Do not puncture the inner shell membrane (see Figure 20 below).

Step Three:

Using forceps, tweezers, or scissors, remove the inner shell membrane covering the air cell. In eggs beyond the second day of incubation, embryonic membranes adhere to the shell membranes. Moisten the membranes with warm water dispensed from an eye dropper while removing the thin transparent shell membrane. The water will prevent the shell membrane from sticking to the embryonic membrane.

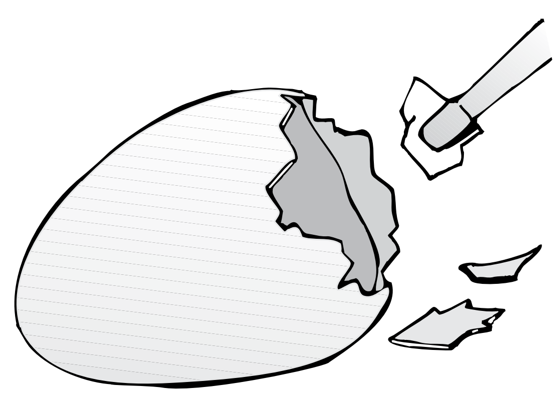


Figure 20. Shell window

Step Four:

Set the egg in an egg carton, window up and observe the embryo with the aid of a magnifying glass.

In young embryos (3 to 8 days), a rich network of blood vessels spread out from the embryo and surround the yolk. This network is the vitelline or yolk sac circulatory system. In embryos 2 to 4 days of age, observe the tiny red heart beating rapidly and pumping the blood throughout the intra- and extra-circulatory systems.

One characteristic of birds is the remarkable growth and development of the eye after the embryo is 24 hours old.

Humane Treatment of Birds and Embryos

Biological experimentation and observation is essential for learning about living processes. The "Beginning of Life" project can be used at all grade levels to teach basic biological principles through hands-on experiences with living subjects. However, such studies must ensure the humane treatment of the subjects. Therefore, it is critical that all aspects of this project conform to these guidelines.

1. Birds and chicks are not to be used in any experiments which may be deleterious to the health or physical integrity of the animals. This allows for the following:
   A. Observations of normal living patterns of birds and chicks maintained under proper living conditions.
   B. Behavioral experiments with positive reinforcement (rewards).
   C. Chick embryo observational studies are permitted. If eggs are to be hatched, then chicks must be transferred to appropriate humane care. Otherwise, all embryos should be destroyed humanely, preferably by the 12th day of incubation and definitely by the 19th day.
   D. Do not allow young children to handle chicks without adult supervision and only for very short periods of time.
2. Minimum numbers of specimens should be used for observation and experiments.
   A. Hatch the minimum number of eggs necessary for observations and for a successful hatch. Most teachers find that 12 eggs are more than sufficient to run a successful "Beginning of Life" program.
   B. Sacrifice a minimum number of embryos for classroom observations. One embryo per six students is usually appropriate.
3. Always arrange for humane handling and care of chicks that are to hatch. This should be done prior to the beginning of the project. Possible repositories for hatched chicks include:
   A. Local Farmers
   B. Agricultural Extension Agents
   C. Local Feed and Seed Suppliers
   D. Local Petting Farms or Zoos
   E. Local SPCA shelters
4. Accepted humane methods for euthanizing unwanted or crippled chicks.
   A. Oxygen deprivation by exposure to carbon dioxide.
   B. Exposure to ether or carbon tetrachloride fumes have been effective methods of euthanizing chicks; however, if used improperly, these substances can be dangerous to human health.
   C. Cervical dislocation.

   You may wish to contact a local SPCA shelter or a veterinarian to assist you in the euthanasia process.
5. Accepted humane methods of disposing of unhatched eggs.
   A. Place eggs in a domestic freezer for 24 hours. This will humanely terminate embryo development and the eggs can then be disposed.
6. Chicks or birds maintained in the classroom must be provided food, water and warmth as discussed in the following section on brooding.

All experiments and observations shall be carried out under the supervision of a competent science teacher, veterinarian, or appropriately trained professional. It shall be the responsibility of the qualified professional to ensure that all birds, chicks, and embryos are humanely handled during the program.

Once the Chicks Hatch

Brooding

Whether there is one chick or 1,000 chicks in the brooding unit, the principles are the same. The chicks must be kept warm, well fed, watered, protected from predators and dampness, and provided with plenty of fresh air without being exposed to drafts. Unless you are properly equipped, it is not advisable to raise the chicks in the classroom for more than a week.

Newly hatched chicks can live on the unabsorbed yolk in their bodies for about 72 hours if necessary. However, chicks with access to feed and water will begin to eat and drink when less than one day of age.

Since you have little time when the chicks hatch, it is extremely important that you build and/or set-up all necessary equipment at least two days prior to the chicks hatching.

Brooders should maintain a temperature of 95°F (taken at one inch above the floor level, the height of the chick's back) during the first week. If you keep the chicks beyond the first week, decrease the temperature 5°F per week until room temperature is reached.

The brooder should have a textured, absorbent litter on the floor. If the floor is slippery, the chicks can damage their legs.

Feed 18 percent to 22 percent protein chicken starter food. This completely balanced ration can be obtained from any feed and garden store. The feed can be placed in jar lids, egg cartons, small tuna type cans or a commercial chick feeder, any item that can hold enough feed to keep feed available at all times and is easy for the chicks to eat from.

Water should be available at all times. Use watering equipment which prevents the chick from getting into it and drowning. Commercially made water fountains can be bought and added to a quart jar. These are inexpensive and work very well for the first four weeks of age when brooding chicks.

Clean the waterer and brooder daily. This will prevent odors and keep the brooder dry. Dampness provides favorable conditions for the development of molds and bacteria. Providing at least 1 square foot for every five chicks will also help keep the conditions more desirable.

How to Build a Brooder and Brood Chicks for the First Week

This information tells you how to build three brooding units: two temporary, disposable brooders and one strong, reusable brooder.

A. Courtyard-type Temporary Brooder for One or Two Weeks of Brooding (see Figure 21)

Materials needed:

- One cardboard box approximately 24 inches square
- Another cardboard box approximately 12 inches by 18 inches and at least 12 inches high.
- One light socket on an electric cord
- One 40- to 60-watt light bulb
- One water fountain
- Old newspaper
- One roll of paper toweling
- One roll of clear wrapping paper

Procedure:

1. Remove the top of each cardboard box.
2. Cut the sides of the largest box (24 inches by 36 inches) down to 6 inches high. This is the chick courtyard where the feed and water will be placed.
3. Now, cut one hole 4 inches high by 6 to 10 inches across (depending on size of box) in 3 of the 4 sides of the small box. These are to serve as doorways to the heat source. Cut these holes close to the open-end edge of the 3 sides (remember, the chicks have to get in and out).
4. Turn this small box over so the covered side is up. Cut a round hole one-half the size of your light socket in the center of the covered end of the box. Then cut three slits from the inside of the round hole approximately one inch out into the box top. Cut these three slits at different angles. Now, punch the light socket down into the hole about three-fourths of the length of the socket. Tape the electrical cord to the box top. This will help keep the light bulb from falling to the floor and causing a fire. Never use a light bulb larger than 60 watts, and never place the light closer than 6 inches to the brooder floor.

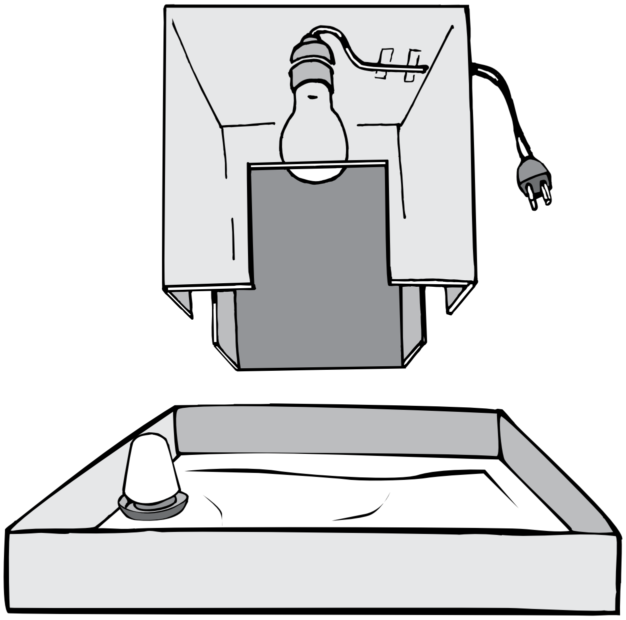


Figure 21. Courtyard brooder.

5. Cover the bottom of the largest box (courtyard) with newspaper and then a layer of paper towels. The paper towels give the chicks traction and prevent leg damage.
6. Put the other box (the open end down) in the center of the box with the paper towel surface.

   Add a waterer and a feeder, and your brooder is ready for the chicks.

   Some instructors cut out part of a side or part of the top of the brooding box (the box with the light bulb) and cover the area with clear plastic wrap so everyone can see the chicks. By covering the open area with plastic wrap, the heat from the bulb is still trapped inside the box and keeps the chicks warm.

B. Gooseneck Brooder (see Figure 22)

Materials needed:

- One cardboard box at least 18 inches long x 18 inches wide and 12 inches high
- One gooseneck lamp with a 60- to 75- watt light bulb
- Waterer and feeder
- Newspaper and paper towels for litter
- Clear plastic wrapping paper (see previous page)

Procedure:

The cardboard box serves as the chick brooder. The size and shape is not important as long as it is large enough to house the chicks and equipment. Put the newspaper in the box bottom, cover with paper towels, and place the feeders and waterers in the box. The neck of the lamp can be bent over the side of the box. The lamp can be bent closer to the chicks if they seem cold or moved upward if they seem too warm.

Many instructors cut a large window in the side of the box and cover it with plastic wrap, then place the box at the observer's eye level for best viewing.

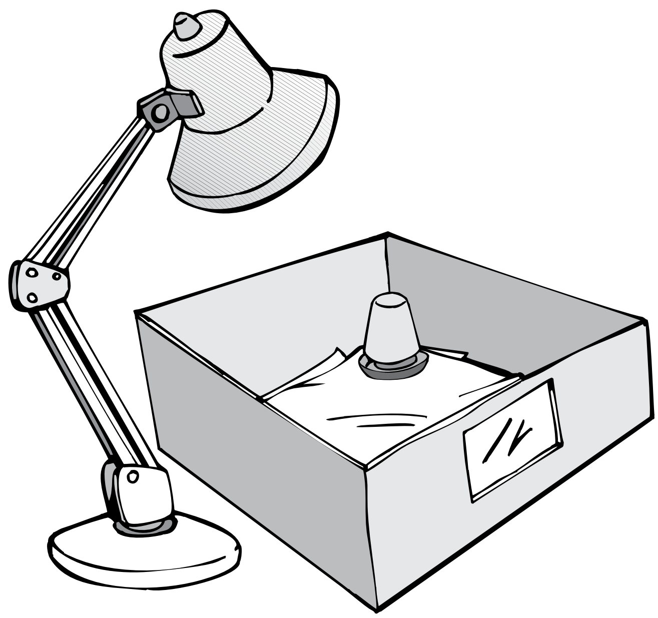


Figure 22. Gooseneck lamp brooder

C. Wooden Brooder, a Strong and Reusable Brooder which is Easy to Build (see Figure 23)

This plywood brooder is easy and inexpensive to build. The proportions can be changed if necessary. The brooder is designed to trap heat in half of the unit to keep the chicks warm. The other half allows you to observe the chicks eating and moving about. The top above the light bulbs should be hinged to allow you to open the top to clean the brooder and catch the chicks.

Use two light bulbs on the heated end of the brooder. If one burns out, the other will help maintain heat in the brooder. In a classroom, two 25-watt bulbs will usually produce enough heat. However, adjust the size of the light bulbs to regulate the temperature. It should be 95°F in the heated side for the first week, then decrease the temperature by 5°F per week by decreasing the light bulb size.

Place a layer of newspaper about five pages thick in the bottom of the brooder and cover with two layers of paper towel. This will keep the chicks from slipping and hurting themselves.

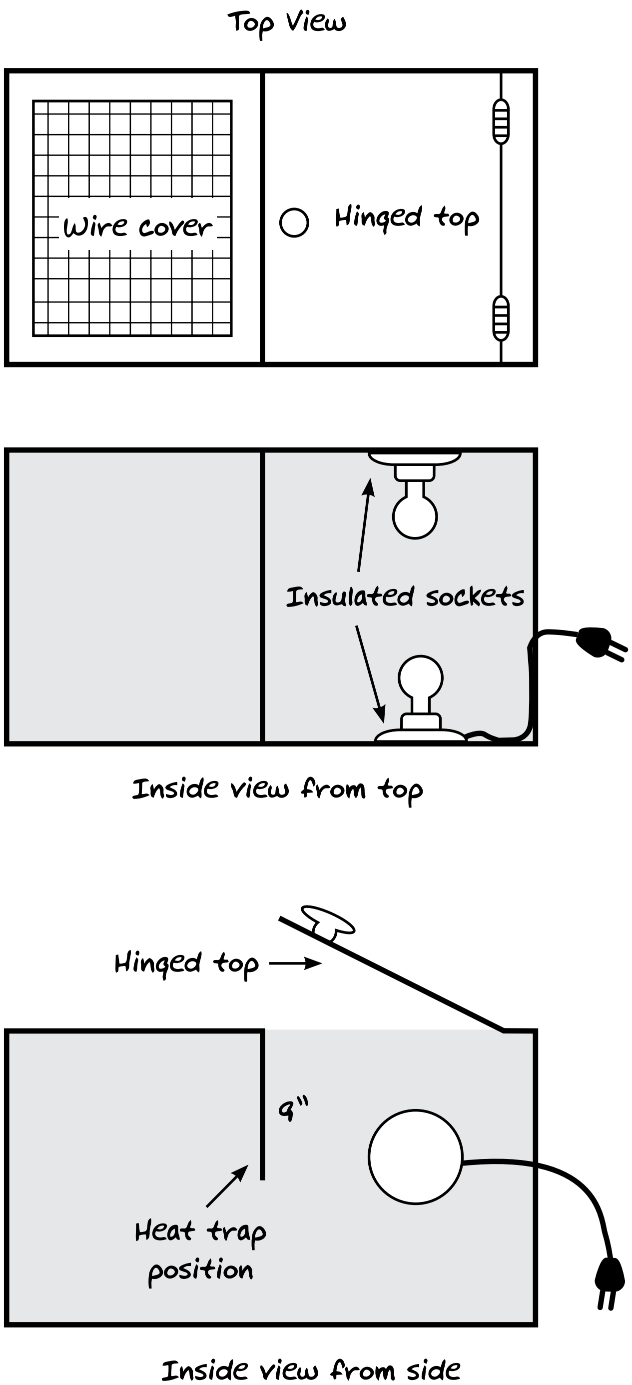


Figure 23. Wooden chick brooder

Raising Coturnix Quail in the Classroom

Coturnix quail have been raised for research, pets, and classroom projects for years. They are hardy, easy to handle, and the equipment needed for their culture is simple. They have a short reproductive cycle and may lay eggs when only 35 to 40 days old. However, coturnix quail should not be confused with Bob White quail or other indigenous quail. Coturnix quail are domesticated and will not survive in the wild if released.

Quail can be raised much like chicks except care must be taken to prevent small quail from drowning in water trays or escaping from their rearing area. Always modify the drinking fountains for quail by placing marbles, pebbles or hardware cloth in the water so the quail will not drown. These protective devices can be removed after the second week. Always cover the brooding and rearing area for quail because they can fly once they are a few days old.

To raise quail to maturity in the classroom, you can build a cage or use an aquarium that provides 1 square foot per bird. Feed the quail a 22 percent protein turkey or gamebird starter food for the first 3 weeks, then feed a 20 percent protein feed for 3 to 6 weeks. Place them on a 20 percent protein layer diet at 6 weeks of age for egg production. At 41 days of age, the adult quail must be given 16 hours of artificial light to stimulate egg production.

This project is well received because you can hatch the quail, raise the birds to production age, then hatch their young. The entire cycle takes only 12 to 15 weeks.

For best results, the quail pens should be cleaned daily or ever other day. If the pens are not cleaned often, a slight odor like that of any animal can be noticed.

Additional Learning Activities

The following projects and activities can be undertaken in the classroom or by individual students as supplements to this project.

1. **Effect of egg's age on hatchability.** Incubate eggs that are 2 weeks old or older when they are placed in the incubator and eggs that are 1 week old or less. Compare the differences in hatchability and differences in time required for hatching.

2. **Effect of improper temperatures during the holding period on hatchability.** Keep control eggs under ideal (55° to 58°F) conditions. Similarly, some eggs could be held at room temperature or preferably above 80°F. All eggs should be the same age and from the same source. Incubate them and compare the results.

3. **Effect of turning eggs during incubation on hatchability.** Place two groups of eggs that are the same age and from the same source in the incubator. Distinguish between the eggs in each group by using an identifying mark on the eggs in one group and a different mark on the eggs in the other group. Turn the eggs in one group three times a day for the first 18 days of incubation. Do not turn the eggs at all in the other group. Compare hatchability. Compare groups of eggs turned on any regular schedule (such as three times per day, five times per day, etc.) during the first 18 days of incubation with eggs that are not turned at all. Compare the hatchability and development of the embryos.

4. **Effect of egg size on weight of the chick.** Set eggs of significantly different sizes and compare the weight of the baby chicks at a given interval of time after hatching.

5. **Effect of shell porosity on hatchability.** Set one group of normal eggs and another group that has had the shell pores sealed by dipping the eggs in mineral oil. Compare the hatchability and embryo development of the two groups.

6. **Effect of incubation temperature on hatchability and embryo development.** If two incubators are available, set eggs in one and operate it at recommended temperature and humidity levels. Place eggs in the other and operate it at a marginal level of temperatures, such as 97°F or 103°F, through the incubation period. Recognizing that it is not as sound experimentally, one incubator could suffice. First, incubate a group of eggs at a marginal temperature level for the incubation period and record the results; then incubate a group of eggs under a recommended procedure and compare the results of the two groups.

7. **Effect on relative humidity on hatchability.** The same general type of plan as outlined in Number 7 could be followed except that the humidity would be varied while all other procedures were kept normal.

8. **Preserving chick embryos.** Embryos can be harvested and preserved in a 10% solution of formalin (1 part 37 percent formaldehyde and 9 parts water). A small glass jar with a screw cap works well for this purpose. Refer to *Animal Microbiology* by Michael F. Guyer for more information.

Some Suggested Language Arts Activities

1. Expand vocabulary by learning and defining new words (e.g., embryo, incubator, humidity, thermometer, egg tooth, etc.)

2. Reading comprehension test: close exercises using a few paragraphs describing the project followed by fill-in or short-answer questions at the end. A PowerPoint quiz is great as a team exercise for comprehension.

3. Compositions by students about their participation in the project and the observations they made. Write simple stories about chickens and eggs.

4. Keep daily log about embryology project.

Some Suggested Mathematics Activities

1. Calendar skills: calculate days and weeks during incubation period.

2. Fractions and percentages: i.e. percent (fraction) of chicks that hatch and do not hatch.

3. Thermometer skills: reading a thermometer, calculating differences in temperature in incubator, difference between human temperature, incubator temperature, and temperature of brooding hen; possibly conversion of Fahrenheit to Centigrade.

4. Measuring skills (use of a ruler): in some instances, incubator will be constructed by students; otherwise dimensions can be measured as part of classroom teachings.

5. Telling time: calculating intervals at which eggs are to be turned

6. Graphs and charts: plotting time-line of incubation period of 21 days, graphing incubator temperature and humidity, graphing number of eggs at beginning of project, number used for experimentation and number that hatch or do not hatch.

7. Weights: weighing and recording weight changes as incubation progresses. Graphs of these weights could also be used.

Some Suggested Art Activities

1. Drawing: draw pictures of chickens and eggs.

2. Coloring: color or paint pictures of chickens and eggs; explore different species and colorations.

History Activities

1. Read/study about the history of incubators. For example, the Egyptian incubator, which was built in 5000 B.C. of clay bricks, was heated by fires built in the incubator chambers, which were 70 feed long, 14 feet high, and had capacities for 90,000 eggs.

2. Make a time-line chart that records the development of embryos each day of the incubation period.

Personal Development Activities

1. Basic "Processes of Life" can be discussed. Discuss the needs of living organisms – air, water, food, heat, and shelter – and note how chicks and human receive each one.

2. Discuss birth defects/handicaps in chicks. Let this lead into discussion of people with disabilities.

3. Sex education can be taught by talking about fertile and infertile eggs.

4. If different breeds of chicks are used, a discussion of two or more races living together in a miniature world could be held.

5. Students can learn "responsibility" by being assigned to care for the eggs and/or the chicks.

6. Students can plan for the "birth-day" by sending a "birth announcement" to other classes in the school. They can invite other classes in to see the hatching and be hosts/hostesses for the day.

Shop (Woodworking and Electric) Activities

1. Build a forced-air incubator with a wooden case, adding the fan, motor, heating element, and thermostat.

Glossary

Albumen – a combination of the four layers of a whitish watery substance (88 percent water, 11 percent protein) that surrounds and contains the yolk within the center of the egg shell.

Allantois – an organ in the embryo of birds which develops into part of the umbilical cord and unites with the chorion, forming the placenta.

Amnion – a thin, membranous, fluid-filled sac surrounding the embryo.

Avian – of or pertaining to aves or birds.

Bacteria – microscopic single-celled organisms.

Blastoderm – the collective mass of cells produced by the splitting of a fertilized ovum from which the embryo develops.

Blastodisc – the germinal spot on the ovum from which the blastoderm develops after the ovum is fertilized by the sperm.

Brood – baby chicks hatched from one nest (setting) of eggs.

Candling – observing the shell and the contents of the egg (blood vessels, embryonic development, blood or meat spots, air cell, etc.) through the shell by holding the egg up to a bright light that is focused on and behind the egg shell.

Cell – a mass of protoplasm (usually microscopic) within a semi-permeable membrane, containing a nucleus and capable of functioning as an independent unit.

Chalazae (singular = chalaza) – prolongations of the thick inner-white that are twisted like ropes at each end of the yolk. Their function is to anchor the yolk in the center of the egg shell cavity.

Chorion – a membrane enveloping the embryo, external to and enclosing the amnion.

Chromosomes – a series of paired bodies in the nucleus, constant in number in any one kind of plant or animal.

Cloaca –in birds, the common chamber into which the intestinal, urinary, and generative canals discharge.

Dorsal – of, on, or near the back.

Dry-bulb thermometer – expresses a temperature reading in number of degrees Fahrenheit (F) or centigrade/Celsius(C).

Egg (avian) – the female reproductive cell (ovum) surrounded by a protective calcium shell and, if fertilized by the male reproductive cell (sperm) and properly incubated, capable of developing into a new individual.

Egg tooth – also called “chicken tooth”, the temporary horny cap on the chick’s upper beak which serves for pipping (breaking through) the shell. Usually dries and falls of within 18 hours after the chick hatches.

Embryo – a fertilized egg at any stage of development prior to hatching. In its later stages, it clearly resembles the fully developed chick.

Embryology – the study of the formation and development of plant and animal embryos

Evaporation – changing of moisture (liquid) into vapor (gas).

Fat – organic combination of carbon, hydrogen, and oxygen in such relative quantities that the caloric value of the compound is high.

Fertile – capable of reproducing.

Fertilized – an ovum impregnated by a sperm.

Follicle (ovarian) – the thin membrane of the ovary which encloses the developing yolk; the yolk sac.

Gene – an element in the chromosome of the germplasm that transmits hereditary characteristics.

Hatching egg – a fertilized egg, one with the potential of maturing.

Humidity – see “relative humidity.”

Incubate – to maintain favorable conditions for developing and hatching fertile eggs.

Incubator – a container with the proper humidity and temperature to allow fertile eggs to hatch.

Infundibulum – any various hollow, conical organs or parts thereof. For example, the grey matter in the brain to which the pituitary body is attached, the entrance to the oviduct.

Membrane – a thin, soft, pliable sheet or layer of tissue covering an organ.

Nutritious – food that contains substances necessary to sustain life and growth.

Ovary – the female reproductive gland in which eggs are formed.

Oviduct – the tube through which eggs pass after leaving the ovary.

Ovum – the female reproductive cell.

Papilla – any small, nipple-like or teat-like projection.

Peristaltic action – involuntary movement of the muscles of the oviduct that forces the egg onward.

Pipping – a baby chick breaking from its shell.

Pores – thousands of minuet openings in the shell of an egg through which gases are exchanged.

Protein – one group of nitrogenous compounds commonly known as amino acids.

Pituitary – a small, oval, two-lobed vascular body attached to the infundibulum of the brain that secretes hormones affecting growth.

Relative humidity – the amount of moisture in the air compared with the amount that the air could contain at specific temperature. Expressed as a percentage.

Semen – the fluid secreted by the male reproductive organs. Serves as a vehicle for the sperm.

Sperm – the male reproductive cell.

Still-air incubator – a container for hatching chicks that does not have mechanical ventilation.

System – functioning unit of the anatomy, such as the skeletal, muscular, glandular, respiratory, and digestive systems.

Testes – the male genital glands (plural).

Testicle, testis – the male genital gland (singular).

Vitamin – a fat- or water-soluble substance necessary, in very small amounts, to allow for normal growth and maintenance of life.

Vitelline – of pertaining to, or like the yolk of an egg.

Wet-bulb thermometer – a device to measure the amount of water vapor in the air.

Yolk – a globular mass of yellow, nutritious semi-liquid contained in a transparent membrane (the vitelline membrane) and located in the center of an egg. The yolk is the chick's food during its pre-hatching life and its first food after it emerges from the shell.

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