CHICK INCUBATION AND EMBRYOLOGY

IN THE CLASSROOM

KENTUCKY CURRICULUM

LEADER'S GUIDE

University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

INTRODUCTION

There are many fun ways to introduce STEM into the classroom. STEM stands for Science, Technology, Engineering, and Math. Certain thinking skills can be developed. Students should learn to make careful observations and measurements, keep records, make calculations, and make conclusions. Students will also develop communication skills by sharing ideas and information.

Embryology is the study of embryos. All plants and animals develop from embryos. This includes apples to zucchinis as well as antelope to zebras. STEM concepts can be brought into the classroom through chick embryology. Because chick embryos develop in a self-contained medium (the egg), it is much easier to study than when the embryo is carried by the mother, as with mammals. The students will learn firsthand how a chick goes from an egg to a chick through a series of activities. Each lesson contains an activity, background information if needed, and discussion points.

Typically, when including chicken incubation and embryology in the classroom, there is a substantial time commitment of teachers, but it can be a great learning experience for the students. The teachers should allow 2-3 days to set up the equipment and let the incubator warm up and stabilize at the correct temperature. It takes 21 days of incubation for chicks to hatch. The teachers should have at least one lesson each day (15 instructional days during the project). It is important to take care of the hatching eggs, incubator and the resulting baby chicks. The eggs and equipment require frequent monitoring. Once the chicks hatch, they will require special care for the few days that they are in the classroom. The teachers are then responsible for cleaning the equipment and returning it in the same condition it was received. It is best that the incubators come with egg turners so that the teachers do not need to come in on the weekend. The equipment will require consistent electricity during the incubation period, and this can be a concern in some energy-saving schools.

It is important to note that there are some health risks associated with chicks in the classroom. Very few things in life are completely risk free, but with a well-controlled chick embryology project the risk is extremely small. It is important to emphasize the importance of sanitation and good hygiene. This is important before AND after handling any animal or eggs.

Although ‘bird flu’ has been in the headlines for its transmission to people handing poultry, the H5N1 Asian avian influenza strain involved has not been detected anywhere in North America. Children are NOT at risk of getting avian influenza while participating in the embryology program.

Salmonella is the main concern. The intestinal tract of all animals (including humans) may contain salmonella bacteria and other harmful organisms. Such organisms are part of the natural intestinal microflora of most animals, so young children have opportunities for exposure when playing with pets, as well as other students and playmates. Most of the estimated 1.5 million human salmonellosis cases that occur annually in the U.S. are caused by contaminated food consumption, direct contact with animals may be a source of infection. This includes reptiles and birds. Salmonella is shed in the fecal material so people can become infected when contaminated food, hands or other objects are placed in the mouth.

Handwashing, therefore, is an important aspect of the embryology project. Students must wash their hands before and after they handle the eggs or chicks. The included Wally Poster on safe handling of chicks should be posted near the incubator as a reminder.

LIFE CYCLE OF THE CHICKEN

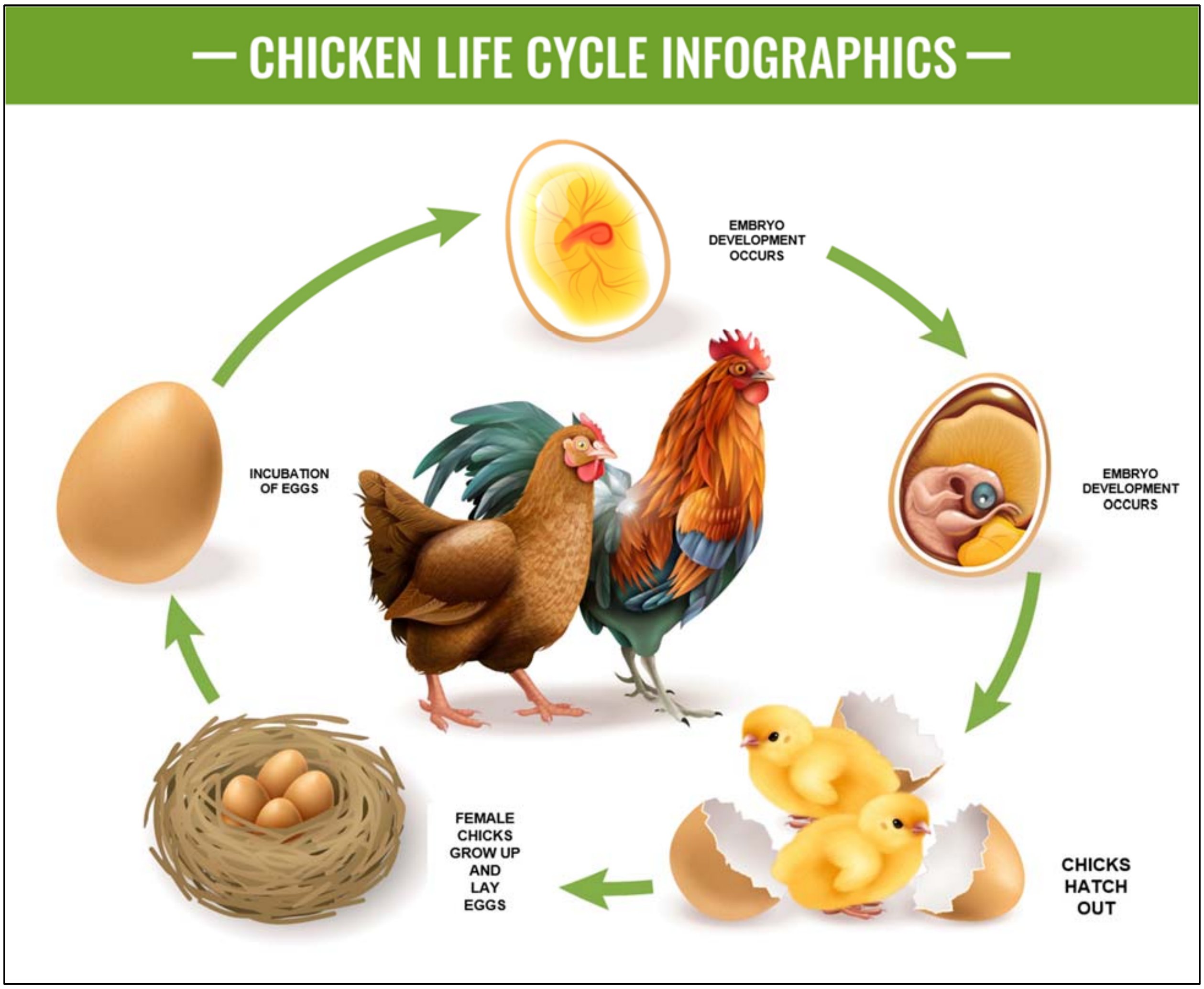


Figure 1. Overview of the life cycle of the chicken

EXTERNAL ANATOMY OF THE ADULT CHICKEN

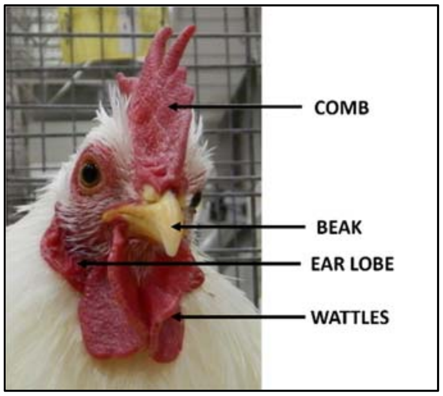


Figure 2. Main parts of the head of an adult chicken.

- The **beak** is the bird's horny projecting jaw used to forage for feed
- The **comb** is the fleshy growth on top of a chicken's head. In a healthy chicken, most are red, but there are breeds with other colors. The comb is important in body temperature regulation.
- The **wattles** are the fleshy lobe or appendage hanging down from the throat or chicken of some breeds of chickens. As with the comb, the wattles are typically red and important in body temperature regulation.

The earlobes of a chicken are the noticeable areas of colored skin on the sides of the head. In general, the earlobe color typically correlates with the breed's egg color. For most breeds, chickens with white earlobes may lay white shelled eggs and those with red ear lobes may lay brown shelled eggs. There are several breeds that are exceptions to this correlation.

Examples of those breeds that do not follow this rule include:

- Red Caps: Has red earlobes but lays white-shelled eggs
- Lamonas: Red earlobes but lays white-shelled eggs
- Dorkings: Red earlobes but lays white-shelled eggs

While single- and rose- combs are the most common, there are many different types of combs as shown below.

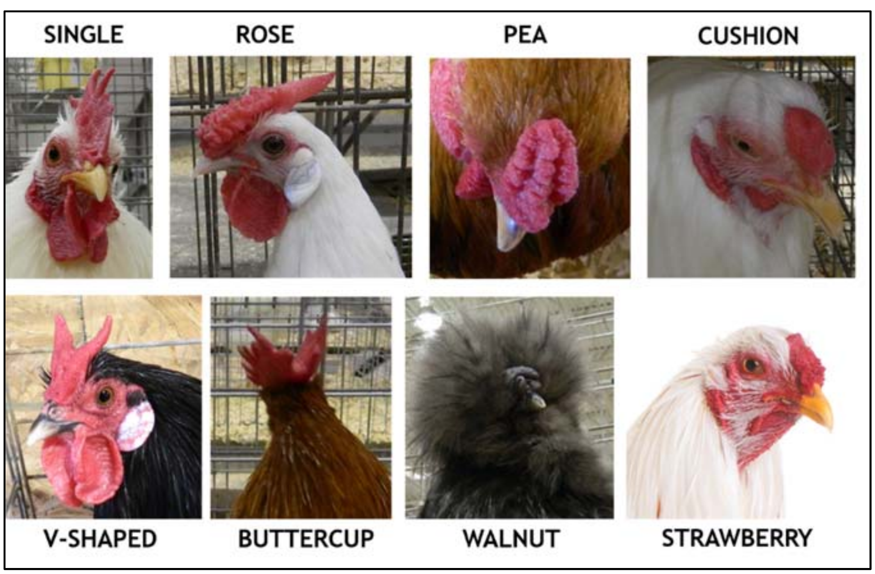


Figure 3. Examples of different types of chicken combs.

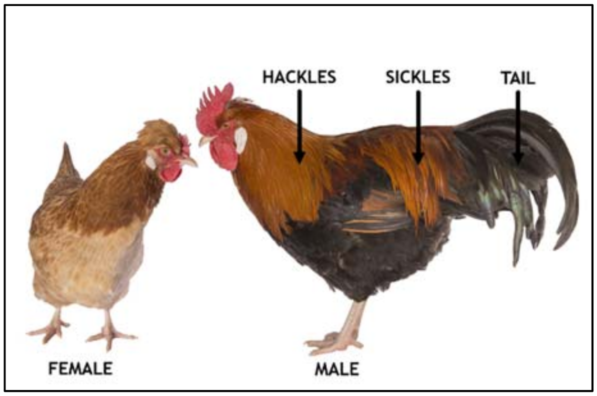


Figure 4. Types of feathers on male and female chickens.

For adult chickens, the feathers can be used to tell the males from the females.

- Males have tail feathers while females to do not.
- Males pointed hackle feathers while females have rounded hackle feathers.
- Males have pointed sickle feathers over the back. Females do not have sickle feathers. Instead they have rounded cushion feathers on the back.

The exception is breeds with ‘hen-feathering’ Such as the Sebright chickens in Figure 5. In such breeds, the male chicken has the same plumage as the females. So, the males have rounded feathers rather than pointed feathers typical of males.

The development of secondary sexual characteristics as birds mature is a result of hormones produced in the testes and ovaries. The characteristics that develop depend on the balance between **androgen** and **estrogen** production. The female plumage type and pattern is dependent on the presence of estrogens to "feminize" the feather follicle, directing the formation of a more rounded feather in the hackles and tail. In breeds in which the feather color differs between males and females, the estrogens are responsible for the reduction in pigmentation in many of the feather tracts. The two breeds with hen-feathered males have a single gene mutation that results in excess production of the enzyme aromatase in several tissues, including feather follicles. Aromatase is the enzyme responsible for the conversion of androgens to estrogens. As a result, the feather follicles of male Sebrights and Campines have excess estrogen. The level of estrogen in the feather follicles is enough to feminize the growing feathers.

Androgens are hormones that control the development and maintenance of male characteristics. The most well-known androgen is testosterone. Androgens are required to induce growth of the comb and wattles in roosters. They are also responsible for roosters crowing. The growth of spurs, however, is independent of androgens and estrogen. Instead, spur growth is determined by the genetic sex of the bird.

Figure 5. A pair of Sebright chickens showing the hen-feathering of the male

HISTORY OF THE CHICKEN

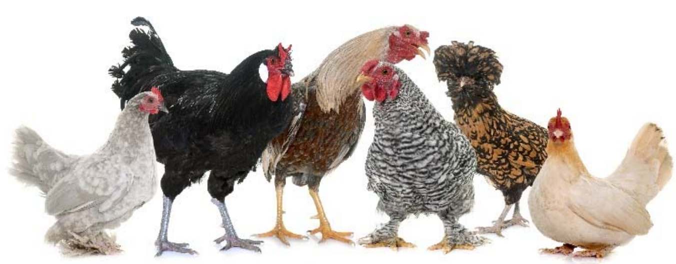
Chickens are believed to have been domesticated around 7000 BC from wild Jungle Fowl of southeast Asia. Recent genetic evidence suggests they were two sites of domestication - China and India. Chickens were easy to keep. People ate the chickens as well as their eggs. A chicken is small enough to eat in a single meal, so storage was not an issue.

After domestication in India, chickens slowly spread to West Asia but there they were considered exotic specialty items since they were not native to the area. In West Asia, the main reason for keeping chickens was mostly likely not for food but for cultural activities. The sport of cockfighting became popular here. Roosters have a natural tendency to defend territory and will fight until dominance is established. In West Asia, people didn't raise chickens for meat and eggs until sometime after 1000 BC, which would be the iron age.

Chickens spread to Europe sometime between 1000 and 550 BC where they became an exciting new food for the population. In addition, Greeks and Romans sacrificed chickens to their gods.

When the Romans spread to Africa, primarily Egypt, they took the chickens with them. Chickens became a staple food about 300 BC. Farmers in both Egypt and China figured out ways to incubate chicken eggs in warm clay ovens. As a result, they didn't need to have broody hens to sit on their eggs to hatch them out. As a result, the hens were left to lay more eggs

BREEDS OF CHICKENS



Chickens exist in many colors, sizes and shapes. There are more than 350 combinations of physical features and the number is growing. In order to be able to identify and classify each of these, there is a system of designations known as classes, breeds and varieties. These are described in the American Poultry Associations Standard of Perfection book.

A **class** is a group of breeds originating in the same geographical area. The names of the classes indicate the region where the breeds originated. These include American, Asiatic, Continental, English, and Mediterranean. There is also a class called ‘All other standard breeds' which includes the game chickens (old English game and Modern game), Orientals, and a variety of miscellaneous breeds.

Breed means of group of chicken types, each of which possess a given set of physical features such as body shape or type, skin color, carriage or station, number of toes, and feathered or non-feathered shanks, and number of toes.

A **variety** is a sub-division of a breed. The characteristics that differentiate the varieties are based on plumage color, comb type, or presence of a beard and muffs. Examples exist in almost all breeds. Leghorns, for example, have different varieties with single- or rose-combs. They are also the possibility of different plumage types including dark brown, light brown, white, buff, black, silver, red, black-tailed red, Columbian, or golden, black.

Strains are families or breeding populations possessing common traits. They maybe subdivisions of a breed or variety or may even be systematic crosses. However, a strain shows a relationship more exacting than that for others of similar appearances. Strains are the products of one person or one organization's breeding program.

Most of the breeds and varieties that exist in the U.S. today were developed between 1875 and 1925. During that time the emphasis throughout the poultry world was on breeds and varieties. Success was measured in terms of excellence of individual birds.

As the commercial egg and poultry meat industries developed, the emphasis changed from the individual bird to the average for the entire flock. This caused some breeders to adopt intensive selection programs based on the performance of certain outstanding families while others worked with breed crosses and crosses of strains within a given breed. Today, the commercial poultry industry is based sole on the strain approach.

Bantams are the miniatures of the poultry world. There are over more than 350 kinds of true breeding miniature chickens. They exist in almost every breed and variety that exists in large birds. They are about one fifth the size of standard breeds. In addition, there are some kinds of bantams that have no large counterparts. Bantams are not unhealthy miniatures. They are raised primarily for exhibition.

Many commercial chicken strains exist. Commercial strains of egg layers and chicken meat chickens exist and have been developed through company-directed breeding programs. The original egg layers produced white-shelled eggs and are descendants from the leghorn. The original meat strains are based on a cross between the Cornish and Plymouth Rock breeds. These are described in more detail in the history of the chicken section.

HISTORY OF THE AMERICAN POULTRY INDUSTRY

Chickens made it to America with the Spanish explorers as well as the early settlers. With the early settlers, individual households kept small flocks of chickens. They were kept mainly for family consumption while excess chicken and eggs were sold to neighbors. By the 1920s-1930s there was an increasing demand for eggs. This resulted in an excess amount of young male chicks. Farmers would sell these excess birds to locals for meat.

This increased the demand for meat chickens. Farmers noticed that some chickens were better suited for laying eggs while others were better producers of meat. This began initial genetic selection with farmers beginning to raise single purpose chickens. They were raised for either eggs or meat rather than using dual purpose breeds that were used for both but just average in production.

In 1923 there was a key development with the first electrically heated incubator. This enabled breeders to increase their genetic selection within their flocks and outsource their incubation and a new industry of hatcheries developed. The hatched chicks were then shipped through the mail.

During this time, the chicken diet was basically whatever they were able to forage with occasional handouts of grain, scraps and waste kitchen products. A meat chicken would be fattened up with extra grains and buttermilk when available. Housing was a non-descript barn and mortality could be as high as 40%. Chicken did not do well over the winter months. This was discovered to be because of a lack of vitamin D which was provided by sunlight through the summer months. Vitamin D was discovered in the early 1920s and lead to a small revolution in poultry keeping. Hens could now survive through the winter months with vitamin D supplements.

During the period of 1930s and 1940s there were important historical events. The Great Depression occurred after the stock market crashed. Then war broke out when Pearl Harbor was attacked in December 1941 leading to World War two. The soldiers needed to be fed increasing demand for eggs and chicken meat.

In the next decades there were major improvement in our knowledge of nutrition and genetics. There was also increased mechanization as well as the beginning of disease eradication programs.

Meat chickens

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Mrs. Wilmer Steele ordered 50 male egg-type chickens intended for family chicken meat consumption. The hatchery made a mistake and sent 500. She raised them and sold them locally. She did very well and increased the number of chicks ordered the following year. By 1926 she had a chicken house with a capacity for 10,000 chickens. Mrs. Wilmer Steele is considered the pioneer of the American commercial chicken meat industry.

In the 1940s the American chicken meat industry began to modernized. Producers began to sell chickens already processed rather than selling them live and having the consumer butcher them once they got home. The chickens were killed, plucked, eviscerated but leaving the head and feet on. This was referred to as New York dressed.

In the 1940s feed mills, hatcheries, poultry farms, etc. were still separate entities. In 1942 a machine was developed to remove the guts from a chicken, known as evisceration. Prior to this, the evisceration of chickens was a kitchen skill. In 1946 the Pilgrim's Pride feed store began giving away free chicks with a bag of poultry feed. Following the war there was a huge change in the way food was produced and resulted in intensive poultry production.

In November 1944 in a poultry meeting in Canada, the research director for a local supermarket chain suggested that someone needed to develop a sumptuous chicken, that we needed a chicken with a breast like a turkey's. By the next summer, this started the Chicken of Tomorrow contest organized by the United States of Department of Agriculture. The purpose of the contest was to breed a better chicken.

This was a large undertaking with 55 national organizers in 44 states. It began with state contests in 1946, progressed to regional judging in 1947, and ended with a national competition in 1948. Arbor Acre's White Plymouth Rock won the purebred category while Vantress Hatchery's Red Cornish outperformed the other breeds. The two breeds were later crossed and result in the Arbor Acre's Cornish Cross which developed into today's broiler.

In 1950 the refrigerator was invented. This allowed for home storage of perishable food products. During this time companies began purchasing feed mills, hatcheries and other poultry-related enterprises in order to control poultry production. Average flock sizes increased dramatically but this resulted in issues with disease control and prevention, medicine and vaccinations.

During this time companies began purchasing feed mills, hatcheries, and other poultry-related enterprises in order to control poultry production. Average flock sizes increased dramatically but this resulted in issues with disease control and prevention leading to the development of medicines and vaccinations.

Chicken meat industry moved to vertical integration. Integrators became involved in every stage of production, processing and marketing. The main advantages were that production was more efficiently, responsive and profitable. By the mid-1960s, 90% of chicken meat sold came from vertically integrated operations.

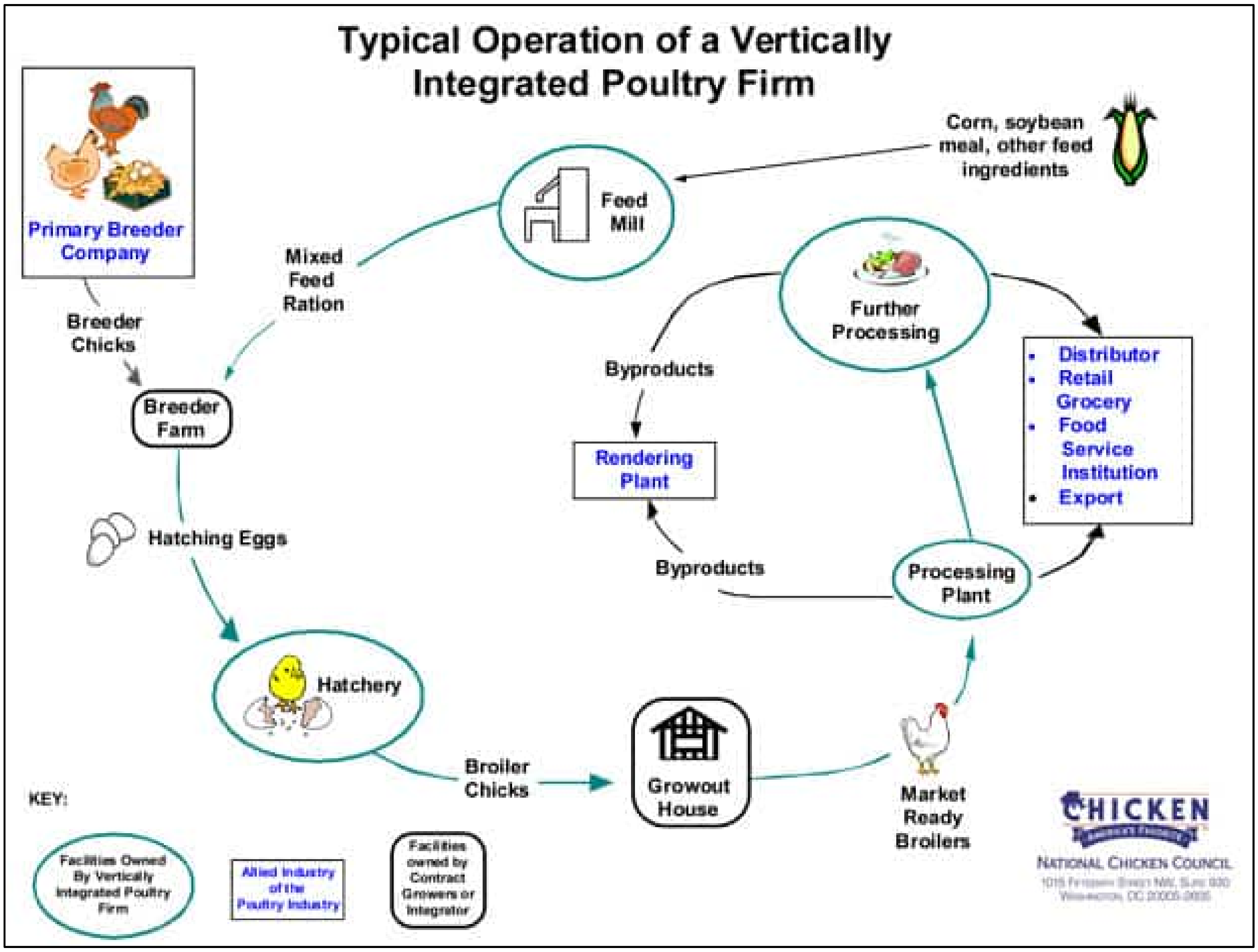

Figure 6. Flow chart from the National Chicken Council showing the flow of materials and productions in a vertically integrated poultry operation

Figure 6, produced by the National Chicken Council, shows the flow of materials and product in a typical vertically integrated chicken meat operation. The company purchases the feed ingredients from farmers or distributors and mixes feed in the company-owned feed mill. The feed will be used with the parents of the chicks that will be grown out for meat. These are known as broiler breeders. The feed will also be used to feed the meat chicks, referred to as broilers. The broiler breeder and broiler grow out facilities are owned by contracted producers who raise the breeders or broiler chicks and paid for the final product of eggs or live chickens to the company. The company owns the hatchery where the fertile eggs from the broiler breeders are incubated to hatch out the chicks for the grow out facility. The company also owns the processing facility where the chickens are slaughter, eviscerated and packaged for shipping. The company also owns the marketing channels for the chicken products sold. The company employees also provide the technical support and medications to the broiler breeder and broiler grow out producers.

Egg laying chickens

In the 1920s producers in California introduced cage systems for laying hens. Improvement in egg production continued and hens were now able to lay 250 eggs per year. Mortality also dropped dramatically to 5%. Breeding programs were developed to dramatically increase egg production and feed efficiency of commercial strains laying hens,

CHICKENS AND EGGS IN THE KENTUCKY ECONOMY

The Kentucky poultry industry is the number one agriculture commodity in the state. It is also the number one food commodity. The Kentucky poultry industry is the largest consumer of the corn and soybeans grown in Kentucky. Depending on the year and the harvest of Kentucky's poultry consumes about 25% of Kentucky's soybeans and 25% of Kentucky's corn. Kentucky's grain farmers realize a 10-15 cent per bushel premium for the grain sold to the poultry industry.

While the poultry industry is big in Kentucky, the Kentucky poultry industry is not large compared to other states. We are not even in the top ten states for egg production. As shown in Figure 7, Iowa is the top egg producing stating, almost double the second and third states of Indiana and Ohio, respectively. Kentucky comes in at number 20.

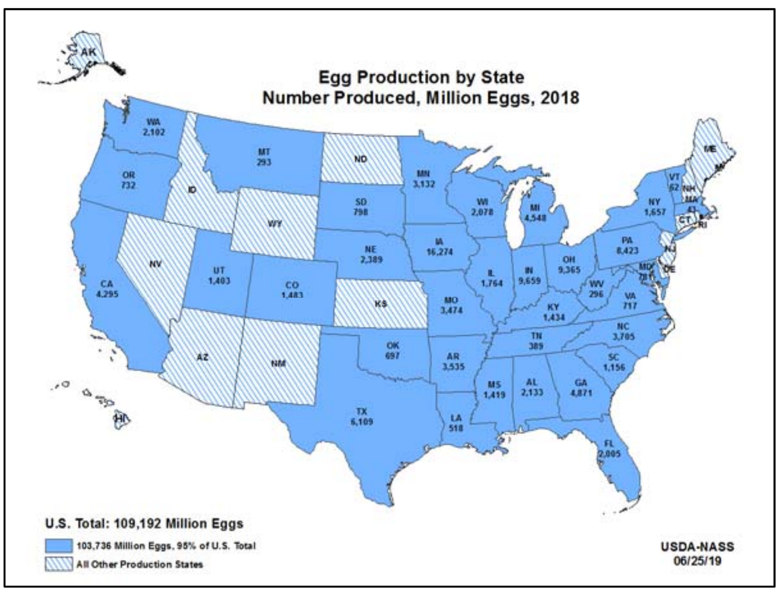

Figure 7. Map of the United States showing the distribution of egg production by state

With regards to chicken meat production, Kentucky ranks seventh in the country. As shown in Figure 8, most of the chicken meat production in the United States occurs in the southeast, with Georgia being the number one producing state. This is followed closely by Alabama and Arkansas.

Kentucky also has a developing turkey industry, but it remains very small. As shown in Figure 8, the largest state producing turkeys is Minnesota followed by North Carolina and Arkansas. Kentucky is not ranked.

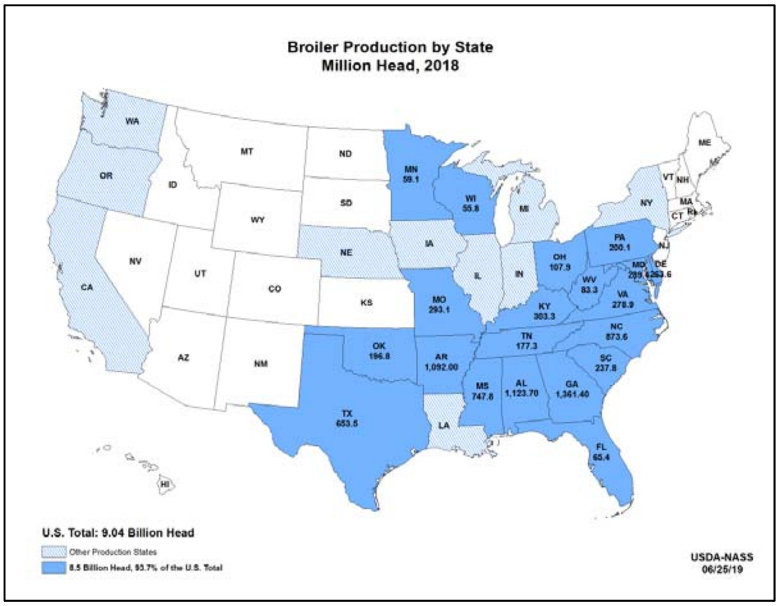

Figure 8. Map of the United States showing the distribution of chicken meat production (broilers) by state

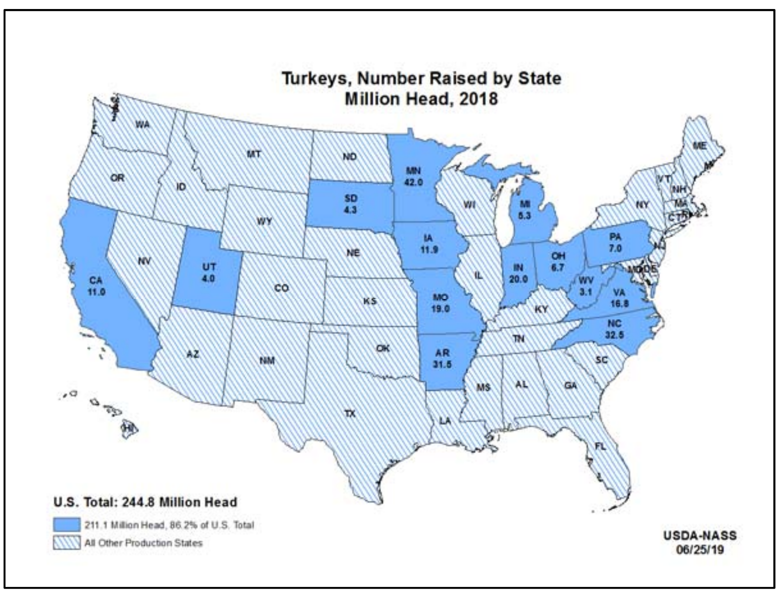

Figure 9. Map of the United States showing the distribution of turkey production by state

WHAT IS IN AN EGG?

While we often see eggs as a source of food, that is not why hens lay eggs. The egg is a means of reproduction of the chicken. Since chick development occurs outside of the hen, chickens are a great tool for studying embryology. The chicken parents mate and produce a fertile egg. When given the proper conditions, an embryo develops, and a chick will hopefully hatch out. The chicks then grow up to become parents themselves.

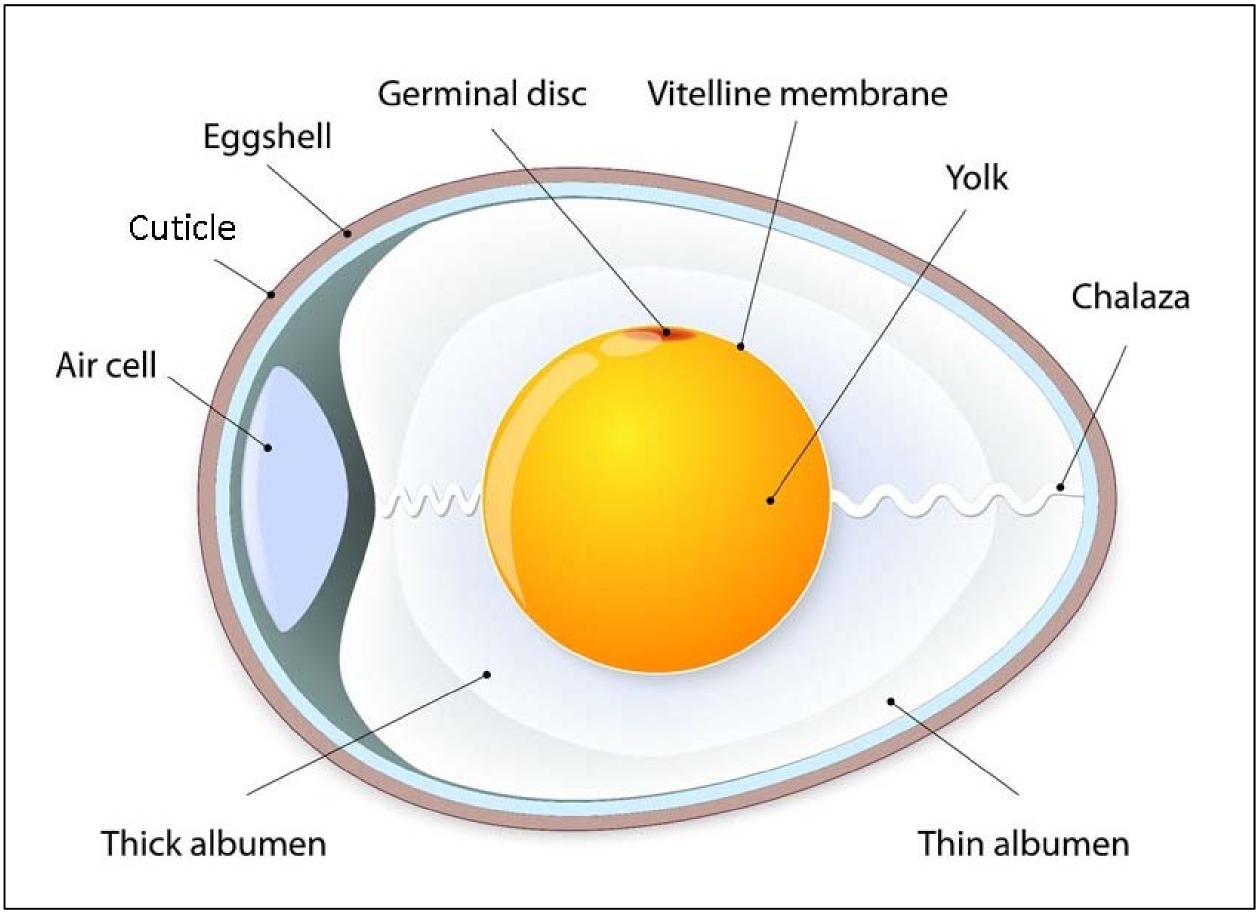

Figure 10. Graphic showing the parts of an egg

Figure 10 shows the different parts of an egg which are discussed below.

SHELL

The shell is the egg's outer covering and accounts for about 9-12% of the egg's total weight, depending on egg size. The shell is the egg's first line of defense against bacterial contamination. The shell can come in different colors. Commercially, the two most common colors are brown and white. There are no differences in the nutrition content of the egg. The shell color is dependent on the breed of the chicken.

CUTICLE

When an egg is first laid it has an invisible covering called the cuticle or bloom. The cuticle is absorbed into the pores and dries. This adds an extra layer of protection to keep out bacteria. The cuticle eventually dries up and falls off.

SHELL MEMBRANES

Just inside the shell are two shell membranes referred to as the inner and outer shell membranes.

AIR CELL

As the egg is laid and starts to cool, an air cell forms between the inner and outer shell membranes in the large end of the egg. The air cell can be seen when a light is shown through the egg, a process known as candling.

YOLK

The yolk is the yellow portion of the egg. It makes up about 33% of the liquid weight of the egg. It contains all the fat in the egg and a little less than half of the protein.

YOLK / VITELLLINE MEMBRANE

The yolk is also known as the vitelline, so the membrane that surrounds it is known as the vitelline membrane. It protects the yolk from breaking. The vitelline membrane is weakest at the germinal disc and tends to become more fragile as the egg ages. Therefore, the yolk tends to break when opening older eggs.

GERMINAL DISC

In fertilized eggs, the yolk is the site of embryo formation, located at the germinal disc. The germinal disc is barely noticeable as a slight depression on the surface of the yolk.

ALBUMEN

The albumen is also known as the egg white and is the clear material in the egg. It only turns white when beaten or cooked. Albumen accounts for most of an egg's liquid weight, about 67%. It contains half the egg's total protein as well as some vitamins and minerals. There are two types of albumen – thick and thin. The thick albumen is close to the yolk and the thin albumen surrounds the thick. As an egg ages, the protein in the albumen changes nature and the thick albumen thins out.

CHALAZAE

The chalazae are ropey strands of egg white which anchor the yolk in place in the center of the thick albumen. The chalazae are not imperfections or the beginning of embryos. They are also not 'sperm sacs'. Chalaza is the singular form and chalazae is the plural form.

FEMALE REPRODUCTIVE SYSTEM

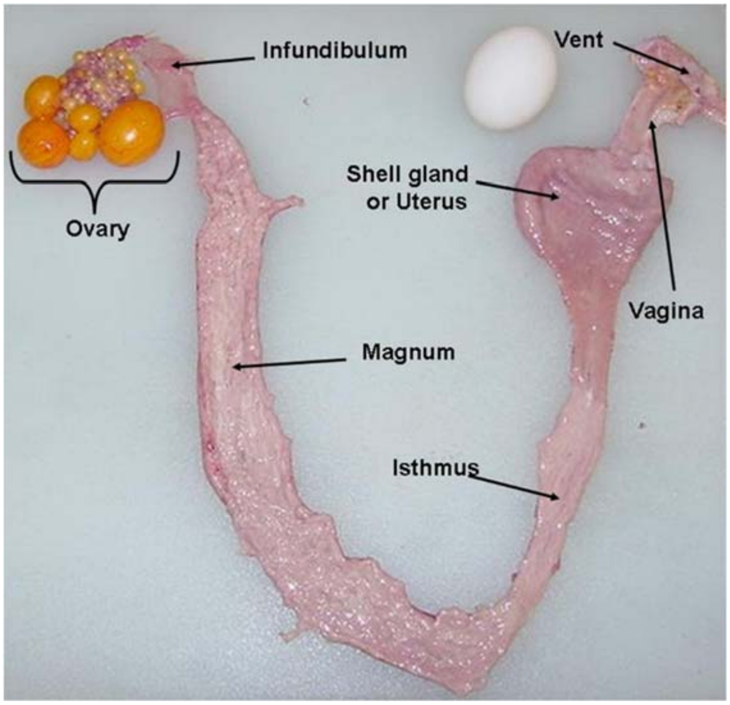

Figure 11. Parts of the reproductive tract of a mature female chicken

There are two main parts of the female reproductive tract (see Figure 11) – the ovary and the oviduct. The ovary (Figure 12) is where you find the yolks being developed. There are tiny cells with the genetic material of the female chicken and yolk material is transported from the liver to the cells. The yolk material is deposited in these cells making them grow and become easily seen. Once the yolk has reached the right size, it is released from the ovary and is picked up by the oviduct. The yolks are released along the stigma or suture line which are the clear lines of the yolk with no blood vessels visible. Typically, a single yolk is released at one time. If the hen releases two yolks, you end up with a double yolk egg. If a blood vessel crosses the stigma and ruptures when the yolk is ovulated, a blood spot can be deposited into the egg.

The oviduct is where the various parts of the egg are assembled. The released yolk is picked up by the infundibulum. This part is also referred to as a funnel since it is the start of the oviduct. But it doesn't really function like a funnel waiting there for the yolk to be dropped. It is a muscle that moves over the yolk bringing the yolk inside the oviduct. If the egg is going to be fertilized it needs to be done in the infundibulum. The yolk remains here for only 15 minutes, so it is a short window of time available for fertilization. Once the albumen has been laid down over the yolk it is too late for the sperm to fertilizer the egg.

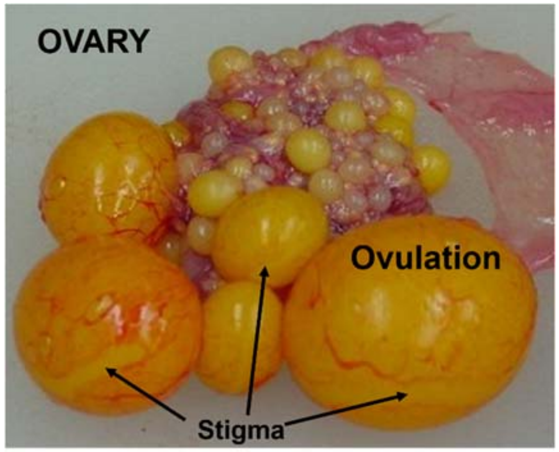

Figure 12. Ovary of the female reproductive tract showing the site for ovulation

The next part is the magnum. The yolk remains here for about three hours. This is where the albumen is added to the egg. As the yolk passes down the magnum it rotates, and strings of albumen are twisted tightly to form the chalazae that hold the yolk in the middle of the finished egg.

The next part of the oviduct is the isthmus. This is where the shell membranes are added. There is an inner and outer shell membrane. The yolk remains here for about 75 minutes. From there the eggs passes into the uterus or shell gland. As the name would suggest, this is where the shell is added. It can take about 20 hours for the shell to be completed. If the shell is going to have a color, like you see with brown eggs, the pigment is added here. There is no difference in the making of a brown or white egg except for the addition of the pigment in the shell gland. Pigment is added to the last layers of the shell.

The last part of the hen's reproductive tract is the vagina. The vagina is a muscle which helps to push the egg out of the hen. This is where the cuticle is added to the eggshell. The egg travels down the oviduct small end first, but when it is ready to be laid, it rotates and is laid large end first. This prevents the egg from contacting fecal material in the cloaca when the egg is laid.

THE STAGES OF EMBRYONIC DEVELOPMENT

The development of a chick starts with a single cell formed by the union of two parental cells - the egg and the sperm. This process is known as fertilization. In birds, fertilization occurs at the start of the female reproductive tract. Since it takes 24-26 hours for a hen to assemble and then lay an egg, fertilization occurs about 24 hours BEFORE the egg is laid. The newly formed single cell then begins to divide into 2, then 4, 8, 16, 32 cells and so on. So, when the egg is laid, hundreds of cells are grouped in a small, whitish spot seen on the upper surface of the yolk. The initial single cell has developed to 4,000 to 6,000 cells.

Avian embryos are unique in that they have a property of physiological zero (68°F / 20°C). When the egg is laid it has a 24-hour embryo. Cooling of the freshly laid egg does not result in embryo death. Instead, the embryo is in hibernation until the correct incubation conditions are provided and embryo development continues. If the temperature goes above physiological zero but below optimal incubation temperatures, there will be some embryo development but will result in weaker embryos and higher mortality.

Once incubation starts, the chicken embryo will grow and develop over a 21-day period and then emerge from the egg as a fully developed chick. Other types of poultry have different incubation periods as shown in Table 1.

Table 1. Incubation period for different poultry species.

SPECIES	**INCUBATION TIME (DAYS)**
Chicken	21
Chukar partridge	24
Duck (except Muscovy)	28
Muscovy duck	35
Goose (except Canada and Egyptian)	28-32
Canada and Egyptian geese	35
Grouse	25
Guinea fowl	28
Peafowl	28
Pheasant (Ringneck)	24
Pigeon*	17
Quail – Bobwhite	24
Quail – Japanese (Coturnix)	16-18
Turkey	28

* Because pigeons are not precocial (able to get up and walk around shortly after hatch) they need to be incubated and cared for by their parents)

During incubation, the embryo develops in a predictable manner with specific events occurring at specific times as shown in Table 2.

For the embryo to develop, it must have a way to receive nutrients from the egg and to get rid of metabolic waste. The embryo develops extra-embryonic membranes to serve these functions. The extra-embryonic membranes include the yolk sac, the amnion, and the chorio-allantois membrane (see Figure 13).

The yolk sac is the membrane that spreads over the yolk and transports nutrients from the yolk to the embryo. The amnion is the fluid-filled sac that covers the embryo and protects it from physical shocks and injury. It also provides an aquatic environment for the embryo to move around in. The chorioallantois has four functions. It functions as a respiratory organ that provides oxygen to the embryo. It is a storage area for the waste products the embryo produces. It provides food from the albumen to the embryo. Finally, it brings calcium from the eggshell to the embryo.

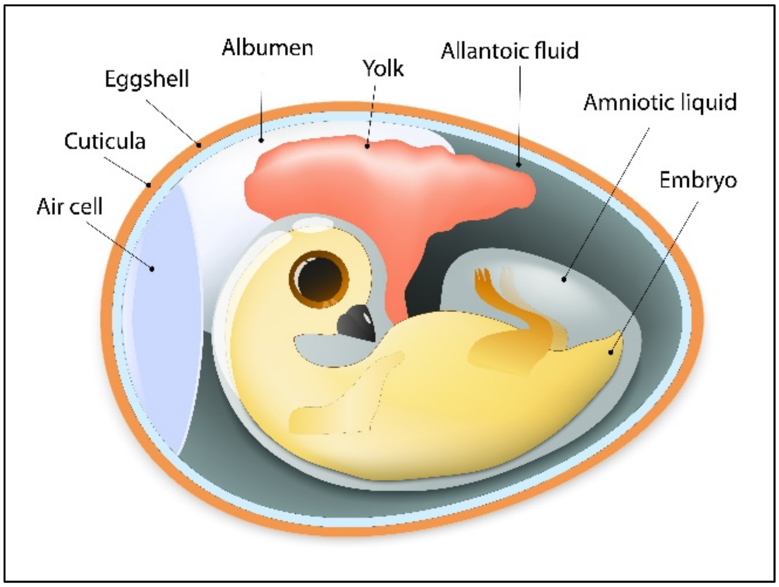

Figure 13. The developing chick embryo showing extra-embryonic membranes

Table 2. Events in the development of the chicken embryo.

TIME FRAME	EVENT
Before egg is laid	Union of sperm and ovum (fertilization) Division and growth of cells
From lay to incubation	Embryo is in rest
Day 1 of incubation	Head begins to form Eyes begin to form Vertebral column (spine) begins to form
Day 2	Blood vessels form Heart begins to beat Ears form
Day 3	Limb buds visible Extra-embryonic membranes begin to form
Day 4	Eye pigmentation begins Tongue begins to form
Day 5	Formation of the reproductive organs
Day 6	Beak begins to form
Day 7	Egg tooth is distinct Segments of wings and legs distinct Feather tracts visible on back
Day 8	Feather tracts more distinct
Day 9	Toes are formed
Day 10	Beak begins to harden
Day 12	Down present on body Eyes nearly closed Scales on shank
Day 14	Eyes closed Embryo turns to point head to air cell
Day 17	Head of embryo under right wing
Day 19	Yolk sac enters body
Day 20	Yolk sac completely in body Chick pips shell
Day 21	Chick hatches

Precocial birds are birds such as poultry and waterfowl, which can move around after hatching. Altricial birds are birds such as parrots or birds of prey, which are incapable of moving around after hatching, and require more, intensive care brooding.

Table 3. Comparison of precocial and altricial birds

PRECOCIAL BIRDS	ALTRICIAL BIRDS
Hatch with eyes open	Hatch with eyes closed
Hatch covered in down feathers	Hatch with little and sometimes no down feathers
Leave the nest within the first two days of hatching	Incapable of departing the nest
Will forage for food within hours of hatching	Fed by parents
Eggs are turned less frequently during incubation	Eggs are turned more frequently during incubation

THE PRINCIPLES OF INCUBATION

There are five factors that are important for a successful hatch of the incubating chickens eggs.

The first is temperature. It is important to have the correct temperature. This is 99-100° for most poultry species. At the correct temperature, the embryo will begin to grow. The correct temperature must be sustained throughout the entire incubation period. The effects of deviations from the correct temperature are given in Table 3.

The eggs need to be turned regularly. As the egg is turned, the embryo will pass through the egg white, making it possible for the embryo to get access to fresh nutrients. Regular turning will also prevent the developing embryo from getting stuck to the inside of the shell. If so, the embryo could become deformed or die. As the embryo grows, correct positioning of the egg ensures that the embryo forms in the correct position for hatching. Automatic turners are used by most commercial hatcheries, with eggs turning on a 45 degree angle every hour. Most small incubators come with an automatic turner that can be used on weekends. Stop turning the eggs at 18 days of incubation.

Automatic turners will typically result in the best hatch and are definitely a time saver. As an option, however, it is possible to include the students in the daily activity of turning the eggs manually on the school days. Three times a day is the best in such situations. The idea of turning the eggs three times per day (an odd number) is so that the eggs do not sit overnight in the same position.

To make sure that the eggs are turned regularly, the eggs are marked with an X on one side and an O on the other. An arrow from the X to the O can be used to indicate the direction the eggs should be turned. The problem comes from turning the eggs horizontally during school days, and vertically on the weekends.

Table 4. Typical effects of temperature on development of the avian embryo – temperature ranges shown are estimates based on available evidence.

INCUBATION TEMPERATURE (degrees)		EFFECT ON EMBRYO
CELSIUS	**FAHRENHEIT**	
47	116.6	Immediate mortality
39-47	102.2 - 116.6	Mortality dependent on length and timing of exposure
38-40	100.4 - 104	Altered rate of development and post hatch performance
37-38	98.6 - 100.4	Normal embryo development
35-37	95 - 98.6	Altered rate of development and post hatch performance
27-35	80.6 - 95	Mortality dependent on length and timing of exposure
14-27	57.2 - 80.6	Embryo development stops, no adverse effects of holding for 24 hours in embryos in last third of incubation
0-14	32 - 57.2	Mortality dependent on length and timing of exposure
< 0	< 32	Immediate mortality

Source: French, 2009: The critical important of incubation temperature. Avian Biology Research 2:55-59.

During the development of the embryo, metabolic water is produced. This metabolic water is about 12-14% of the initial egg weight. A minimum of 9-10% of this water needs to be lost to create a large enough air cell for the embryo to breathe after internal pipping (breaking through the inner shell membrane and into the air cell). If the total amount of moisture loss is more than about 17-18%, the embryo may get dehydrated and stick to the shell membranes. Infertile eggs do not produce metabolic water since they do not have an embryo. The rate of moisture loss, however, is about the same as for fertile eggs. The presence of an embryo does not influence the moisture loss, as this is determined by relative humidity, temperature and shell conductance.

Humidity is important during incubation. Relative humidity is a measure of the amount of moisture in the air. It is extremely important during egg incubation. To maintain humidity, every incubator must have a source of moisture. The easiest way is to provide this moisture is to put a shallow pan of water in the bottom of the incubator. Some incubators come with troughs for the water. Water should be added every day. Relative humidity should be set at 86° wet-bulb temperature. Humidity should not fluctuate more than 1-2 wet-bulb degrees.

It is important to monitor the weight of the eggs during the 21-incubation time. The eggs should be weighed periodically, and the weights recorded. The percent weight loss can then be calculated and graphed over time as shown in Figure 13. The graph shows time as percent of incubation time since it can be applicable to any poultry species. For this project, use the days of the incubation rather than the percent of incubation time.

Ventilation is important for incubation to provide the eggs with fresh air. The chick embryo uses oxygen and gives off carbon dioxide. The impact of the carbon dioxide can be small during the early period of incubation or when a small number of eggs are incubated, but later in the incubation ventilation becomes critical.

It is also important to keep the environment clean. During incubation, eggs are susceptible to infection. The warm, egg incubator is a perfect breeding ground for bacteria. Eggs should be clean and disinfected before egg incubation begins.

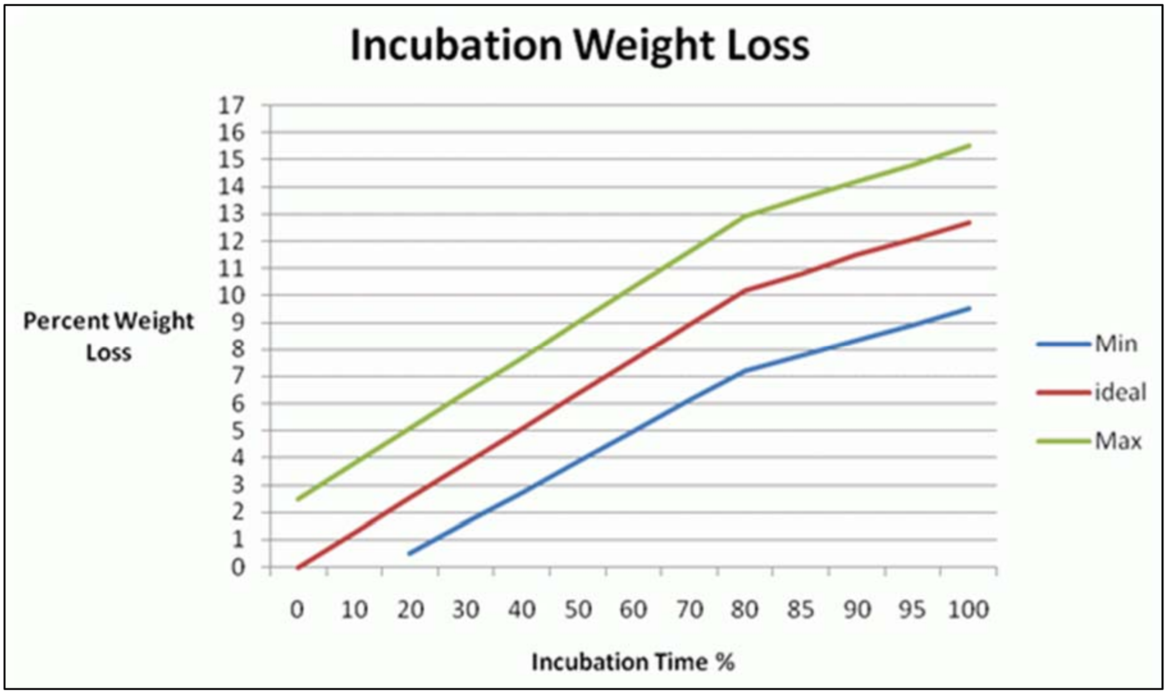

Figure 14. Graph showing the ideal, max and min percent weights loss over incubation time

STORING FERTILE EGGS PRIOR TO INCUBATION

Poultry have physiological zero which makes it possible to store eggs for a week or two before setting them in the incubator and have them all hatch out at the same time. The hatchability, however, depends on the storage conditions. It is recommended that you don't store eggs more than 10 days. During storage it is very important that you ensure the quality of your eggs. Cracked, misshapen or heavily soiled eggs should be discarded to avoid contamination. Do NOT use soiled eggs.

When storing eggs, it is recommended to keep them at a room temperature of between 59-64.4°(15-18°C). Cool, draft-free locations are an ideal place to store your eggs. It is important to note that refrigerators are set at too low a temperature and should NOT be used for storing hatching eggs. Before incubation, eggs should be brought steadily up to room temperature. This avoids drastic temperature changes and 'thermal shock' to the egg. During storage, lower humidity is better, but not essential. Some recommend turning the eggs at least once a day during storage, but this is not essential.

HATCH TIME

Do not help the chicks from the shell at hatch time. If it doesn't hatch, there is usually a good reason. Prematurely helping the chick hatch could cripple or infect the chick. Humidity is critical at hatching time. Do not allow your curiosity to damage your hatch.

As soon as the chicks are dry and fluffy, or 6-12 hours after hatching, remove the chicks from the incubator. It is good practice to remove all the chicks at once and destroy any late hatching eggs. Hatching time can be hereditary so late hatchers should not be kept as breeders.

EVALUATING THE HATCH

It is important to look at the overall hatchability. This is calculated by the equation below:

% Hatchability $= \dfrac{\text{\# of chicks hatched}}{\text{\# of total eggs set}} \times 100$

If you have a poor overall hatch, there could be two reasons. The first is poor fertility in the breeder flock. The second is a problem with the hatch itself. It is typically a good practice to open any eggs removed during candling sessions as well as any unhatched eggs when the chicks are pulled. The eggs are then evaluated for fertility, early embryo development, and stage of death. This information can be helpful in troubleshooting the hatch.

Percent fertility is the percentage of fertile eggs of all eggs produced. It is calculated by the equation below:

% Fertility $= \dfrac{\text{\# of fertile eggs}}{\text{\# of total eggs set}} \times 100$

Percent hatch of fertile is the percentage of fertile eggs which hatch out as live young. It is calculated by the equation below:

% Hatch of fertile $= \dfrac{\text{\# of eggs which hatch out}}{\text{\# of fertile eggs}} \times 100$

If the percent fertility is low, notify the source of your hatching eggs so that they are aware of the problem. If you have poor hatch of fertile eggs, troubleshoot to see what the problem was with the incubation process.

IN CASE OF POWER OUTAGE

In cases of power outages, if you have battery backups such as those used for computers, they can be used so that the hatch is not disrupted. If you do not have the battery backups, it may not be necessary to throw out the eggs. This will, of course, depend on the length of the power outage.

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 or blankets over the top of the small incubator for additional insulation. To warm the eggs, place candles in the 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. The heat from the candles can easily keep the eggs above 90°F until the power returns.

Embryos have survived at temperatures below 90°F for up to 18 hours. You should continue to incubate the eggs after the outage. Then candle the eggs 4 to 6 days later to check for further development or signs of life. If, after six days, you do not see life or development in any of the eggs, then terminate incubation. Most of the time, a power outage will delay hatching by a few days and decrease the hatchability to 40-50 percent.

SANITATION OF INCUBATOR AND EQUIPMENT

No matter what type of incubation you use, it is important that you thoroughly clean and disinfect the incubator before and after you use it. The lack of sanitation will decrease hatchability of subsequent incubations.

Immediately after each hatch, thoroughly clean and disinfect the automatic turner, water pans and the floor of the hatcher. Scrape off all eggshells and adhering dirt. The incubator bottom, liner, and wire floor rack should be washed with hot soapy water after use. Similarly, wash the top of the incubator. After rinsing with clean water, the incubator top, bottom, liner and racks should be sprayed with 10% bleach solution and allow to dry. Once dry, pack the incubator in the box. Wash and dry the waterer and feeder.

DISPOSITION OF THE CHICKS

Chicks should not be moved from the incubator to the brooder until they are dry and fluffy. This is usually a few hours following hatch. Students may handle the chicks once they dry. Remember it takes a lot of effort for the chick to get out of its shell, so it will be tired and will need rest. Do not be alarmed if the chicks are not very active this first day.

A simple brooding unit may be used to keep a few chicks for a short period of time (3-5 days). A large cardboard box or container may be used as a brooder. Provide feed and water to the chicks as soon as they are moved from the incubator to the brooder. It is a good idea to dip the chick’s beak in the water to teach them where the water. It is important that they learn to drink. Just before hatch, the chicks absorbs the remainder of the yolk material and can live of this nutrient source for the first day or two, but water is important to prevent dehydration.

The litter or bedding in the brooder serves as insulation and as an absorptive material. Shavings, sawdust, straw or sand may be used. Do not use newspaper or kitty litter. Never place chicks on a smooth surface, because they cannot grip a slippery surface, their toes will curl, and their legs will spread out to the side. This may result in permanent leg damage.

A suspended heat source should be provided to maintain the proper temperature for brooding chicks. The temperature under the light should be about 85°F. To determine if the chicks are at the proper temperature watch the chick behavior. If the chicks are moving to the outer edges of the brooder box (away from the heat source) then the light should be raised as it is too hot. If the chicks are huddled together directly under the light, they are cold so the light should be lowered. Comfortable chicks are usually distributed throughout the brooder.

Remember, all domestic animals depend on humans for survival. Make sure the chicks are properly housed, kept warm and out of drafts, and have plenty of food and fresh water. This means checking the brooder first thing in the morning, at noon, and at the end of the day.

When the project is over, send the chicks to their new home. This new home should be arranged before beginning the project.

TROUBLE SHOOTING

Table 4. List of possible problems during the incubation and the possible causes.

PROBLEM	POSSIBLE CAUSES
Eggs exploding	• Dirty eggs from nest • Improperly cleaned eggs • Water condensation on eggs • Water sprayed on eggs • Contaminated from earlier exploders • Contaminations form handling with dirty hands
No embryonic development	• Infertile eggs • Rough handling of eggs • Incubation temperature too high • Incubation temperature too low
Blood ring	• Old eggs • Incubation temperature too high • Incubation temperature too low
Dead embryos, second week	• Incubation temperature too high • Incubation temperature too low • Electric power failure • Eggs not turned
Air cell too small	• Large eggs • Humidity too high days 1-19
Air cell too large	• Small eggs • Humidity too low days 1-19
Chicks hatch early	• Small eggs • Temperature too high
Chicks hatch late	• Large eggs • Old breeding stock or inbreeding • Eggs stored too long • Temperature too low
Chicks dead after pipping shell	• Eggs not turned first two weeks • Thin-shelled eggs • Incorrect temperature days 1-19 • Temperature too high days 1-19 • Humidity too high days 1-19 • Humidity too low days 19-21
Malformed legs and toes	• Improper temperature days 1-21 • Improper humidity days 1-21
Slow, drawn out hatch	• Mix of eggs (different sizes, different aged breeding stock, different storage times) • Poor egg handling • Hot or cold spots in the incubator • Incubator or hatcher temperature too high or too low
Sticky chicks smeared with albumen at hatch	• Low incubation temperature • High incubation humidity • Poor egg turning • Eggs stored too long • Very large eggs

Chicks stuck in shell; dry shell fragment stuck to feathers	• Low humidity in storage • Poor egg turning • Cracked shell or poor shell quality
Small chicks	• Small eggs • Low humidity • High incubation temperature • High altitude • Thin, porous shells
Unhealed naval, dry, rough down feathers	• High incubator temperature or temperature fluctuation • Humidity too high when hatching • Inadequate nutrition
Weak chicks	• High hatching temperature • Poor hatcher ventilation • Contamination
Chicks mal-positioned	• Eggs sat small end up position • Inadequate turning • Excessive turning at late stages • Too high or too low temperature • High humidity • Old breeders • Round shaped eggs • Nutritional deficiencies • Retarded development • Poor egg handling or storage conditions
Malformations	• Poor storage conditions • Jarring of eggs • Nutritional deficiencies • Inadequate turning • High or low temperature • Inadequate ventilation
Crooked toes, bent legs	• High or low temperature • Poor nutrition (especially vitamin B)
Short down, wiry down	• Nutritional deficiencies (especially riboflavin) • High incubation temperature
Eyes closed, down stuck to eyes	• Temperature too high in hatcher • Chicks remain in hatcher too long after hatching • Excessive air movement
Dwarf embryos, runts in growing chicks	• Egg contaminations • Breeder diseases • Nutritional deficiencies
Hemorrhage	• Incubator or hatcher temperature too high • Rough handling of eggs at transfer • Nutritional deficiencies (vitamin K or E) • Contamination
Swollen head or back of neck	• Nutritional deficiencies
Small air cell, egg weight loss under 10%	• High humidity • Very thick shells • Low temperature
Exposed brain	• High incubation temperature • Low oxygen levels

VOCABULARY

ALBUMEN – A combination of four layers of a whitish water substances (88% water, 11% protein) that surrounds and contains the yolk within the center of the eggshell

ALLANTOIS – An organ in the embryo of birds which develops into part of the avian version of the umbilical cord and unites with the chorion, forming the avian version of the placenta

AMNION – Thin, membranous, fluid-filled sac surround the embryo

AVIAN – Of, or pertaining to, Aves or birds

BACTERIA – Microscopic single-celled organisms

BLASTODERM – The collective mass of cells produced by the spitting 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 eggshell.

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 egg white that are twisted like ropes at each end of the yolk. Their function is to anchor the yolk in the center of the eggshell cavity.

CHORIO-ALLANTOIS – A combination of the chorion and allantois to make a single extra-embryonic membrane.

CHORION – A membrane enveloping the embryo, external to, and enclosing the amnion.

DORSAL – Of, on, or near the back.

DRY-BULB TEMPERATURE – Expresses a temperature reading in number of degrees Fahrenheit (F) or centigrade/Celsius (C).

EGG TOOTH – Also called the ‘chicken tooth’, is the temporary horny cap on the chick’s upper beak which aids in pipping (breaking through) the shell at hatch. The egg tooth usually dries and falls off within 18 hours after the chick hatches.

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

EMBRYOLOGY – The study of the formation and development of plant and animal embryos.

EVAPORATION – Changing of moisture (liquid) into vapor (gas).

FERTILE – Capable of reproducing

FERTILIZED – An ovum impregnated by a sperm

FOLLICLE (ovarian) – The thin membrane of the ovary which encloses the developing yolk

FORCE-AIR INCUBATOR – A container for hatching eggs that has a mechanical ventilation.

HATCHING EGG – A fertilized egg, one with the potential of maturing.

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 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.

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.

RELATIVE HUMIDITY – The amount of moisture in the air compared with the amount that the air could contain at specific temperatures, usually expressed as a percentage.

SEMEN – The fluid secreted by the male reproductive organs and 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 anatomy, such as reproductive, skeletal, muscular, endocrine, respiratory and digestive systems.

TESTES – the male genital glands (plural)

TESTIS – The male genital glands (singular)

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.

FREQUENTLY ASKED QUESTIONS

1. **Can I hatch eggs from the store?**
   No. The eggs bought at the store are not fertilized and only fertilized eggs will hatch.

2. **Where can I get fertilized eggs?**
   University of Kentucky provides fertilized eggs to the counties, free of charge. Possible breeds include leghorn, broiler (meat-type chicken), Black Australorp, Rhode Island Red and Barred Plymouth Rock. Contact is Mr. Michael Ford. The phone number is 859-259-1701. Email is m4dranger@aol.com.

   Alternatively, eggs can be obtained from local farms. If near a commercial chicken meat company, they may be willing to donate fertilized eggs for meat chickens. Some smaller breeders may have fertilized eggs and be willing to take back the hatched chicks. If hatching eggs are brought across state lines, there are restrictions. The eggs must come from flocks that are participants in the National Poultry Improvement Plan (NPIP) and from a flock that is tested to prove it is avian influenza free.

3. **Where should eggs be stored, if they cannot be set right away?**
   If the eggs cannot be put in an incubator immediately, then they should be kept, small-end down, in a cool room at a temperature between 55-60°F. Typical refrigerators should NOT be used since they are typically set at too low a temperature and will adversely affect the hatchability of the eggs.

4. **What is the maximum length of time eggs can be held before incubating?**
   Eggs should be stored no more than ten days.

5. **Why is it important to turn the eggs?**
   The eggs are turned to prevent the embryo from sticking to the inside of the shell, and it is like what the mother hen does when she sets.

6. **How often should the eggs be turned?**
   The eggs should be turned at least three times a day.

7. **When do we stop turning the eggs?**
   The eggs should not be turned on days 19-21.

8. **What happens if the eggs are not turned?**
   If the eggs are not turned, the embryo will die about day 11.

9. **What should I use to mark the eggs?**
   You should use a lead pencil.

10. **Why is water added to the incubator?**
    Water is needed to maintain proper relative humidity in the incubator. If the relative humidity is too low, then the chick will stick to the shell membrane and death will occur.

11. **How can I be sure that I have enough humidity?**
    If the appropriate troughs are kept full of water, then the correct humidity should be maintained. You may also check humidity using a wet-bulb thermometer or a hygrometer.

12. **How can I tell if I have too much humidity?**
    If there is too much humidity, there will be a great deal of condensation on the inside of the incubator window.

13. **How do I add the water to the incubator?**
    Add warm water with a squeeze bottle being careful not to get the eggs wet.

14. **What is candling?**
    Candling involves shining a bright light through the egg (in a darkened room) to determine egg quality, if the eggs is fertile and to check embryonic development.

15. **When should eggs be candled?**
    Eggs should be candled anytime between day five of incubation through to day seventeen.

16. **How long should the eggs be kept out of the incubator?**
    No more than five to ten minutes at a time.

17. **What should I do if I find a clear egg?**
    A clear egg will not hatch and should be removed from the incubator, opened to verify that it is indeed infertile and not with an early dead embryo, and disposed of.

18. **How long should I leave the eggs in the incubator if they do not hatch on the twenty-first days?**
    Leave the unhatched eggs until the twenty-third or twenty-fourth day. If they still have not hatched, then dispose of them.

19. **Will all the eggs hatch?**
    In most hatches there will be a few eggs that will not hatch even though you have followed the directions. This is just a fact of nature.

20. **Should I help the chick out of the shell?**
    This is not recommended and is often painful for the chick.

21. Can we hold the chicks as soon as they hatch?
The chicks should not be handled until they are completely dry and fluffed up. After they are dry, they may be handled but remember to be gentle.

22. What is a brooder box?
A brooder box is a temporary home for baby chicks up to one week of age. It contains bedding, feed, water, and a heat source suspended above the container.

23. When should I move the chicks to the brooder box?
The chicks should be moved once they are dry, usually within 24 hours of hatching.

24. When do the chicks need water?
The chicks need to drink water when they are moved to the brooder.

25. Do I need to teach the chicks to drink?
The chicks should be taught to drink as being placed in the brooder. This can be done by dipping their beaks in the waterer.

26. When do the chicks need feed?
The chicks should have food the first day but can survive for up to three days after hatching.

27. Do I need to teach the chicks to eat?
It is not usually necessary to teach the chicks to eat, but feed can be spread on a paper towel near the feeder to make sure they do learn where the feed is.

28. Can the students take chicks home?
Chicks cannot go home with the students unless they have adequate poultry facilities. Chickens are a flock animal and individual chicks should not go home to individual students.

29. Do chickens make good pets?
Many suburbanites have small flocks of chickens. For some, they consider them pets. In reality, chickens are livestock and should not be brought into the house and hugged or kissed. Salmonella can make people sick.

30. How long do chickens live?
Commercial meat chickens reach market quickly – usually 6-8 weeks. On most commercial egg farms, laying hens are usually kept for 18-20 months. Records show that when allowed to live out their lives naturally, they can live for 6-10 years.