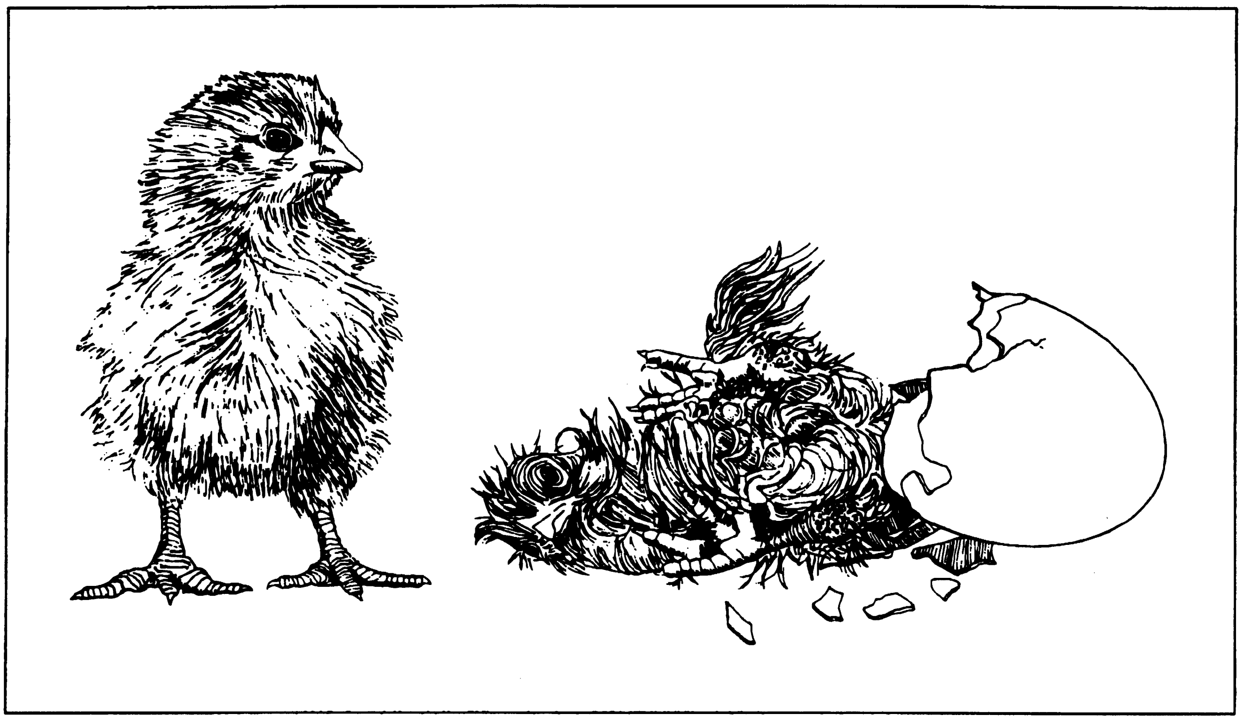
Beginning of Life



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BEGINNING of LIFE

A Leader's Manual for Avian Embryology

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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, church, and home in helping young people develop. As you involve your young people in this program, consider introducing 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 Pennsylvania Cooperative Extension (PCE) office.

The purpose of all 4-H programs is to develop youths 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 your 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 other.

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 this 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.

Commercial products are named in this publication for informational purposes only. The author does not intend or imply discrimination against similar commercial products not named but which may also be suitable.

Introduction

The "Beginning of Life" 4-H project is designed to help youths obtain better understandings 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 that you are 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 bird 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 the student, even the youngest.

Extension professionals, teachers and youths should feel free to contact the poultry science faculty at Penn State with specific questions that may arise. However, it is important that youths 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.

This project can be used at any grade level from kindergarten though high school. It is very flexible, so it is easily adapted to comply with student interests and abilities. The time you have available and the characteristic of your student group will bear on the extent to which you use the information in this manual.

This project should:

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

Whether you do a detailed experiment or just incubate the eggs, everyone involved in this project should 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, as mentioned in this text.

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 that 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 insure 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 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 insures that the chicks will not hatch on a weekend. Dates of the embryology project: ____/____/____ to ____/____/____.

_____ Contact your local PCE office and be aware of any possible requirements for enrollment or egg procurement.

_____ Before you order eggs, plan what you will do with the chicks that hatch.

_____ Order the eggs you will need as soon as possible. **To insure egg availability, order the eggs at least 3-6 months in advance of the day 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 who 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 plan and order or obtain any materials you need to support the lesson plan.

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 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 2 hours before putting them in the incubator.

_____ Mark the eggs with "X" and "O" on opposite sides to aid in daily turning. Also, number egg on the large end for future reference.

_____ 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, candling, and other activities). These records are extremely helpful for trouble-shooting causes of poor hatches.

_____ Candle the eggs every 4-6 days to check progress.

_____ Stop turning eggs three days prior to the expected hatch day.

_____ Prepare brooding area two days prior to expected hatch.

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

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

_____ Clean and disinfect the incubator within 4 hours after the power is disconnected. Once the dirt has dried to the surface it becomes difficult to remove.

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

Securing Needed Materials

In order to implement and complete a successful 4-H Embryology Project, it is necessary to obtain a number of materials in a timely manner.

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

1. Material Needed: Incubator (see section titled "Types of Incubators" (page 13)
   Where to Obtain:
   A. Purchase from local feed and seed store.
   B. Order from supply company. Contact Pennsylvania State University, Poultry Science Department, for additional sources and companies.
   C. Eggs can be purchased from:
      - G.Q.F. Manufacturing Co., Inc., P.O. Box 1552, Dept. Z, Savannah, GA 31498 (912-236-0651)
      - Kuhl Corporation, Dept. G, P.O. Box 16, Flemington, NJ 08822-0026 (201-782-5696)
      - Marsh Manufacturing Inc., 14232 Brookhurst Street, Garden Grove, CA 92643 (714-534-6580)
      - Nasco, 901 Janesville Avenue, Fort Atkinson, WI 53538 (414-563-2446)

      Note: This is not a complete listing. No discrimination and no endorsement is implied.

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

2. Material Needed: Fertile Eggs
   Where to Obtain:
   A. 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 because roosters are not kept with the hens, and therefore, they 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 county extension office for suggestions.
   B. Many times, fertile eggs can be obtained from local farmers or hobbyists. Also contact Pennsylvania State University, Poultry Science Department, for additional information.

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

3. Material Needed: Resource Materials Available Through Your PSU 4-H Agent
   Where to Obtain:
   A. Embryology Project Book for ages 8-13. Member exercise booklet to give youth an opportunity to actively test their knowledge about embryology and poultry.
   B. Key to Embryology Project Book for ages 8-13. Key to above member project book.
   C. Literature and visual aids - Contact your local Extension office for additional resource and supplemental literature for this and other projects.

   Time Frame: One month prior to start of project.

4. Materials Needed: Other Educational Aids
   Where to Obtain:
   A. Carolina Biological Supply, 2700 York Road, Burlington, NC 27212 (Phone: 1-800-334-5551)
   B. Wards Natural Science, Inc., 5100 West Henrietta Road, P.O. Box 92912, Rochester, NY 14692-9012 (Phone 1-800-962-2660)

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

5. Materials Needed: Feed, Feeders, and Waterers
   Where to Obtain: From local pet stores or feed-and-seed farm-supply stores.
   Time Frame: One week prior to expected hatch date.

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 the needed materials, you are ready to implement a successful project.

About the Chicken

History

Domestication of the chicken dates back to at least 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 throughout 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 chicken 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 including 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* - have yellow skin, lay brown-shelled eggs and have 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* - are similar to New Hampshire Reds except they are usually better layers and Rhode Island Reds have deep-red adult plumage. The chicks of Rhode Island Reds are brown in color.

C. *Barred Plymouth Rock* - are dual-purpose chickens that have 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* - are mainly raised as 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. Cochins have feathered shanks and have extremely loose, soft feathers that give them their fluffy appearance.

E. *Cornish* - were developed as the ultimate meat bird and have contributed to build the vast broiler industry of the world. The Cornish originated in England.

F. *Leghorn* - are grandparents of our modern white-egg industry. Originating in Italy the Leghorn have a large single comb and are flighty by nature. Most chicks hatched from white shelled eggs will be white Leghorn-type chickens.

G. *Polish* - are another unusual and beautiful breed. They have a crested or hat of feathers on top of their heads.

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

I. *Naked Neck* - have a bare neck totally absent of feathers. This single gene trait affects the arrangement and number of feather tracts over the chicken's body.

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

K. *Araucanas* - were discovered in South America and are nicknamed Easter egg chickens because of the blue and green eggs they lay. This is again a genetic modification in which a blue cuticle is applied to the egg. When introduced to brown egg layers, the result is an olive-green shell; introduced to white egg layers, the result is a blue shell.

L. *Bantams* - are the miniatures 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 of 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 female 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. Today's broiler can achieve a 4-pound market weight in 6 weeks. Twenty years ago, it took 14 weeks to achieve a 5-pound market weight. 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 106°F. 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.

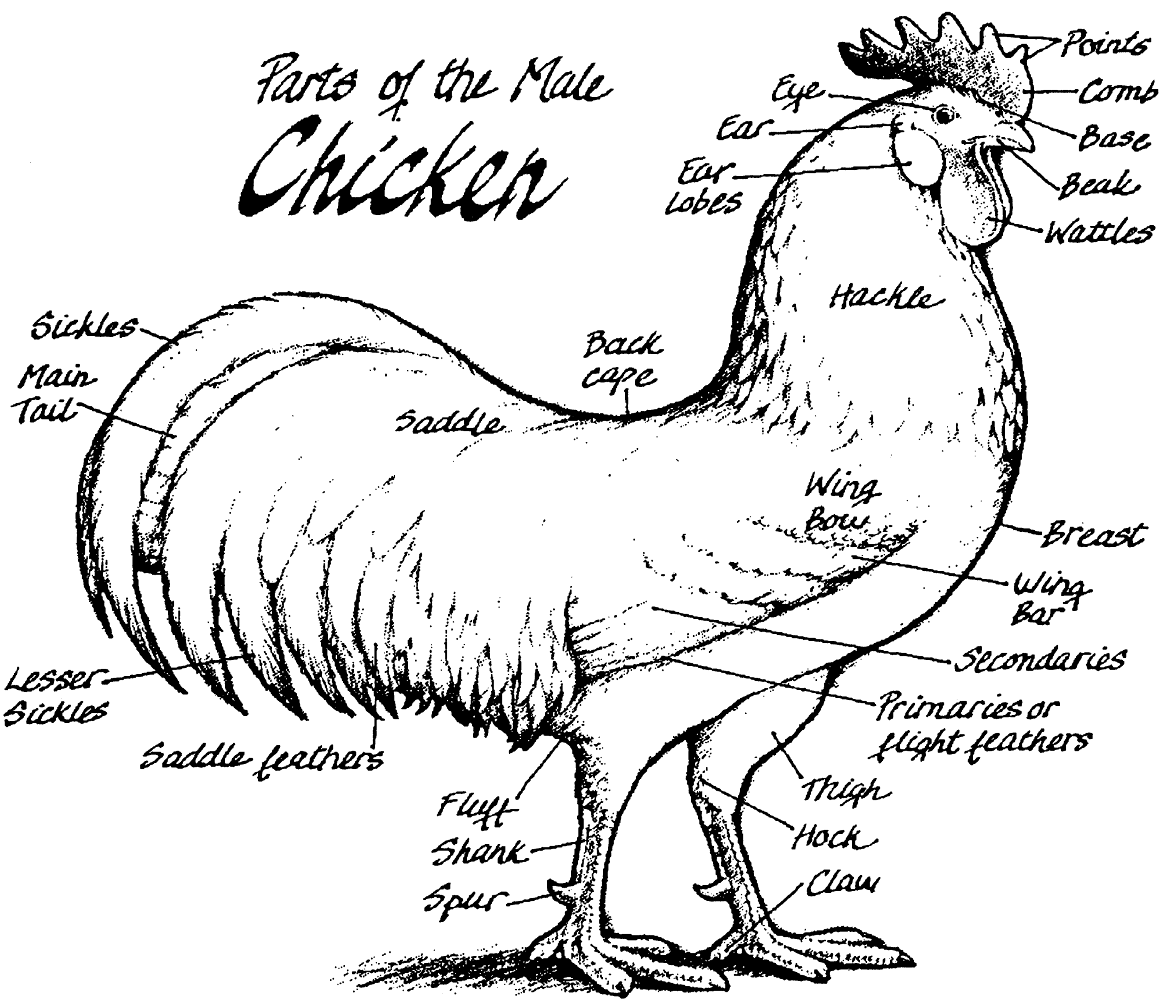

Figure 1. There are seven different comb types
(*Bantams,* North Central Regional Extension Publication #201)

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: Araucanas 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 shiny. Female hackle and saddle feathers have rounded ends. The breeds of "Sebright" and "Campine" are the only exceptions. In these two "hen-feathered" breeds, the feathers are alike in both sexes.

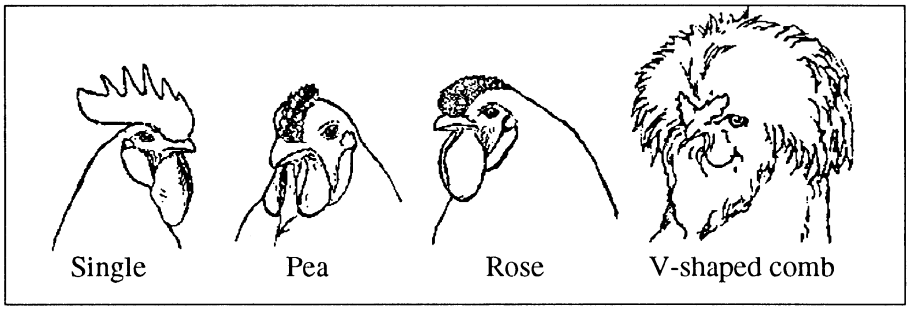

Figure 2. Four comb types
(*Chicken Breeds and Varieties*, U. of Wisconsin Extension #A2880)

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 medullary bone. This bone fills the narrow cavity with a readily available source of calcium for eggshell formation when calcium intake is not sufficient. Medullary 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 like in ruminants such as cattle. Chickens depend on enzymes to aid in breaking down food so it can be absorbed, much like humans.

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

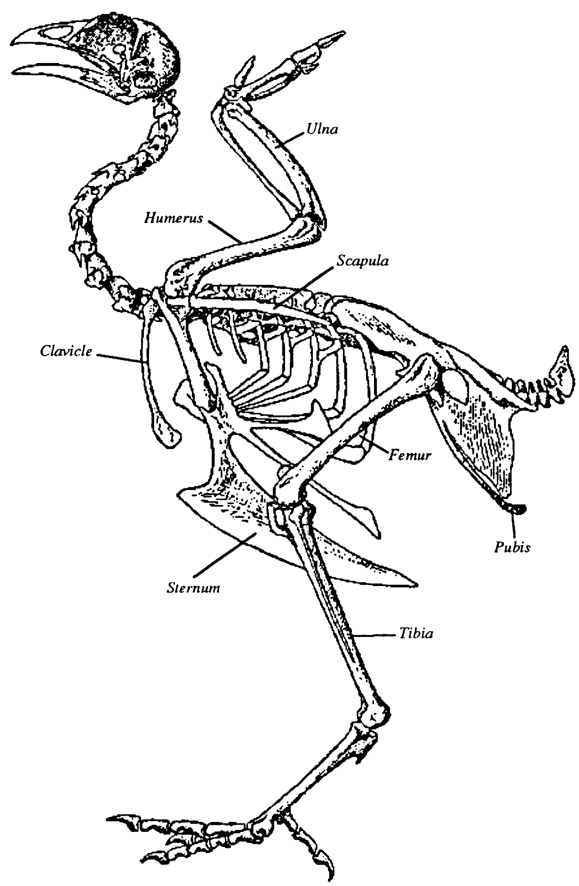

Figure 3. The skeleton of a fowl

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 intromittent 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. These in turn cause enlargement of the testes, androgen secretion, semen production and stimulate 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 the 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 sexual maturity, these ova develop a few at a time into yolks.

The ***oviduct*** is a tubelike 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 4).

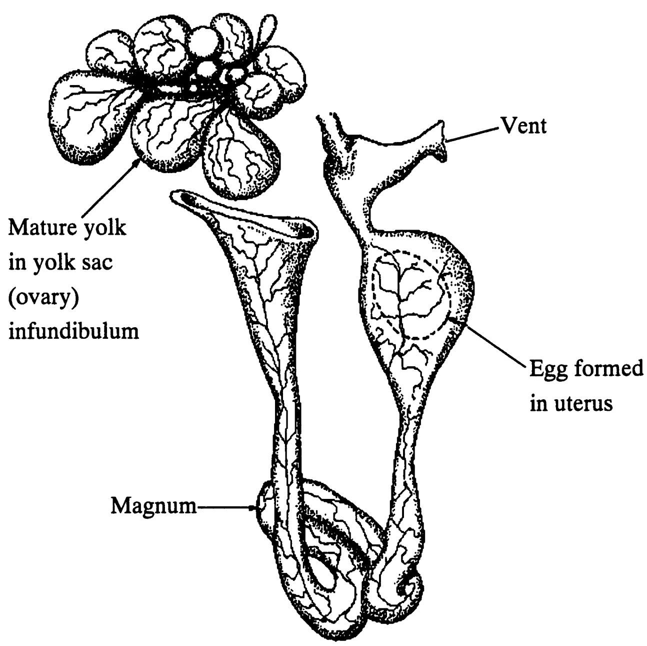

Figure 4. Reproduction organs of hen
(Artwork from North Carolina Extension Service)

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. Development takes place as follows:

Part of Oviduct	*Length of Part*	*Time Spent There*	*Function of Part*
Infundibulum	2 inches	15 minutes	Picks-up yolk, egg fertilized
Magnum	13 inches	3 hours	40-50% of white laid down-thick albumen
Isthmus	4 inches	1 $^1/_4$ hours	10% albumen shell membrane laid down, slope of egg determined
Uterus	4.2 inches	20 $^3/_4$ hours	40% of albumen, shell formed, pigment of cuticle laid down
Vagina & Cloaca	4 inches		Egg passes through as it is laid

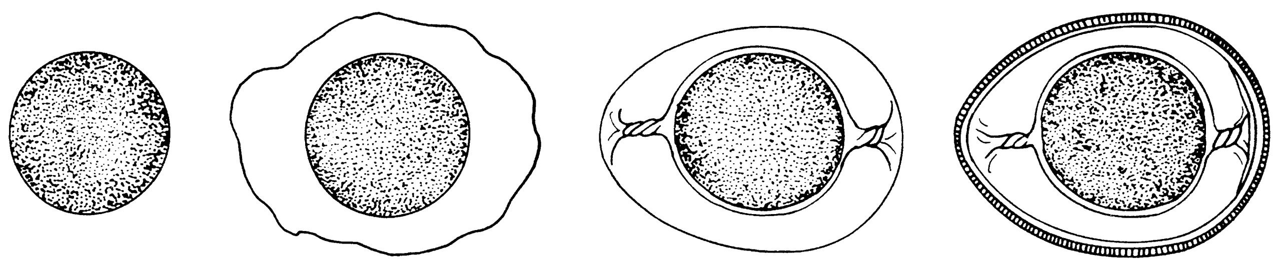

Figure 5. Order of egg formation in hen's oviduct
(*Embryology 4-H Manual I,* North Carolina Extension Service)

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 the 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), it 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 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 egg can develop and become a chick. Only fertilized eggs grow into chicks. The chicks grow and become adult birds.

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 where eggs are produced to be eaten 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 crack 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.

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 or the most fanciful meals.

Scientifically speaking, an egg (ovum) is the reproductive cell produced by the female. It remains a single cell until it is fertilized by the single cell (nucleus) of the male sperm. 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.

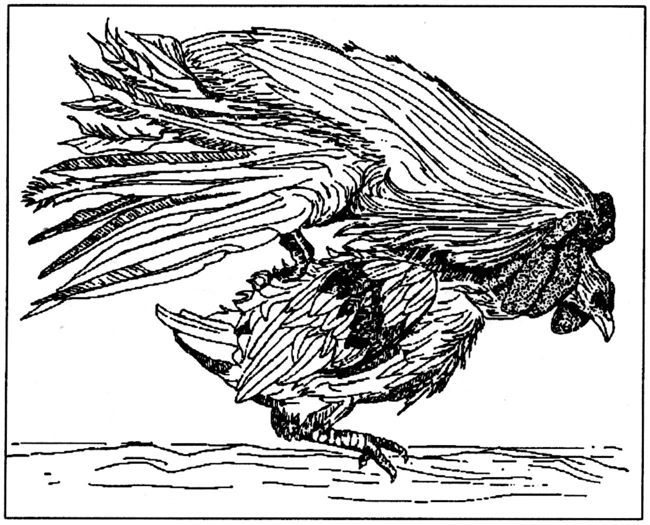

Figure 6. Rooster mounting hen
(Artwork from North Carolina Extension Service)

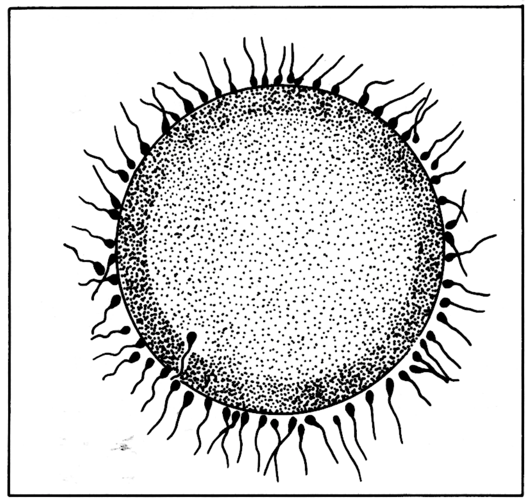

Figure 7. Sperm unites with the egg
(Artwork from the North Carolina Extension Service)

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.

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.

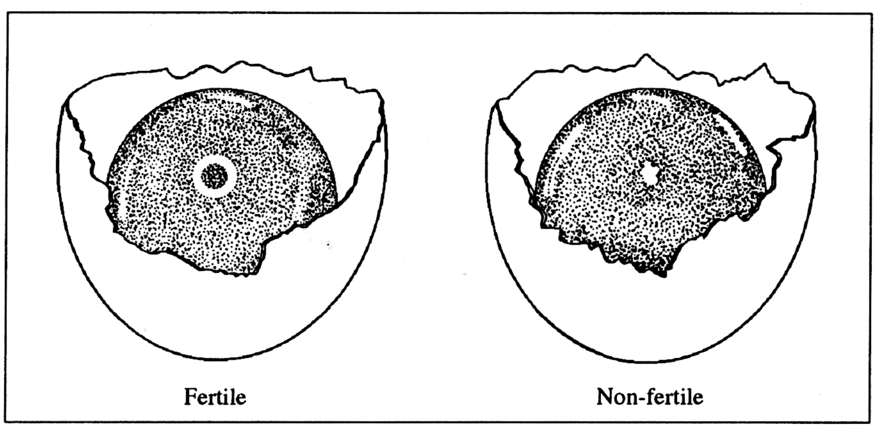

Figure 8. Fertile and non-fertile eggs
(Artwork from North Carolina Extension Service)

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 larger and 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 9 and 10).

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 too 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 does the shell of the egg. This creates a vacuum and air is normally 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 20th 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 breaths 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.

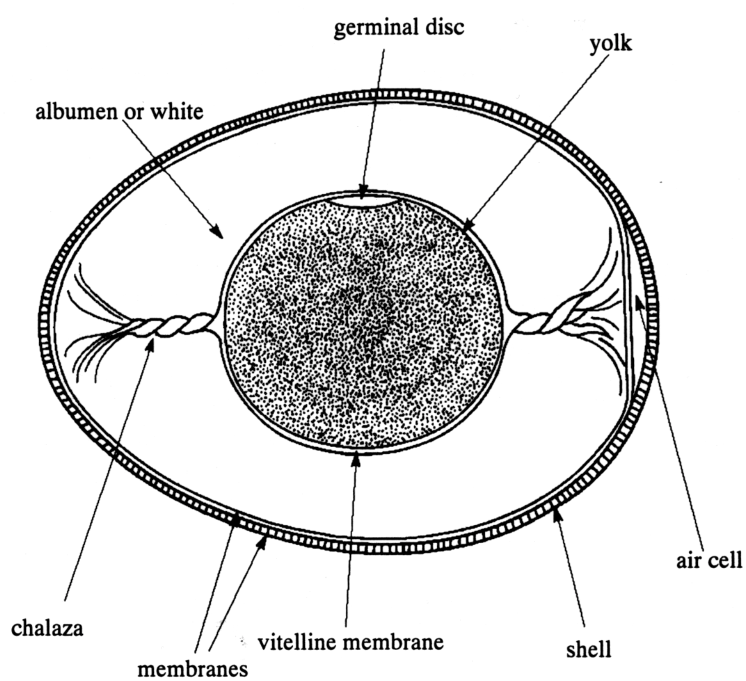

Figure 9. Parts of the egg
(*Embryology 4-H Manual I,* North Carolina Extension Service)

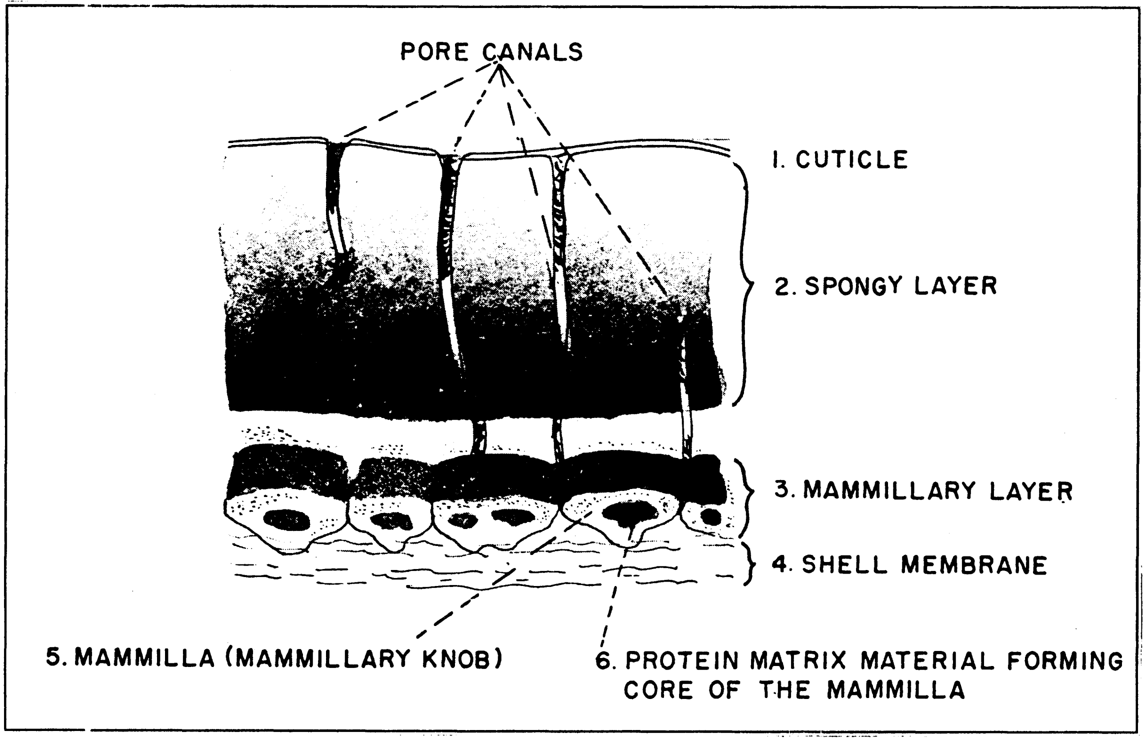

Figure 10. Magnified radial section through the shell
(*Egg-Grading Manual,* USDA Agricultural Handbook #75)

The yolk contains large amounts of carbohydrates, 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). These substances combine with the oxygen taken in through 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. Water is used by the embryo to replace moisture lost through evaporation. Carbon dioxide is transpired through the pores of the shell. Calcium absorbed from the yolk and shell is used by the embryo to make its bony structure, or skeleton.

Table 1. Nutrition Value of Eggs

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

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

Percentage of U.S Recommended Daily Allowances (U.S.RDA)

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	Phosphorus	20		

* Contains less than 2% of U.S. RDA of these nutrients.

(*A Brighter Idea: Egg!* Virginia Cooperative Extension Publication 408-032)

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 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 chicks that are hatched. If possible, line up someone who has experience in keeping chickens and is willing to take the chicks. Do not hatch chicks and then abandon them or give them to someone who is unable to care for them properly.

When you have located a source of fertile eggs, pick them up yourself, if possible, rather than have 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.

If it is necessary to store fertile eggs before setting, store small-end-down at a temperature of 50° to 65° F. Cell division can begin if temperatures exceed 86° F. Refrigerators can be used to store eggs only if room temperatures exceed 80° F. Modern frost-free refrigerators can dehydrate eggs stored more than a couple of days. *Never* store eggs more than 10 days after the eggs are laid. Hatchability drops quickly if they are stored for more than 10 days.

Transport fertile eggs in a protective carton, small end down. Do not leave eggs in the sun or a hot parked car. In winter, don't let the eggs get below 35° F.

It is always best to set the 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 (see Table 2). 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 when relative humidity is 60 percent, concentrations of oxygen 21 percent, carbon dioxide 0.5 percent, and air movement past the egg is at 12 cubic feet per minute.

Table 2. 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 - dry 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	92-95	90-94	90-94

(Incubating Eggs of Domestic Birds, Clemson University Extension)

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 100° F for still air, 99°-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 insure you are getting an accurate reading.

Incubator temperature should be maintained between 99° and 100° 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 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 11).

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 48-72 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 6-8 hours or until the egg warms to 99°-100° F.

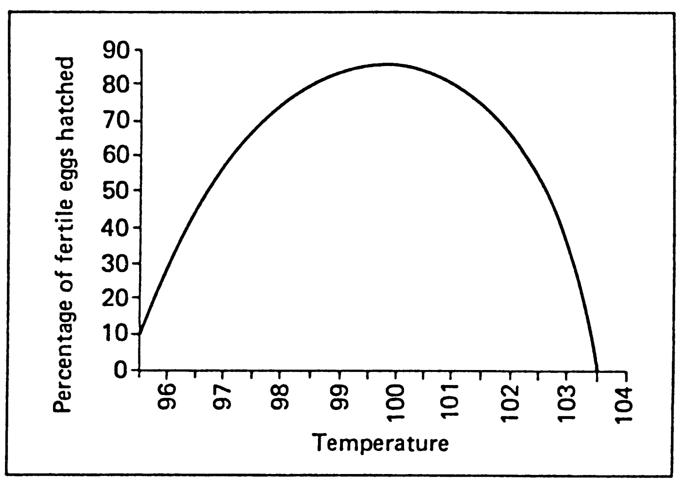

Figure 11.
The effect of incubation temperature on percentage of fertile eggs hatched. Relative humidity 60%, Oxygen 12%, CO_2 below 0.5%
(*From Egg to Chick,* Northeast States Cooperative Extension Service)

In Case of Power Outage

If you experience a power failure, do not scrap the project. Most of the time, the hatch can be saved. The key is to keep the eggs as warm as possible until the power returns.

This can be done by placing a large cardboard box over the top of the incubator to create additional insulation. Many teachers place a box over their incubators at night and on weekends to help insulate the incubators as a protection from possible power outages. In extreme cold, covering the box with blankets may help. To warm the eggs, place candles in jars, light them and place the jars under the box that covers the incubator. Be careful not to put any flammable material closer than a foot from the top of the candles to prevent fires. The heat from the candles can easily keep the eggs above 90° F until the power returns.

Embryos have survived at temperatures as low as 70° F for a short period of time. Some embryos can survive at temperatures below 90° F for up to 18 hours, so do not give up. You should continue to incubate the eggs after the outage; then candle them 4 to 6 days later to see if there has been further development or signs of life. If, after 6 days, you do not see life or development in any of the eggs, then stop the project. Most of the time, a power outage will delay the hatching by a few days and decrease the hatchability to 40-50 percent.

Humidity

The relative humidity of the air within an incubator for the first 18 days should be about 60 percent. During the last 3 days (the hatching period) the relative humidity should be nearer 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 stick to the shell sometimes and hatch crippled at hatching time (see Figure 12).

Table 3 (Relative Humidity) will enable you to calculate relative humidity using readings from a wet-bulb thermometer and the incubator thermometer.

During the hatching period, the humidity in the incubator may be increased by using an atomizer to spray a small amount of water into the ventilating holes. (This is especially helpful when duck or goose eggs are being hatched.)

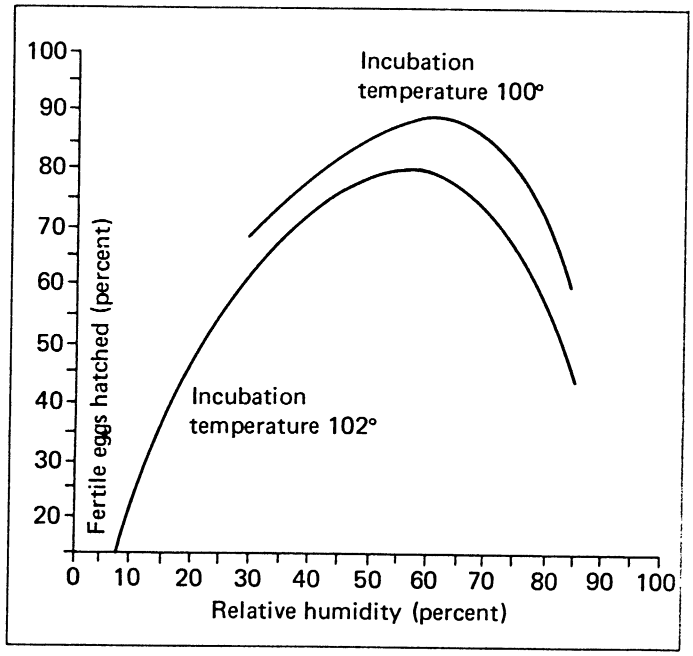

Figure 12.
The effect of relative humidity at two different incubation temperatures on percentage of fertile eggs hatched. Oxygen 20%, CO_2 below 0.5%
(*From Egg to Chick,* Northeast States Cooperative Extension Service)

An 8-inch pie tin or petri dish containing water and placed under 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.

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.

Table 3. Relative Humidity

Incubator Temperature	Wet Bulb Readings					
100° F	81.3	83.3	85.3	87.3	89.0	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 Extension Service)

Using a *wet-bulb thermometer* is also a good learning experience for determining relative humidity. The wet-bulb thermometer measures the evaporative cooling effect. If the wet and dry bulb read the same temperature, you would have 100 percent humidity. The greater the 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 readings.

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 13.

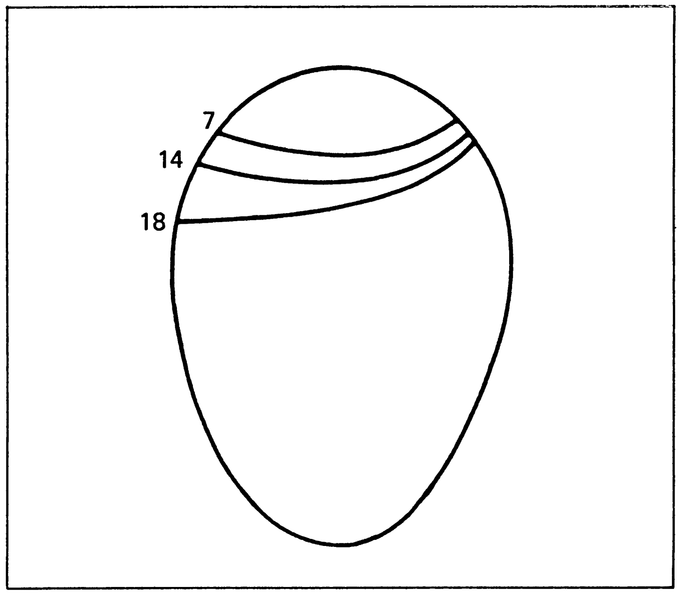

Figure 13. Diagram showing the air cell on the 7th, 14th and 18th days of incubation
(*From Egg to Chick,* Northeast States Cooperative Extension Service)

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 an air-tight container.

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 side 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 "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 weekends. 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°-106° F. When the hen sits on the eggs, this heats the eggs to 100°-101° F. The hen turns the eggs on a regular basis by using her beak to scoop under the egg and roll it toward her. The humidity comes from the environment, the bird's body, and any moisture the female transfers back to the nest on her feather. Brooding hens often leave their nests to feed at dawn or dusk when the 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 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 becoming 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 it is inconvenient for you to turn the eggs—on weekends and snowdays, 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.

Incubation 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 if you have questions. If you follow these instructions you will have a successful project.

Embryology "Must" Schedule

1. 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.

2. Set-up the incubator. Make sure it operates correctly for at least 24 hours before you set the eggs.
   a. Set-up the incubator in a room that stays above 60° F.
   b. Adjust the incubator so it holds the desired temperature. In still-air units (without fans), adjust the temperature to 100° F. In forced-air units (with fans), adjust the temperature to 99° F. Always adjust the thermostat so the heat source comes on when the temperature drops below the desired temperature.
   c. Use two (2) thermometers to insure an accurate temperature reading.
   d. DO NOT set the incubator next to or on top of a heat register or in a sunny window.
   e. DO NOT set the incubator in a drafty location (i.e., near an air conditioner, a fan blower or an open hallway).

3. Make a calendar for the project.
   a. Have a place to mark when the eggs are turned.
   b. Have a place to enter the daily dry- and wet-bulb temperatures.
   c. Have enough space to write down daily observations.

4. Prepare the eggs for setting.
   a. Place eggs at room temperature for 2 hours before setting.
   b. Candle the eggs for cracks. DO NOT set cracked eggs.
   c. Remove any excessive dirt from the eggs.
   d. 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 permanent or toxic ink pen.

5. Set the eggs in the incubator with all the "x" sides up.

6. Turn the eggs daily. All eggs should be turned three times daily. You must turn them at least once on weekends. Be sure eggs are turned gently; rough turning for the first 10 days can be fatal.

7. Record temperature each time before you turn the eggs.

8. 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.

9. Only open the incubator to turn the eggs, to add water or to set the eggs at the beginning of the project.

10. Candle eggs every 4-6 days to check progress. If an egg remains clear, it is infertile or you overheated it during the first 48 hours.

11. Stop turning the eggs three days before the hatch date. For chicken eggs, stop turning them on the 18th day. For quail eggs, stop turning them on the 14th day.

12. Prepare for brooding three days before the hatch date. You want everything prepared before the chicks hatch.

13. Remove dry, fluffy chicks on the 21st and 22nd day but don't leave the chicks in the incubator more than 12 hours after they hatch.

"Do Not" List

1. 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 7 days.

2. 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.

3. DO NOT open the incubator more than necessary.

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

5. DO NOT let the water tray become low or dry.

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

7. DO NOT turn the eggs after the 18th day for chickens or the 14th day for quail.

8. 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, chlorox, 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 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 a 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 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.

Table 4. Incubation Periods (species and days required to hatch)

Bobwhite Quail	(23-24)	Guinea	(27-28)
Canary	(13)	Muscovy Duck	(35)
Chicken	(21)	Pheasants	(24-26)
Chukar Partridge	(23-24)	Pigeon	(16-19)
Coturnix Quail	(16-18)	Ostrich	(42)
Ducks	(28)	Swan	(35)
Geese	(28-33)	Turkey	(28)

Trouble Shooting

Maximum hatchability requires fresh eggs from well-bred and properly managed flocks. However, egg care and incubation is 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 during 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 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 #7: **Sticky chicks—chicks smeared with egg contents.**

Causes:

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

Correction:

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

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-bodies, 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 openings 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% 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, egg and sperm, in the process known as fertilization. In birds, fertilization occurs 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, whitish spot (the blastoderm or germinal disc) that is easily seen on the upper surface of the yolk. This spot in a fertilized, freshly laid egg is the beginning of the chick (see Figure 9).

When the egg is laid and cools, division of the cells ceases. Cooling the egg at ordinary temperatures 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 divisions. 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 grouping or layer. 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, the 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 bones, 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 these 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 of 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 (1) yolk sac, (2) amnion, (3) chorion, and (4) allantois.

1. 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 reabsorbed at hatching. At this time, enough nutritive material remains to adequately maintain the chick for up to two days.

2. 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.

3. 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 chorio-allantoic membrane. This brings the capillaries of the allantois into direct contact with the shell membrane, allowing calcium resorption from the shell.

4. 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 nutriment (protein) for the embryo. (4) It absorbs calcium from the shell for the structural needs of the embryo. The allantois differs from the amnion and chorion in that it arises within the body of the embryo. In fact, its proximal portion remains intra-embryonic throughout development.

Functions of the Embryonic Membranes

Special temporary organs or embryonic membranes are formed within the egg, both to protect the embryo and to provide for its nutrition, respiration and excretion. These organs include the yolk sac, amnion and allantois (see Figure 14).

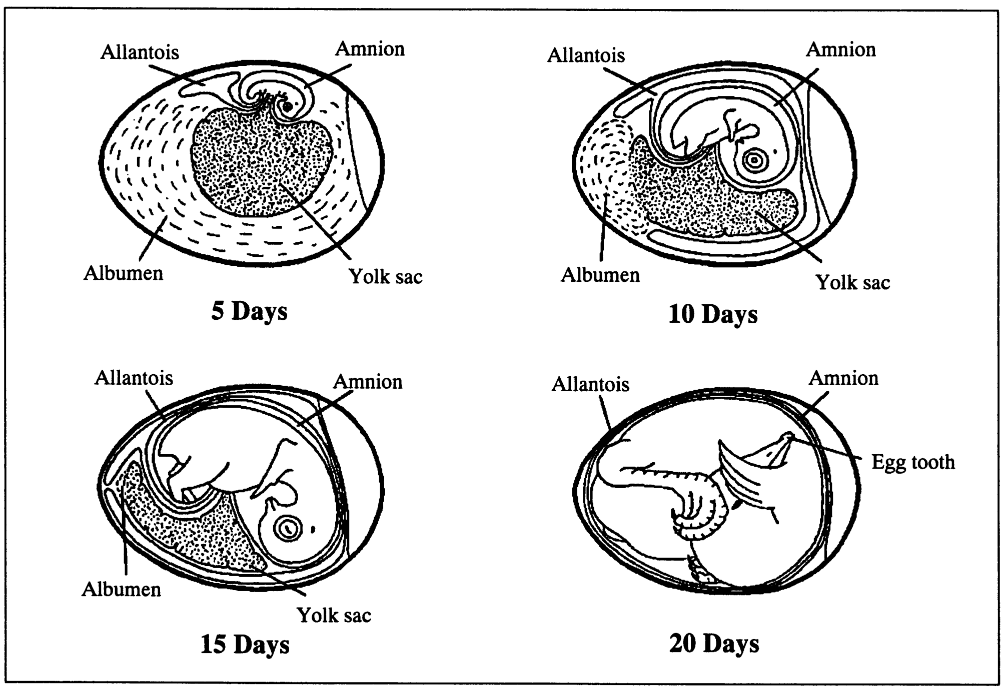

Figure 14. Sucessive changes in the position of the embryo and its membranes (*From Egg to Chick,* Northeast States Extension Service)

The yolk sac supplies food material to the embryo. The amnion, by enclosing the embryo, provides protection. The allantois serves as a respiratory organ and as a reservoir for the excreta. These temporary organs function within the egg until the time of hatching and form no part of the fully developed chick.

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 15).

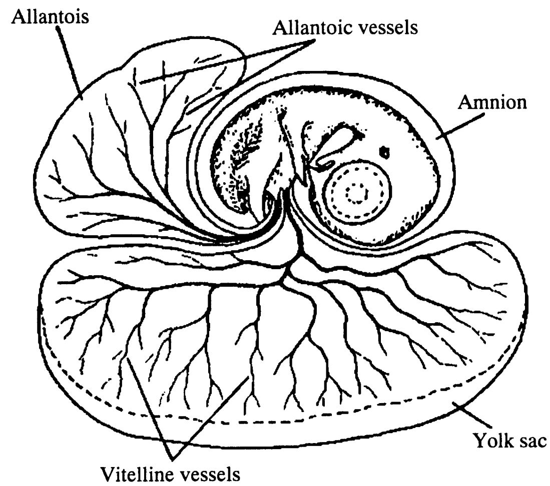

Figure 15. 7-Day embryo with its embryonic membranes and blood vessels (*From Egg to Chick,* Northeast States Extension Service)

Hatching

Several changes take place during the 18th and 21st days. The residual yolk sac is surrounded by the abdominal wall 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 shell. The large neck muscle contracts and forces the egg tooth through the air cell, and the chick takes its first breath. 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 initial break in the shell is made by the egg tooth, a sharp, horny structure located near the top of the beak. 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 still 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 of development of the embryo on a daily basis.

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.

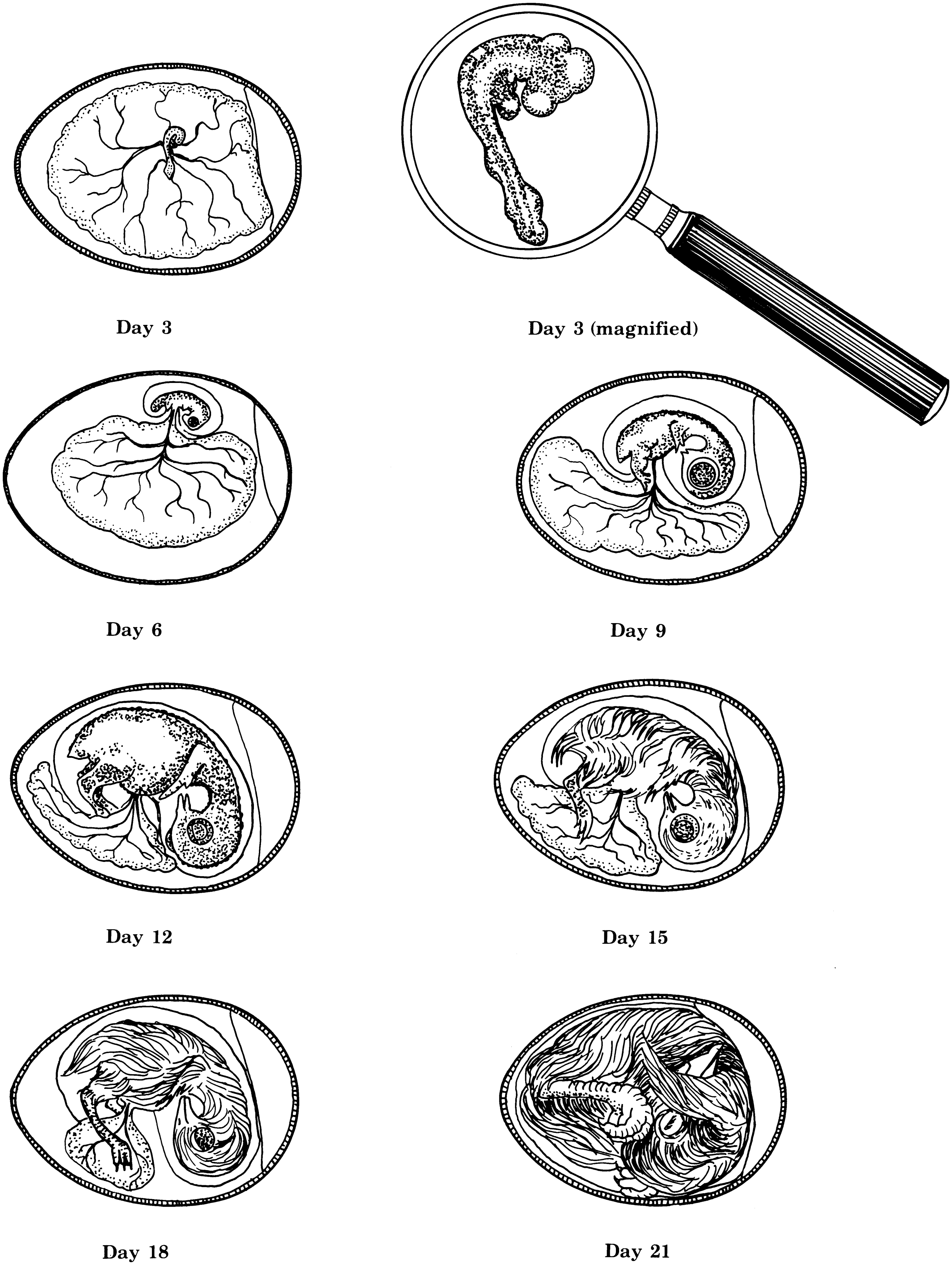

Figure 16. Stages of development
(Artwork from North Carolina Extension Service)

During Incubation (see Figure 16)

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 brain clearly defined, as is 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.

Day Three: (see Figure 17)
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. Formation 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.

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 towards blunt end of egg.

Day Fifteen:
1. Small intestines taken into body.

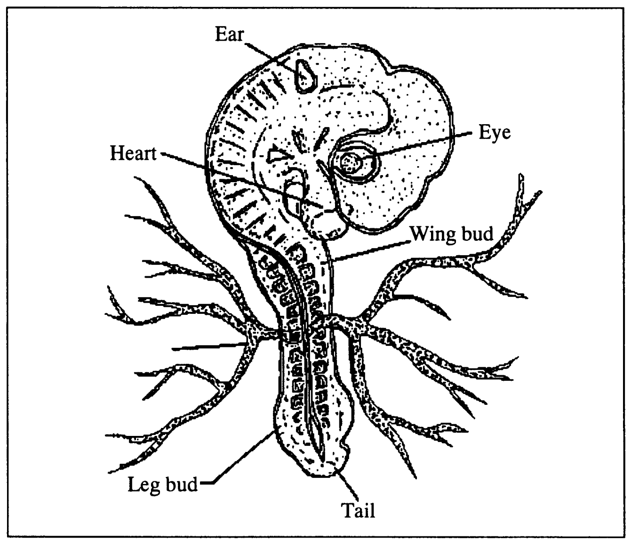

Figure 17. 3-day embryo

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 nutriment.

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 draws into body cavity through umbilicus.
2. Embryo occupies most of space within egg except air cell.

Day Twenty:
1. Yolk sac completely drawn into body cavity.
2. Embryo becomes chick, breaks amnion, 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)

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 in a few days.

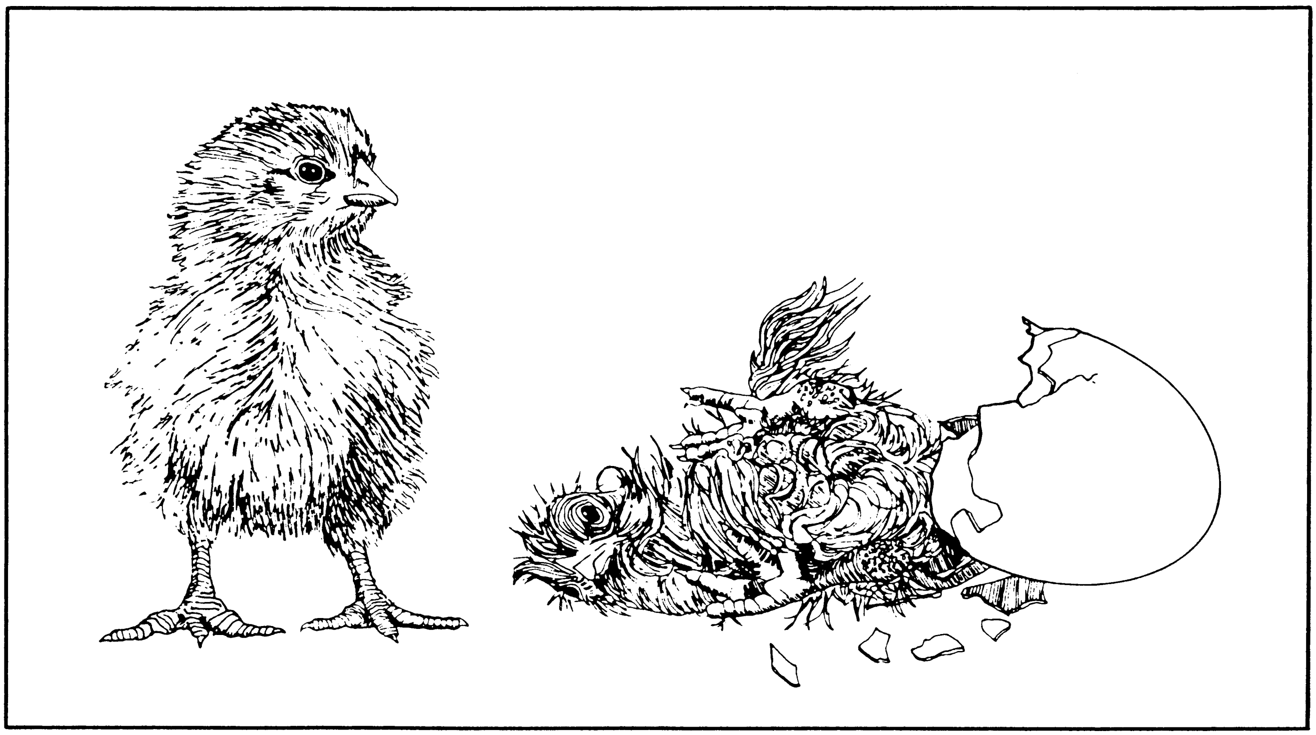

Figure 18. Chick hatches
(Artwork from North Carolina Extension Service)

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 — of course, this kills the embryo and requires 20-30 additional eggs 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" x 4" and 1" deep)

Procedure: (see Figure 19)

1. Cut an oval hole approximately 2" x 2" in the center of the sheet of cardboard.
2. Cut the same size (2" x 2") 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 x 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 shape hole up) so that the holes are lined up. Use a strong wrapping tape to fasten them together.

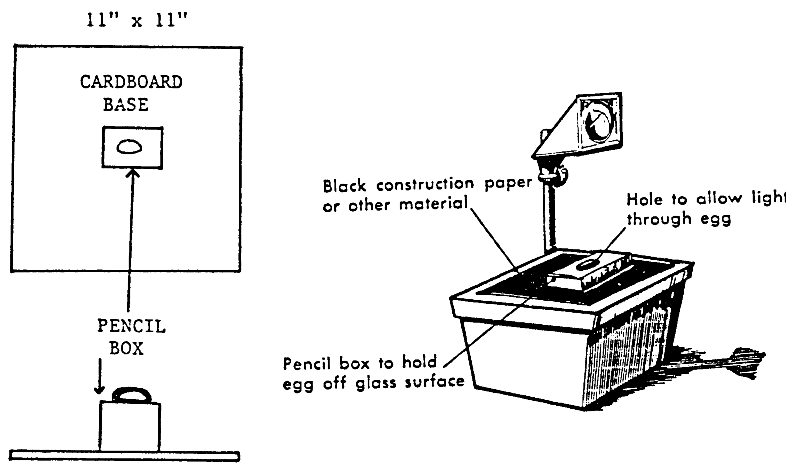

Figure 19. Overhead projector egg candler

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 the 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.

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).

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 membrane 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.

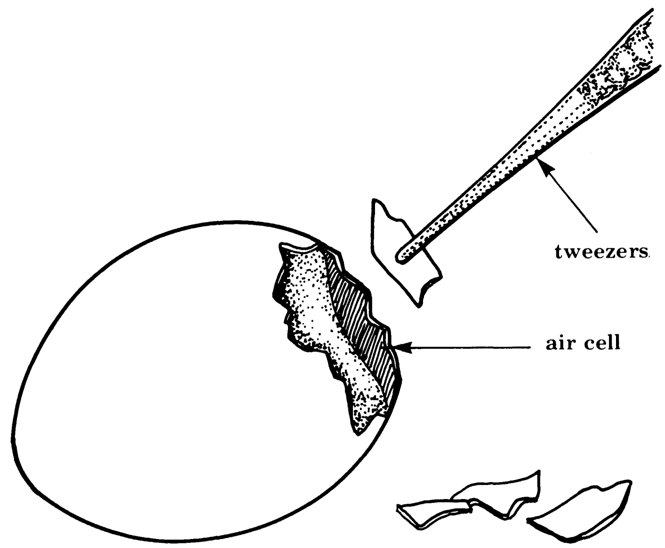

Figure 20. Shell window
(Artwork from North Carolina Extension Service)

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 intro- 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, through hands-on experiences with living subjects, basic biological principles. 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 beginning of 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 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 chick 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 18-22 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 which 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 sq. ft. 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)

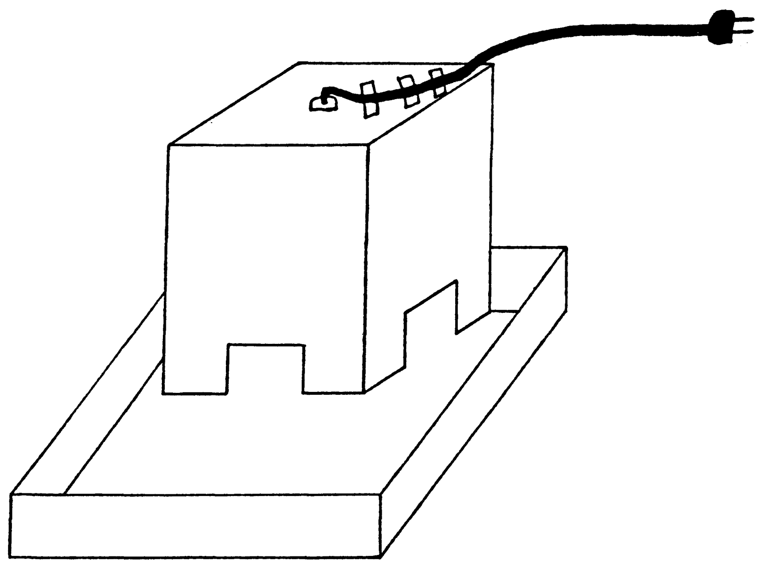

Figure 21. Courtyard brooder

Materials needed:

1. One cardboard box approximately 24 inches square
2. One cardboard box approximately 12 inches x 18 inches and at least 12 inches high
3. One light socket on an electric cord
4. One 40- to 60-watt light bulb
5. One water fountain
6. Old newspaper
7. One roll of paper toweling
8. Roll of clear wrapping paper

Procedure:

1. Remove the top of each cardboard box.
2. Cut the sides of the largest box (24" x 36") down to 6" in height. This is the chick courtyard where the feed and water will be placed.
3. Now, cut one hole 4 inches high x 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 1/2 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 3/4 of the length of the socket. Tape the electric 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.

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.
7. Add waterer and 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 Good For Two Days of Brooding* (see Figure 22)

Materials needed:

1. One cardboard box at least 18 inches long x 18 inches wide and 12 inches high
2. One gooseneck lamp with a 60- to 75-watt light bulb
3. Waterer and feeder
4. Newspaper and paper towels for litter
5. Saran wrap (optional)

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.

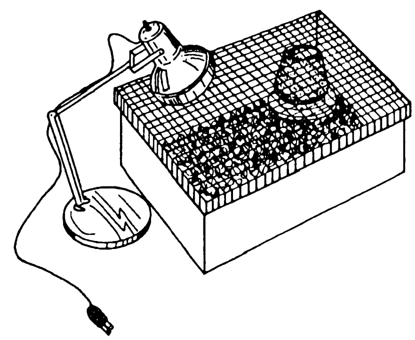

Figure 22. Gooseneck lamp brooder

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 class room, 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.

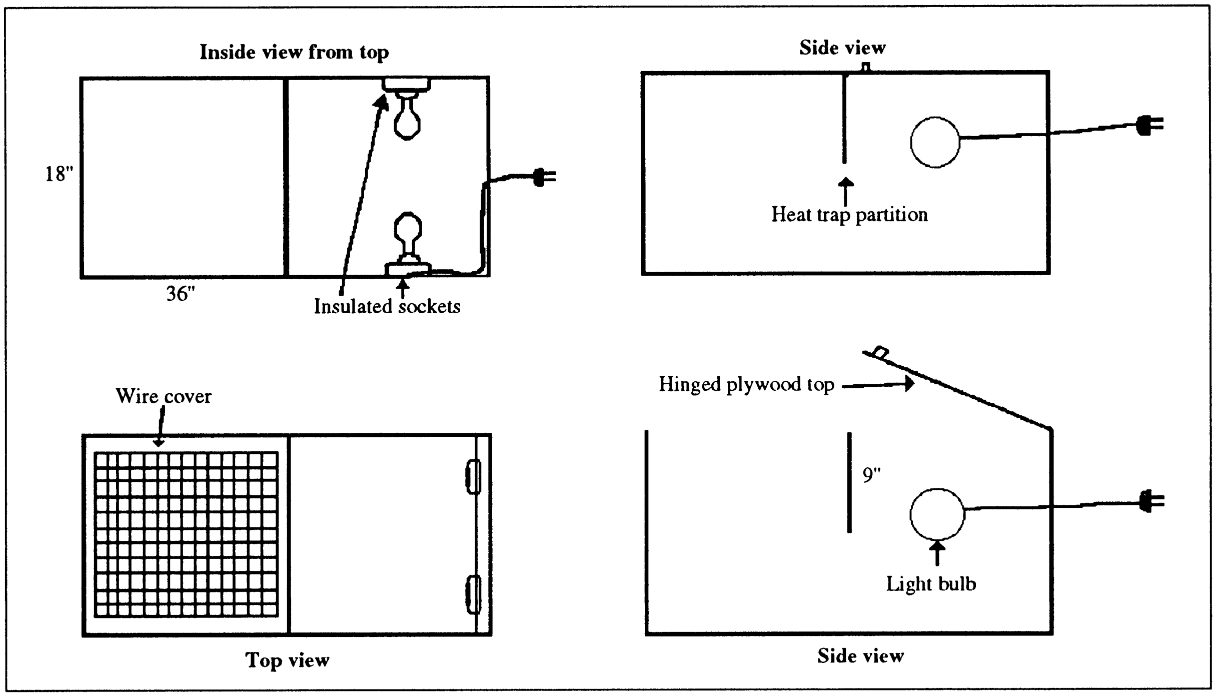

Figure 23. Wooden chicken brooder

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 sq. ft. 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 3-6 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 every 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 age of eggs at setting on hatchability.* Incubate eggs that are 3 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 of hatchability.* Place groups of eggs in a household refrigerator for several different lengths of times, such as 24, 48 and 96 hours. Keep control eggs under ideal (55°-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 in the incubator two groups of eggs that are the same age and from the same source. 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.

4. *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 temperature, such as 97° F or 103° F, throughout the incubation period.

5. *Effect of relative humidity on hatchability.* The same general type of plan as outlined in #4 listed above could be followed except that the humidity would be varied while all other procedures were kept normal.

6. *Preserving chick embryos for future observations.* Embryos can be harvested and preserved in a 10 percent solution of formalin (1 part of 37 % formaldehyde and 9 parts water). A small glass jar with a screw cap works well for this purpose.

Some Suggested Language Arts Activities

1. Expand vocabulary by learning and defining new words (e.g., embryo, incubator, humidity, thermometer, chick tooth, etc.)
2. Reading comprehension test: mimeographed materials with a few paragraphs describing the project followed by fill-in or short-answer questions at the end.
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 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 Graphic Activities

1. Drawing: draw pictures of chickens and eggs.
2. Coloring: color or paint pictures of chickens and eggs.

History Activities

1. Read/study about the history of incubators. For example, the Egyptian incubators, which were built in 5000 B.C. of clay bricks and heated by fires built in the incubator chambers were 70 feet 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 "Process of Life" can be discussed. Discuss the needs of living organisms — air, water, food, heat, and shelter — and note how chicks and humans receive each one.
2. Discuss birth defects/handicaps in chicks. Let this lead into discussion of handicapped people.
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 - 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 off within 18 hours after 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 germ plasm 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 of 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 minute openings in the shell of an egg through which gases are exchanged.

protein - one of a 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 temperatures. 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 moisture or 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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4-H ACTIVITIES REPORT

This report will help you keep a better record of your club activities. Fill it in as you complete each assignment. Refer to this record when you are entering county, state, and national programs. Ask your local leader to explain these programs to you.

My 4-H Activities Report for the 19____ Club Year

Projects taken ______________________________

____

____

TV member ☐ yes ☐ no

Program title ______________________________

Offices held

Club ______________________________

County ______________________________

"Show-and-tells" given to:

Family ______________________________

Friends ______________________________

Local club ______________________________

County ______________________________

Regional ______________________________

State ______________________________

News articles ______________________________

Radio ______________________________

TV______________________________

Things done to improve your health

____

Community service or citizenship work done

By myself ______________________________

With club ______________________________

Number of meetings your club(s) held this year ________

Number you attended ______________________________

Number of new members you encouraged to join 4-H ______

Number of boys and girls you helped with projects ______

In what way? ______________________________

____

Check those attended and tell how you helped

- ☐ 3- or 4-day camp ______________________________
- ☐ 1-day camp ______________________________
- ☐ Club or county tours______________________________
- ☐ Club picnic______________________________
- ☐ Countywide picnic______________________________
- ☐ 4-H Sunday ______________________________
- ☐ County fair ______________________________
- ☐ Achievement programs ______________________________
- ☐ Roundup ______________________________
- ☐ Teen Leader Retreat ______________________________
- ☐ State 4-H Capital Days ______________________________
- ☐ Camp Leadership Training ______________________________
- ☐ Penn State 4-H Achievement Days______________________________
- ☐ Pennsylvania Farm Show ______________________________
- ☐ National 4-H Week ______________________________
- ☐ State Ambassador Conference______________________________
- ☐ Others ______________________________

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