Incubation Handbook

A hobbyist's guide to hatching backyard poultry

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Incubation Checklist

This checklist highlights several important factors to consider during the incubation process but does not serve as a substitute for reading and understanding all factors outlined in this handbook.

- ☐ **DO** prepare your breeding stock prior collecting incubation eggs including selecting the best, unrelated parents, worming your birds, feeding high quality feed, and cleaning nests, & renewing nesting material.
- ☐ **DO** carefully plan your incubation and hatch schedule. Whenever possible, avoid setting eggs at different times or of different species unless you have a second incubator dedicated to hatching only.
- ☐ **DO NOT** wash or refrigerate eggs for incubation. For best results, use eggs that are less than 7 days old. However, eggs up to 14 days old can be successfully hatched if stored correctly.
- ☐ **DO** consider the accuracy of any digital thermometer you decide to purchase. Most thermometers are only accurate to +/-1.0 to 2.0° when an accuracy of +/-0.1 to 0.2° is required.
- ☐ **DO NOT** trust the gauges built into your incubator. **DO** use a separate, ***calibrated*** thermometer to monitor the incubation environment. Improper temperature control is the primary reason for hatch failure.
- ☐ **DO** place your incubator in a room with a steady temperature, away from windows, drafts, or direct sunlight. Difficulties with regulating an incubator are often the result of poor incubator placement.
- ☐ **DO** calibrate and regulate your incubator at least 48 hours prior to setting eggs. For best results, use water bottles to fill empty space during the regulation and calibration process.
- ☐ **DO** become familiar with warm and cool spots within your incubator by measuring the temperature at various locations during the regulation and calibration process.
- ☐ **DO NOT** keep your eggs in the same spot for the entire incubation period. For best results, move the eggs sitting on the outer edges to the center and the eggs sitting in the center to the outer edges daily.
- ☐ **DO NOT** fiddle with the thermostat while eggs are in the incubator. Some fluctuation in temperature is normal and you're likely to cause more problems by fiddling with the temperature controls.
- ☐ **DO** remove any automatic egg turner at the beginning of day 19 to avoid injury or death of newly emerged hatchlings.
- ☐ **DO** completely fill troughs/pans full prior of water prior to lockdown – the last three days of incubation. **DO NOT** open the incubator unless absolutely necessary until the hatch is complete.
- ☐ **DO** add sufficient warm, wet sponges during lock down to raise the humidity to at least 60% or until a small amount of moisture accumulates on the viewing pane.
- ☐ **DO** remember that chicks burn a great deal of oxygen during the hatching process. **DO** remove any vent plugs during lockdown. **DO NOT** sacrifice fresh air for humidity during the final days.
- ☐ **DO** remember that hatchlings live for 36-48 hours after hatch by feeding from the absorbed egg yolk. The bumping of unhatched eggs by hatchlings encourages the unhatched to pip, zip, and emerge.
- ☐ **DO** remember that 12 or more hours may elapse from the first pip to the first emergence and that hatching is an exhausting process… hatchlings may rest for extended periods of time during the process.
- ☐ **DO NOT** assist eggs during the hatching process unless it is absolutely necessary. In most cases, a healthy hatchling will emerge on their own and assisting can easily cause more harm than good.
- ☐ **DO** carefully evaluate your hatch results using the recommendations in this guide. DO view each hatch as a learning process with a primary goal of improving with each subsequent batch.
- ☐ **DO NOT** forget that home flock hatching should be an enjoyable process… not every egg will hatch and not every hatchling will survive. Celebrate your successes and do not focus on your failures.

Beginner's Guide

- **TARGET AUDIENCE**: Chicken eggs takes 21 days of incubation under a specific temperature and humidity. While not rocket science, the challenge can seem overwhelming for beginners. This section is intended to assist inexperienced hobbyists who want to incubate a small number of eggs in a desktop incubator.
- **EGG COLLECTION & STORAGE**: Proper egg collection and storage has a significant impact on hatching success.
  1. Use fresh, large pine shavings to line nesting boxes or nesting areas. Replace any soiled lining as soon as it becomes contaminated. Use of hay in nesting boxes has been known to induce problems with mold.
  2. Thoroughly WASH YOUR HANDS prior to collection and use a clean container for collection.
  3. Collect eggs two or three times a day, more frequently if temperatures are unusually high or low.
  4. Remove eggs that are unusually dirty, large, small, or misshaped as these eggs hatch poorly and consume valuable incubator space.
  5. Using a pencil or non-toxic marker, label eggs with the species, pen, date laid, and any other important information. These markings aid in identifying hatchlings and assist with accurate record keeping.
  6. DO NOT WASH or wipe off dirt or waste from the egg. If the egg is marred by a small amount of waste, allow it to dry and then gently scrape it off with a finger nail. Washing, wiping, or sanding dirty eggs removes the bloom, the natural antibacterial coating and can push any contamination into the pores.
  7. Store eggs in new, paper cartons with the small end down at a temperature between 65-69°F. Tilt the container to its side 45° and change the tilt direction daily. Do not store eggs in the refrigerator as the temperature is too cold and will have a negative impact on hatching and chick health.
  8. For best results, store eggs for no longer than 10 days. However, clean eggs stored at 55-62° F and a humidity of 70% and turned daily can remain viable for up to 21 days.

  Whenever possible, AVOID mixing eggs in different stages of development in the same incubator – doing so complicates hatching and may lead to poor results. It is better to collect and carefully store eggs for 14-18 days and hatch all eggs at the same time.

  9. Allow cool eggs to warm to 75-80° F for 4-6 hours before to placing in the incubator.
  10. ***SHIPPED EGGS***: Shipped eggs should be allowed to settle with the large end pointed up for at least 24 hours prior to setting. This settling may help any detached air cell to reattach before incubation.
- **THERMOMETERS**: An accurate and consistent temperature is essential to a successful hatch.

  1. DO NOT TRUST the gauges built into the incubator and DO NOT use the small, cheap thermometers that might have come with your incubator.
     - An inexpensive red spirit filled, glass thermometer is well suited for desktop incubation:
     - They react well to changes in temperature without overreacting like digital ones.
     - They are easily obtained from Wal-Mart, Lowe's, or Tractor Supply.
     - They are easily calibrated to ensure temperature readings are accurate.
     - They are necessary when checking the accuracy of digital thermometers.
     - They are not difficult to read if you draw a clear red line at the target temperature.
  2. When buying a separate digital thermometer, BE SURE that it has an ACCURACY of not less than ±0.2° F.

  There is a huge difference between *READOUT PRECISION* and *ACCURACY*. Although a thermometer may read 99.5° F, it may not be accurate to that 0.1°. Carefully check the package and be sure it says, "Reads to 0.1° F with an accuracy of ± 0.2° F."

  3. ***DO CALIBRATE*** your thermometer by submerging in settled ice water. It should read 32° F. Most digital thermometers cannot be calibrated but must be checked against an old fashion glass thermometer. To calibrate a glass thermometer, submerge it in melting ice water – it should read 32° F. If not, loosen the glue, slide the glass portion up or down until it is accurate, and then place a drop of hot glue to reattach.

- **INCUBATOR PREPARATION**: Incubators should be calibrated ***AT LEAST TWO DAYS BEFORE*** setting eggs.
  1. Read the instructions that came with the incubator. While most provide very little information, the instructions will help you learn how to operate your incubator and troubleshoot most problems.
  2. Place your incubator in a room with a steady temperature. Place the incubator away from heating/cooling vents, direct sunlight, or drafts. It is impossible to maintain a consistent incubator environment if room conditions are constantly changing. Many beginners find it helpful to place their incubators in an unused closet or bathroom.
  3. Place your separate, calibrated thermometer in the middle of the incubator where it is easily visible through the viewing pane. Use this thermometer to calibrate your incubator's temperature.
  4. Turn on your incubator and allow a warm-up period of no less than two or three hours. When making adjustments, make only small ones and allow at least one hour between adjustments. Do not expect the temperature calibration to take less than 24 hours.

AVOID getting in a hurry to set your first batch of eggs. Most beginners get into trouble by not taking the time to ensure that their incubator is operating properly, that the temperature is steady, and that the humidity is constant.

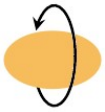
  5. **TEMPERATURE SETTINGS**: Temperature should be measured at the top of the eggs. When calibrating your incubator, place your thermometer on top of eggs that you can throw away when the calibration process is complete. Circulated air incubators (those with a fan) operate best at a consistent temperature of 99.5° F. Still air incubators (those without a fan) operate best at a consistent temperature of 101.5-102.0° F. Your incubator instructions may give a different recommended temperature; for best results, follow your incubator instructions.
  6. **HUMIDITY SETTINGS**: The best humidity setting for chicken eggs is often debated. I prefer a humidity of between 43% and 48% for days 1-18 increasing the humidity to about 65% on days 19-21. When calibrating your incubator, fill only one water chamber at first. Check your humidity, and fill a second chamber if your reading is low. ***DO NOT TRUST*** the built in gauge rather use a separate hygrometer.

CHECKING YOUR HYGROMETER: Dampen a towel (not dripping wet) then wrap the hygrometer in the towel for 30 to 45 minutes. Then unwrap it and quickly read the humidity; it should read exactly 100%. You should make a mental note of how far over or under the actual humidity is from the reading from your hygrometer.

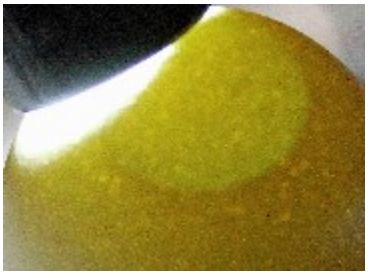
- **SETTING EGGS – NO AUTOMATIC TURNER**: ***DO NOT*** attempt to set any eggs until the incubator's temperature and humidity has been stable for at least 24 hours. Getting in a hurry will lead to multiple problems that are difficult to correct once eggs are in the incubator.
  1. Allow the eggs to warm if they have been stored below 75-80° F.
  2. Using a pencil, mark one side of each egg with an **X** and the other side with an **O**. These markings will help ensure that each egg is completely turned.
  3. Lay the eggs on their side, on top of the mesh, in the middle of the incubator. It is perfectly fine for the eggs to touch but they should not be overly crowded or stacked.
  4. Close the lid, walk away, and do not return for several hours. It is normal for the incubator to take some time before warming to the set temperature. It is also not uncommon for the temperature to spike a degree or two above the set temperature after setting eggs. ***Avoid fiddling with the thermostat during the first 24 hours***.
  5. Before opening the incubator to turn your eggs, examine your temperature and humidity readings. While you will need to occasionally add water to keep the humidity up, you should not need to touch the thermostat. If the temperature is off, do nothing and check the temperature in another hour. If the thermometer continues to read high or low, you may carefully make a small adjustment.

Temperatures normally fluctuate from time to time. If your incubator has difficulty maintaining the set temperature, look at where you placed your incubator… perhaps a more stable place will help. Always be reluctant to alter your thermostat settings as fiddling with the thermostat frequently causes more problems than it solves.

6. Three times a day – morning, afternoon, and bedtime – move the eggs in the middle to the edge and roll the ones on the edge to the center. Check to ensure that each egg has been turned by checking your **X**'s or **O**'s.



- **SETTING EGGS – WITH AUTOMATIC TURNER**: ***DO NOT*** attempt to set any eggs until the incubator's temperature and humidity has been stable for at least 24 hours, Getting in a hurry will lead to multiple problems that are difficult to correct once eggs are in the incubator.



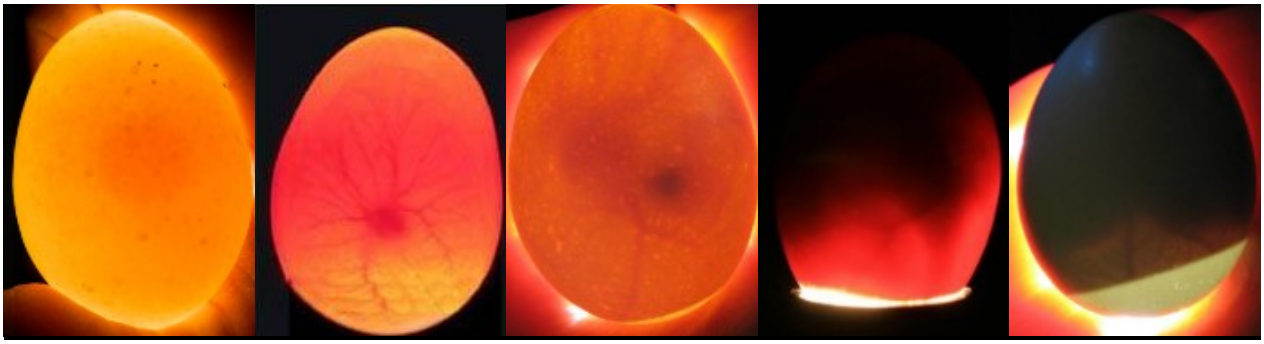
1. Allow the eggs to warm if they have been stored below 75-80° F.
2. Identify the large end of the egg and draw a small circle on that end with a pencil. If you have difficulty determining which end is the large one, place a small flashlight on each end – the large end contains the air cell.
3. Place the eggs in the center section of the turner with the large end up – the small (pointy) end down.
4. Close the lid, plug in the auto-turner, walk away, and do not return for several hours. It is normal for the incubator to take some time before warming to the set temperature. It is also not uncommon for the temperature to spike a degree or two above the set temperature after setting eggs. ***Avoid fiddling with the thermostat during the first 24 hours***.
5. Twice daily check your temperature and humidity. While you will need to occasionally add water to keep the humidity up, you should not need to touch the thermostat. If the temperature is off, do nothing and check the temperature in another hour. If the thermometer continues to read high or low, you may carefully make a small adjustment.

Temperatures normally fluctuate from time to time. If your incubator has difficulty maintaining the set temperature, look at where you placed your incubator… perhaps a more stable place will help. Always be reluctant to alter your thermostat settings as fiddling with the thermostat frequently causes more problems than it solves.

6. Some automatic turners turn at a very slow pace and you may not see any motion. Occasionally, take a look at which way the eggs are tilted. You know that your egg turner is working when the eggs are tilted in different directions at various times.

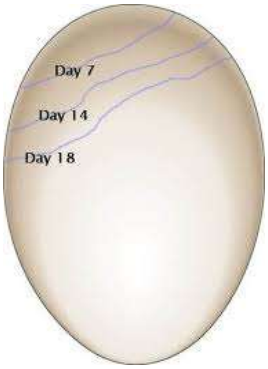
- **CANDLING EGGS**: Candling is not a necessity but can help ease anxiety about how eggs are progressing.

1. Candling is the process of applying a strong light to the outside shell allowing a glimpse of the inside. A small LED flashlight and a dark room is sufficient to candle lightly colored eggs, many utilize their smart-phone flashlight app.
2. Most people candle their eggs on day 7, 10, and 18. However, on day 4 you should be able to see a small reddish embryo with blood vessels in white eggs. For darker colored or thick eggs, you may not be able to see much until after day 10.



Day 0 Day 4 Day 7 Day 14 Day 18

3. Eggs that are clear and show no signs of development may be discarded on day 10. If in doubt, leave the egg in the incubator. If an egg develops a bacterial infection, it probably will develop an odor. You can locate the bad egg by sniffing each egg individually.
4. Potential problems such as cracks or internal bacterial infections should be removed as early as possible to prevent possible contamination of other eggs.
5. You will also want to examine the size of the air cell. The longer the egg is in the incubator, the more water will evaporate. This is normal. If the humidity is too high, the air cell will be small. If the humidity is too low, the air cell will be large. The air cell should approximate the size illustrated to the right.
6. For illustration of normal development visit: http://www.backyardchickens.com/t/261876/chicks-are-here-egg-candling-pics-progression-though-incubation.



- **HATCHING**: How many chicks will hatch? There are numerous variables involved in incubation and if any single variable goes wrong, a chick will not hatch. For your first few hatches, focus on your successes not your failures.

1. **TIMING**: Lockdown begins at the end of day 18 and includes days 19, 20, and 21.
2. **AIR VENTILATION**: Remove all plugs from ventilation holes. Hatching requires great physical exertion and the chicks need fresh air in order to prevent exhaustion and possible death.
3. **TURNING**: Eggs should be removed from the turner and placed on their side with the large end angled slightly upward.

> Some hobbyists prefer to allow eggs to stay in the turner during hatching; they simply unplug the automatic turner. Eggs remaining in the upright position place the chick in an unnatural position delaying hatching and making zipping more difficult. For best results, remove the eggs from the tray and lay them on their side.

4. **HUMIDITY**: Humidity should be increased to 65-70%. Fill all chambers in the lower portion of the incubator with water. If additional moisture is needed, add as many warm, wet sponges as needed.

> Many beginners become overly worried about humidity during these last three days. If a small amount of moisture forms on the viewing pane then you know your humidity is sufficient. When the chicks begin to emerge, the humidity will naturally increase – don't worry, the chicks will not drown from this extra humidity.

5. **CLOSED LID**: Close the incubator lid and keep it closed. Open the incubator only if additional water is needed performing the task as quickly as possible.

> The membrane that protects the chick from outside bacteria or an excess loss of water during incubation can dry out in as little as 60 seconds if humidity is lost during the hatching process. Once dried out, this membrane prevents the chick from hatching and becomes a death shroud. Guarding your humidity – it's a matter of life and death.

6. **INTERNAL PIPPING**: One or two days before hatching, the chick will puncture the air cell membrane with its beak and begin to breath. You may hear chirping at this time. If the humidity level is low during this time, the air cell membrane may dry out making it difficult or impossible for the chick to puncture it. Chicks who cannot puncture this membrane will eventually suffocate – they will drown.
7. **EXTERNAL PIPPING**: On the day of hatch, the chick will punch a small hole in the shell – pipping. After the initial pip, the chick may rest for 12 or more hours before continuing.
8. **ZIPPING**: Once the initial hole is made, the chick will turn inside the shell and proceed to make a crack around the diameter of the shell – zipping. If the humidity is low during this process, the membrane may dry out, shrink, and the chick may become stuck – shrink wrapped. The task of zipping may take anywhere from a few minutes to a few hours.
9. **EMERGENCE**: Once zipping is complete, the chick may rest for a spell. Once it regains strength, it will push against the bottom of the shell using its feet eventually freeing itself from the shell.

Assisting a chick too early can easily result in permanent harm or death. In most cases, a healthy chick will rest periodically and will emerge in time. If you decide you must assist a chick, please use caution and follow the advice in the following article:

http://www.back yardchickens.com/a/step-by-step-guide-to-assisted-hatching

10. **UMBILICAL CORD**: Prior to hatching, the chick will absorb the remainder of the egg yolk and the blood vessels attached to the shell contends will dry out. If a chick emerges too quickly, what appears to be an umbilical cord will be attached to its bottom. This cord will fall off without any assistance.
11. **HERNIATED YOLK SAC**: On rare occasions, a chick will emerge from its shell before the egg yolk is completely absorbed – herniated yolk sac. It should absorb on its own if the area remains moist.
12. **PATIENCE**: Even the experienced feel anxiety at hatch time; beginners may be overwhelmed with excitement and concern. Be patient. Mother Nature has designed each step in the process for a reason and each step takes time.
13. **EARLY HATCHING**: If the incubation temperature has been a little high throughout incubation or the eggs are small, the chicks may begin to hatch early. If they do, there is little you can do except maintain your temperature and humidity.
14. **LATE HATCHING**: If the incubation temperature has been a little low throughout incubation or the eggs are large, the chicks may begin to hatch late. If they do, there is little you can do except maintain your temperature and humidity.

15. **ENDING THE HATCH**: How long should you give an egg to hatch? Many people wait 2-3 days after the due date before discarding unhatched eggs. Personally, I will end the hatch a few hours after any visual activities have stopped. With experience, you will adopt your own preference on how long to wait.
16. **REMOVING HATCHLINGS**: Hatchlings should be completely dry and actively moving about before removing from the incubator. Hatchlings absorb their egg yolk just prior to hatch and can easily survive 36-48 hours after hatch without food or water. In most cases, it is best to wait until the entire hatch is complete before removing any hatchlings… Do not be in any hurry to remove hatchlings.
17. **CLEAN-UP**: Although styrofoam incubators appear flimsy and easy to destroy, they are actual durable. After the hatch, gently remove gunk using dish soap and a gentle brush – some soaking may be necessary. Then saturate all non-electronic surfaces with a 10% bleach solution, rinse completely, and allow to air dry. Bright sunlight is one of the most effective means to disinfecting your incubator.
18. **HATCH EVALUATION**: In order to improve future hatches, carefully consider what went right and what went wrong with each batch. Consider the following:
    - **DID THE CHICKS HATCH ON TIME?** If they hatched early, then your temperature may have been a little high. If they hatched late, then your temperature may have been a little low. You may need to recalibrate your thermometer.
    - **DID ALL EGGS HATCH WITHIN A 24 HOUR PERIOD?** If more than 24 hours transpired between the first chick and the last chick, then you may have warm and cool spots. Randomly moving the eggs around periodically will prevent an egg from staying within a warm or cool spot for a long period of time. Additionally, eggs will begin developing if they are stored in temperatures above 70° causing older eggs to hatch a little earlier than fresh ones. When possible, store eggs at below 70 °.
    - **EGGTOPSY**: Not all chicks will hatch. There are multiple reasons why this occurs from hen nutrient deficiencies, cold temperatures during collection, bacterial contamination, genetic flaws, and flaws in incubation methods. Eggs that did not hatch should be opened and examined to determine, if possible, why the chick failed to hatch. The following link from The Chicken Chick provides an excellent look at the stages of development: http://www.the-chicken-chick.com/2012/03/chicken-embryo-development-views-from.html.

PROBLEM SOLVING

Problem	Possible Causes
Eggs candle clear	♦ Rooster too young or too old ♦ Too many hens for each rooster ♦ Poor hen health ♦ Eggs stored at below 40° F
Eggs candle clear with blood ring present	♦ Eggs stored too long ♦ Eggs stored at wrong temperature ♦ Spike in temperature ♦ Excessively high temperature ♦ Hens too old or in poor health
Dead embryos before day 18	♦ Insufficient turning ♦ Lack of ventilation ♦ Dirty eggs – pores blocked ♦ Egg contamination ♦ Hens too old or in poor health
Eggs pipped but not hatched *Chick dead in shell* *Sticky chicks* *Shell sticking to chick*	♦ Low average humidity ♦ Low average temperature ♦ Low humidity at hatching time ♦ Insufficient turning ♦ Lack of ventilation
Chick pips wrong end	♦ Eggs incubated small end up ♦ Inadequate turning ♦ Not placed on side end of day 18
Eggs hatch early	♦ Temperature too high ♦ Small eggs ♦ Humidity too low days 1-18
Eggs hatch late	♦ Temperature too low ♦ Large eggs ♦ Humidity too high days 1-18
Hatch window longer than 24 hours	♦ Eggs stored above 70° F ♦ Temperature variations in incubator ♦ Mix of both large and small eggs ♦ Mix of eggs from young and old hens ♦ Eggs stored for different lengths of time
Crippled chicks	♦ Air cell too large – low overall humidity ♦ Poor nutrition of hens ♦ Genetic defects
Weak chicks	♦ Temperature too high at hatching ♦ Lack of ventilation ♦ Contaminated eggs

NOTES

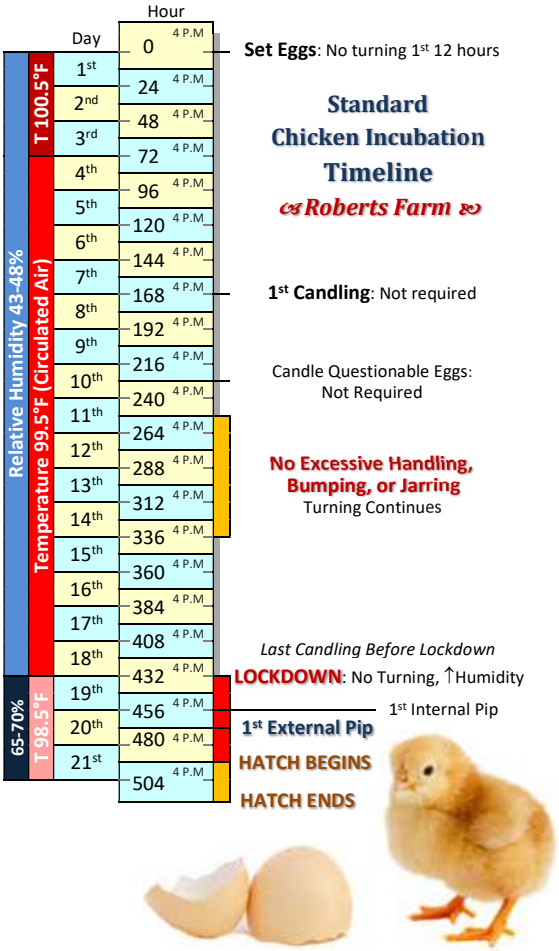
- **BAD EGGS**: Eggs with severe bacterial infections can be identified during candling by multiple small dark spots floating within the egg or by an unusually large dark area. For best results, compare a questionably bad egg with other eggs that possess a normal appearance.

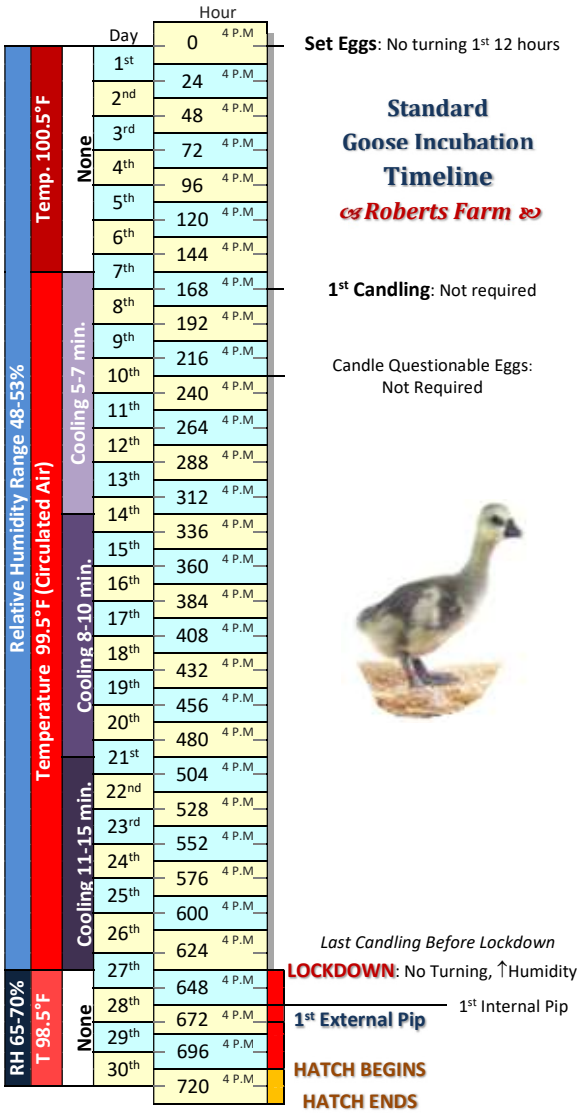
  There should be very little odor coming from your incubator. If you notice an unusual smell, open the incubator and sniff each egg individually. Removing any egg that smells will reduce the chances of a bad egg leaking or exploding and contaminating other eggs within the incubator.

- **CLEANLINESS**: Placing porous, cloth shelf liner placed on top of the mesh prior to hatching will allow moisture to pass through from the bottom water chambers but prevent the gunk from dropping into the lower portion of the incubation… easing the task of cleaning the incubator following a hatch.
- **CRACKED EGGS**: It is generally a bad idea to incubate cracked eggs; it is also generally a good idea to discard any eggs that develop a crack during incubation. However, if an expensive or prized egg develops a crack, the cracked can be repaired using a small amount of un-perfumed wax. Use as little as possible and watch the egg during hatching as the seal may make hatching more difficult.
- **FERTILITY**: The ***fertility rate*** is calculated by dividing the total number of eggs that show signs of development by the total number of eggs set. [28 set ÷ 30 show development = 0.93 or 93%] The recommended rooster to hen ratio is 1 rooster for every 8-10 hens. In some breeds such as rare bantams, that ratio may be lower 1:6. A hen generally remains fertile for 12 days following the removal of a rooster. To guarantee that chicks are fathered by a specific rooster, hens should be separated for three or four week.
- **HUMIDITY**: Humidity is determined by surface area not water depth. To increase the humidity, increase the area water is exposed to the air either by using a wider pan or sponge.

  - When adding water to an incubator, the water should be lukewarm – neither hot nor cold. Adding hot water will temporarily boost the humidity and may result in temporary uneven heating.
  - During the final three days, placing warm wet kitchen sponges on top of the mesh will boost the humidity. Be sure all detergent is washed out of the sponges before using. Also be sure to carefully wash and scald sponges after each batch to prevent bacterial growth.
  - To decrease humidity within an incubator, add uncooked dry rice to the incubator pan.
  - If you have difficulty seeing the water in the water chambers, add a drop or two of food coloring. As the water level drops, the color will drop. It will lighten once again as you add more water.
  - You can add water to the chambers underneath the mesh without opening the incubator. At lockdown, thread a small tube through a ventilation hole, through the mess, and into the chambers. Attach a children's medical syringe with the plunger removed to the tubing and then use the syringe as a funnel.
- **POWER OUTAGES**: Power outages do occur and usually at the most inopportune time. Fortunately, an outage of 2-3 hours and a temperature drop in to the mid-80s will have little effect on embryos. Longer power outages may harm the embryos and a delayed hatch. Placing a blanket over your incubator will help reduce heat loss. Additionally, if you have access to non-electric heat source, such as natural gas, cranking up a space heater can reduce possible negative effects. Regardless of the length of the power outage, do not abandon the hatch; candling the eggs a few days later will help determine if any embryos died.
- **SEPARATING CHICKS AT HATCH**: Using plastic canvas knitting sheets, construct cages for each group of eggs you wish to keep separate. The cages should be as large and tall as possible avoiding the heating or other incubator components. Each mini-cage must have a lid to prevent the hatchling from climbing over the side and into the next cage.
- **TEMPERATURE STABILITY**: Full incubators will experience fewer temperature fluctuations than nearly empty ones. If you must incubate only a small number of eggs, add a heat sink – sealed water bottles or rocks. A heat sink will absorb excess heat during short spikes in temperature and release that heat during short dives.

Incubation Timelines

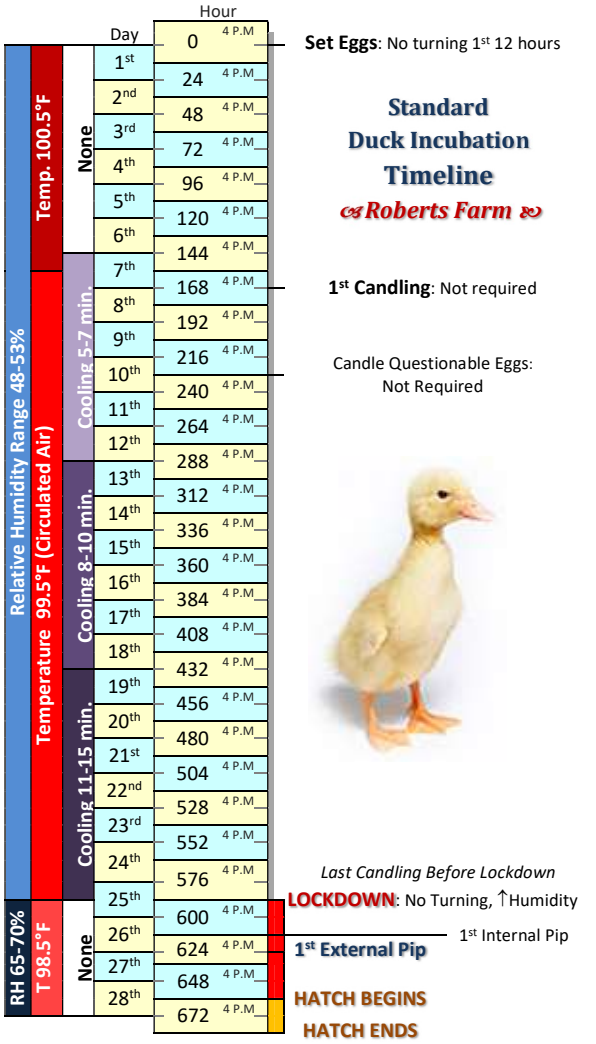


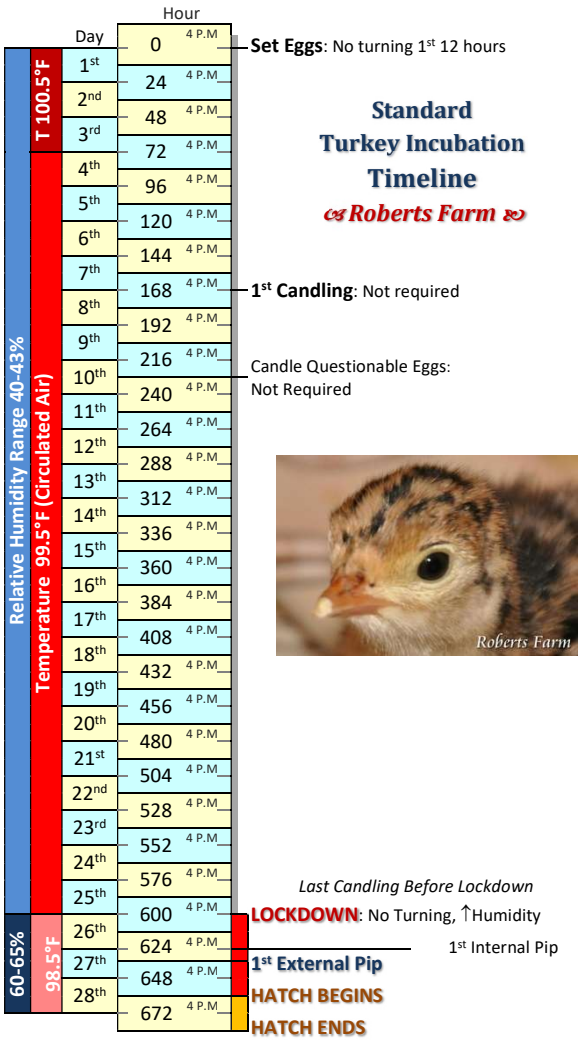


Incubation Days						
Species	**Incubation Period**	***Temp**	**Humidity (RH)**	**⁺Stop Turning**	**Hatch Humidity**	**Setting Notes**
Chicken	21 days	99.5° F	40-43%	19th day	+60%	Pointed end down
Duck, Mallard	26.5 days	99.5° F	43-48%	23th day	+65%	Pointed end down
Duck, Domestic	28 days	99.5° F	43-48%	25th day	+65%	Pointed end down
Duck, Muscovy	35 days	99.5° F	43-48%	32nd day	+65%	Place on side
Geese, Chinese	30 days	99.5° F	43-48%	27th day	+60%	Place on side
Guinea Fowl	26-27 days	99.5° F	40-43%	23rd day	+60%	Pointed end down
Quail, Bobwhite	23 days	99.5° F	40-43%	20th day	+60%	Pointed end down
Peafowl, India Blue	28 days	99.5° F	43-48%	26th day	+60%	Place on side
Pheasant, Golden	22 days	99.5° F	40-43%	19th day	+60%	Place on side
Turkey, Bronze	28 days	99.5° F	40-43%	26th day	+60%	Pointed end down

Temperatures are for forced air/circulated air incubators. FOR STILL AIR INCUBATORS, PLEASE ADD 2.0° F.

⁺Stop turning eggs, remove turner, and increase humidity at the very beginning of the day indicated – three days before the hatch.





http://www.thechickenwhisperer.co.uk/2013/01/hatching-chicks-week-2.html

Incubator Types

A common question among beginners, "Which incubator should I buy?" The answer is fairly simple, "The best one that you can comfortably afford." In general, incubator manufacturers produce the best product possible within a given price range – if they didn't, they wouldn't stay in business very long. Incubation problems generally stem from the user, not the equipment. If used properly, almost all incubators can reliably hatch eggs. My first incubator was an inexpensive styrofoam Little Giant desktop model; it has been extremely reliable and is still in use today.

Avoid inexpensive, plastic, no-name incubators made in China. Their price and description makes them very attractive; however, use of cheap parts and lack of quality control frequent result in poor results.

- **DESKTOP MODELS**: ($50.00-$800.00) Small desktop models holding between 3-48 chicken eggs. For beginners, I recommend purchasing a relatively inexpensive foam model with circulated air and an automatic egg turner. Although these models require greater time and effort, they give the hobbyist time to *figure out the incubation process* enabling them to better understand the type, style, and price range of the incubator best suited for their needs. Some hobbyists discover they don't like incubating eggs while others realize need greater capacity and flexibility.

  Automatic Egg Turners: Most desktop automatic egg turners do not tilt the eggs a full 45 degrees – the optimal angle for embryonic development. While they function adequately for chicken eggs, other, more sensitive species such as mallards and peafowl should be laid on their side and turned manually.

- **CABINET MODELS**: ($700.00-$2,350.00) Large floor models holding between 190-600 chicken eggs. These models, intended for serious hobbyist or small professionals, range from semi-automatic to fully automatic operation with almost all models having automatic egg turning capabilities. Which one is right for you? Each brand has their loyal fans who assert that their brand has the best hatch rate and is the easiest to use. My recommendation? Choose the one within an affordable price range and the capacity to meet your needs.

- **INDUSTRIAL MODELS**: If you're reading this guide, then an industrial incubator should be outside your realm of consideration. Before reaching this level, you may wish to consider multiple cabinet models along with a dedicated hatcher.

- **HOMEMADE MODELS**: My first cabinet incubator was made from ½ inch foam board sandwiched between two sheets of ½ inch plywood. It had three tilt trays that held 54 chicken eggs each – I was too cheap to spend the money necessary for a commercially made model. It worked superbly and continues in use today. Its only problem was the trays had to be tilted manually. If you're an industrial individual who likes to build things, then you may want to consider building your own. Multiple examples of homemade incubators can be found at http://www.backyardchickens.com/a/homemade-chicken-egg-incubator-designs-pictures.

- **MAJOR COMPONENTS**: An effective artificial incubator maintains a constant temperature, generally 99.5° F, provides a means to regulate humidity, and permits routine egg turning. They can either be manual where the user does all the work, semi-automatic where the incubator does some of the work, or automatic where the incubator does all of the work. The more you spend, the more automated the process:

  1. **INSULATION**: What materials are used to separate the eggs from the room environment? The least expensive models utilize polystyrene foam (styrofoam) or simple plastic, others use plastic board, while still others use insulation sandwiched between plastic and metal. While all incubators do best in a climate controlled room, better insulated incubators have fewer temperature and humidity fluctuations than those that use a thin layer of plastic.

2. **THERMOSTAT**: How is the temperature regulated? The simplest, and perhaps most accurate, thermostat uses a simple wafer switch to regulate temperature – as the temperature warms, the wafer expands and opens the heating element contact. Unfortunately, these models rely upon a screw or knob to set the temperature. Many manufacturers are currently using digital thermostats employing an LED panel to display and control temperature. While this type of control is certainly easier to use, quality may suffer in lower end units. Additionally, most digital controls can only be calibrated by the manufacturer and may lose accuracy over time – it is best to always use a separate, calibrated thermometer to validate the control's reading.

3. **AIR CIRCULATION**: How are all sides of the eggs warmed? The least expensive incubators are "still air" and contain no fan to circulate the warmed air. Many claim that this method is the best one in that is closely resembles a hen setting on eggs where only one side is heated. However, most prefer a "circulated" or "forced" air system where a fan circulates the warmed air throughout the incubator. In lower-end models, a fan in an optional component and must be purchased separately. A third and rare method attempts to replicate a broody hen using a plastic bladder to cover and warm the eggs; this method but is rare because of the expense and limited batch size.

Example of Hobbyist Type Incubators

Model	Capacity	Price	Ease	Type	Air Flow	Control	Turning
Rcom Mini	3	125.00	★★★★☆	Automatic	Circulated	Digital	Automatic
Brinsea Mini ECO	7	95.00	★★★★☆	Semi-auto	Circulated	Digital	Automatic
Brinsea Mini ADV	7	160.00	★★★★☆	Semi-auto	Circulated	Digital	Automatic
Janoel JN-12	12	120.00	★★★☆☆	Semi-auto	Circulated	Digital	Automatic
Rcom Max 20	20	385.00	★★★★★	Automatic	Circulated	Digital	Automatic
Brinsea Octagon 20 ECO	24	180.00	★★★☆☆	Semi-auto	Circulated	Digital	Optional
Rcom King Suro Eco 20	24	190.00	★★★★★	Semi-auto	Circulated	Digital	Manual
Janoel JN-24	24	230.00	★★★★☆	Semi-auto	Circulated	Digital	Automatic
Rcom King Suro 20	24	280.00	★★★★★	Automatic	Circulated	Digital	Cradle
Brinsea Octagon 20 ADV	24	350.00	★★★★★	Semi-auto	Circulated	Digital	Cradle
HovaBator 1602	41	50.00	★★☆☆☆	Manual	Still Air	Knob	Optional
Farm Innovators 2100	41	50.00	★★☆☆☆	Manual	Still Air	Knob	Optional
Little Giant 10300	41	75.00	★★★★☆	Manual	Circulated	Digital	Optional
Farm Innovators 4200	41	90.00	★★★☆☆	Manual	Circulated	Knob	Optional
Little Giant 9300	46	45.00	★★★☆☆	Manual	Still Air	Digital	Optional
Janoel JN-48	48	140.00	★★★★☆	Semi-auto	Circulated	Digital	Automatic
Brinsea Octagon 40 ECO	48	380.00	★★★★☆	Semi-auto	Circulated	Digital	Optional
Brinsea Octagon 40 ADV	48	450.00	★★★★★	Semi-auto	Circulated	Digital	Cradle
Rcom Max 50	48	685.00	★★★★★	Automatic	Circulated	Digital	Automatic
Hovabator 2362E	50	80.00	★★★☆☆	Manual	Circulated	Knob	Optional
HovaBator 1588	50	140.00	★★★★☆	Semi-auto	Circulated	Digital	Optional
Janoel JN5-60	60	130.00	★★☆☆☆	Manual	Circulated	Digital	Manual
Rcom Max 190C	168	1,100.00	★★★★★	Automatic	Circulated	Digital	Automatic
Brinsea Ova-Easy 190	192	1,150.00	★★★★★	Semi-auto	Circulated	Digital	Automatic
Sportsman 1502	270	720.00	★★★★☆	Semi-auto	Circulated	Digital	Automatic
Rcom Maru 380C	336	1,500.00	★★★★★	Automatic	Circulated	Digital	Automatic
Brinsea Ova-Easy 380	384	1,400.00	★★★★★	Semi-auto	Circulated	Digital	Automatic

***NOTATION**: This chart is intended only as an example of types, options, and price ranges. Model numbers, features, and prices will vary. Carefully compare current models before purchasing.*

Broody Hens vs. Artificial Incubation?

Many hobbyists and breeders prefer to incubate eggs the old fashion way – let a broody hen do all the work. This method is helpful in that we don't need to worry about temperature, humidity, turning, or power outages. Unfortunately, it also removes the hen from egg production. Many report that a broody hen improves hatch rates and viability especially with more difficult species such as peafowl and rare bantams. Some professional breeders, such as Legg's Peafowl Farm[1], allow broody hens to incubate eggs for the first week before placing them in an incubator.

Incubator vs. Broody Hen[2]	
Artificial Incubation	**Broody Hen Incubation**
Incubators are easily obtained	Broody hens availability may be limited
Initial investment high with low maintenance cost	Initial investment low with some maintenance cost
Incubators available 365 days a year	Broody hens generally limited to Spring and Summer
Batch size virtually unlimited	Clutches limited by hen size
Hatchling hatch within a 24 hour period	The hatch window may be spread over several days
No effect of egg production	Removes the hen from egg production
Scheduled according to incubator space availability	Scheduled according to broody hens availability
Success rate generally stable and predictable	Success rate may vary according to hen traits
Lower success among more difficult breeds & species	Higher success among difficult breeds & species
Must manually monitor temperature and humidity	No manual input required
Requires electricity	Self-powered
Losses due to human error	Losses due to hen's weather, predators, and accidents
Artificial brooding required	Hens brood the hatchlings
Must manage exposure to Coccidiosis	Coccidiosis exposure naturally occurring, less impact
Loss due to brooder disease and power outages	Losses due to predators and other flock members

Personally, I artificially incubate all eggs during the spring months to keep up egg production. I do allow most species to go broody during the summer months and have experienced mixed results:

1. **Bantams**: My bantams tend to go broody frequently and do an excellent job in hatching and brooding their young. Since they usually nest inside their coop, fire ants are less of a problem than with those that nest on the ground. While my Old English bantams share in the responsibility of incubating and brooding a clutch, my bantam Cochins squabble over the chicks and from time-to-time will crush chicks in the struggle.
2. **Brown Chinese Geese**: My geese have yet to successfully hatch a gosling primarily due to our warm climate and the presence of bacteria in the ground. In most instances, one or more eggs will spoil, break, and contaminate the nest. For Brown Chinese geese, I incubate the eggs artificially and then return the goslings to the parents a week after hatch. Both male and female geese are excellent parents.

3. **Guineas**: Guinea hens are known to lay their eggs on the ground and are not known to be particularly good mothers. My only experience ended in failure when fire ants invaded the nests killing any keets that successfully hatched or were in the process of hatching.
4. **Heritage Turkeys**: I raise both standard Bronze and Royal Palm turkeys. Both are quick to go broody and do an excellent job hatching poults. Unfortunately, neither tends to be good parents as I usually find small poults wondering about the yard after they hatch. If a hen is successful in tending to the brood, the heavier males can easily crush the young poults.
5. **Mallard Ducks**: My mallard ducks are excellent about both hatching and tending to their young. Since ducks are terribly messing, allowing the mother to brood young ducklings eliminates the need for messy brooders. Unfortunately, fire ants frequently invade nesting sites and kill the ducklings once they start to hatch.
6. **Peafowl**: Peafowl are known to do a good job at incubating and brooding their young; however, since peachicks are expensive and peahens will only lay about 18 eggs each year, I artificially incubate all eggs.

[1] *Brad Legg, "Incubation & Hatching Peafowl Eggs," Legg's Peafowl Farm, NDA, <http://www.leggspeafowl.com/incub.htm>*
[2] *Several ideas drawn from "INCUBATOR VS. BROODY HEN," Community chickens, NDA, <http://www.communitychickens.com/incubator-vs-broody-hen/>*

How do I get a hen to go broody? Generally, a hen will go broody when she's is good and ready. Silkies and Cochins tend to go broody frequently; however, many breed, such as Leghorns have been bred over many decades not to go broody – they're expected to lay eggs not hatch chicks.

Five Ways to Encourage a Hen to go Broody[1]

1. The first thing you can do is choose breeds that tend towards being broody, such as Australorps, Brahmas, Buffs, or Cochins and bantam breeds such as Silkies, bantam Cochins or Orpingtons.
2. A second way to encourage a hen to go broody is to leave some eggs in the nests ('dummy' eggs, such as golf balls or plastic Easter eggs work just as well as real eggs and don't risk being broken). This can encourage your hen to start sitting on them.
3. You can also encourage a hen's broody nature by providing her a dark, safe place to sit on the eggs. Hang some curtains across the front of the nesting boxes, even a piece of sheet or fabric will help convince her the nest is a secret place to raise her chicks.
4. Adding some herbs to the nesting boxes such as lavender or chamolile can help the hen relax and feel safe and secure.
5. Check the nesting boxes for insects, mites and mice. A hen generally won't sit if she senses critters in the boxes that could harm her eggs or chicks. Be sure the nesting box material is fresh and clean, and that there is a nice thick layer so the eggs won't touch the wooden floor and risk breaking.

How to I Break a Broody Hen? When I was a child, I noticed a neighbor's hen in a small wire cage and asked him why he had locked her up… His response, "She stopped laying eggs and a chicken that doesn't lay eggs isn't worth much." Within my flock, spring eggs are valuable; they produce hatchlings; and hatchlings pay the feed bill… I collect eggs two or three times a day to discourage broodiness.

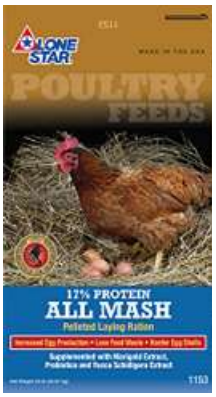
Five Ways to Break a Broody Hen

1. Collect the eggs frequently; however, some hens will sit on anything that looks like an egg or even imaginary eggs.
2. Remove the hen from the nest, carry her for 10-15 minutes, and then place her outside the coop; however, since broodiness generally involves hormones, I wouldn't have high expectation.
3. Deny access to her nesting spot or place her in a small pen without any nesting spots; sometimes, just a change in the environment or making it difficult to nest may be sufficient to end the process.
4. Dunking the lower portions of her body in cool water until her feather is wet; some give a full bath hoping the "cooling off" will break the cycle.
5. Place her up in a wire cage for five days, a small dog crate with food and water but no nesting material. (Old timers, like my neighbor did not always include food or water.)

Care for a Broody Hen: Hens are designed by Mother Nature to spend three to four weeks on a broody nest. They will select a nesting site best suited to their needs. During incubation, a hen will stop laying, consume 80% less feed, and lose up to 20% of their total body weight. During the first week, hens almost never leave their nest relying upon body stores for the water and nutrient needs. After the first week, a hen may leave the nest seeking food, water, and waste elimination. The length of time she is off the nest depends upon the stage of development, the weather, and her personality. Some species, such as mallard ducks, may stay off of the nest for hours at a time during warm weather. A broody hen's needs are few but food and water should be available close for her convenience. In most cases, a broody hen will do an excellent job at incubating her eggs, and it is usually best ***just to leave her and her eggs alone***… she knows what she is doing!

[1] *"Five Ways to Encourage a Hen to go Broody," Fresh Eggs Daily, Apr. 10, 2014 <http://www.fresheggsdaily.com/2014/04/five-ways-to-encourage-hen-to-go-broody.html>*

Feed: The Importance of Freshness



Several factors have a significant impact on egg production and hatchability; one of the most important is hen nutrition. Commercial poultry feed is a cooked product and is therefore perishable – it loses nutritional value as it ages. When stored under ideal conditions, poultry feed has a shelf life of up to 120 days. Feed stored under less than ideal conditions has a shelf life of less than 60 days. Nutrena recommends using pelleted feeds, including crumbles, within 60 days during summer months and 90 days during winter months.[1]

For best results, learn to decipher (decode) the Lot # printed on each bag of feed and check those numbers each time you make a purchase. It is especially important to check the mill dates for less popular feeds such as Game Bird Starter or specialty feed such as Chick Starter during the off-season. Additionally, farm stores often employ individuals who may not understand FIFO (First In, First Out)… they may stack new feed on top of old feed.

Examples of Lot # Deciphering

PURINA MILLS

	Year	Month	Day of Month	Plant	
7MAY01RVI	7	MAY	01	EV1	May 1st, 2017

Manna Pro

	Plant	Month	Day	Year	Hour	
A05/01/17J	A	MAY	01	2017	J	May 1st, 2017

	Plant	Month	Year	Day	Hour	
AE701J	A	MAY	2017	01	J	May 1st, 2017

NUTRENA

	Plant	Year	Day of Year	
WB7121	WB	7	121	May 1st, 2017
567121	56	7	121	May 1st, 2017

LONE STAR

	Plant Code	Day of Year	
D121	D	121	May 1st, 2017

FEED STORAGE:

1. DO store feed in a well ventilated, cool (below 77°F), dry location away from direct sunlight. When selecting a storage location, DO consider the temperature during the hottest summer months.
2. DO NOT store on a concrete floor – moisture will wick through the concrete into the bags. Store feed on pallets or similar barrier permitting air to circulate around and underneath.
3. DO protect feed from rodents and insects. Using chocolate as rodent baits can be more attractive than the feed. Consider galvanized or plastic containers for smaller feed amounts.
4. DO NOT mix old and new feed in the same container which can easily cross-contaminate new feed with mold, mildew, mites, and other pests.

PROTEIN CONTENT: Layer feeds are basically formulated for hens laying table eggs (16% protein). Small benefits may be gained by providing breeder hens with feeds with ***slightly*** higher protein levels (17-18%). However, significantly higher protein levels tend to decrease hatchability and unnecessarily strains the metabolic process because excess protein must be converted to nitrogen and then excreted.

> Egg production and fertility of eggs were not significantly affected by protein level or vitamin B12 supplement. However, increasing protein level in the hen diets resulted in a significant decrease in hatchability.[2]

[1] *"General Feed FAQs: Feed Freshness," Nutrena World: Cargill, Inc., 2017 <https://www.nutrenaworld.com/general-feed-faqs>*
[2] *M. B. Patel J. McGinnis, "The Effect of Levels of Protein and Vitamin B12 in Hen Diets on Egg Production and Hatchability," Poultry Science, Jan 1977, Pages 45–53.*

Eggs: Production and Quality

Since commercial egg and meat producers generally only keep their laying flocks in production for a single year, formal studies on backyard egg production and quality do not exist. Much of what we do know is either anecdotal (unproven) or from personal experience:

***Hatchery Chicks**: Many hatcheries place their new pullets into production in late winter or early spring. While these chicks can be of good quality, the highest quality chicks come from more mature hens. When buying hatchery chicks, order chicks during the mid-summer months for the highest quality chicks.*

- **HEN AGE**: Eggs from pullets between the age of 34 and 52 weeks have higher fertility rates and produce higher quality chicks than those younger or older. Small, large, misshaped, and discolored eggs all indicate poorer egg quality and should not be incubated if the highest quality chicks are desired.

  Personally, I change out my breeder flocks every two for chickens and three years for ducks. After these ages, the hens lower egg production and decrease hatchability becomes unprofitable. Selling the older hens to individuals who want a few hens in the yard permits older hens to live long lives while permitting me to replace the hens with their higher quality offspring – my flock quality improves with each generation.

- **HEAT STRESS**: Unlike humans, chickens do not sweat and are fairly inefficient in dealing with temperature above 85°F. Heat above 90°F leads to a significant decline in feed consumption, egg production, and egg quality. Forced ventilation (fans) is perhaps the most effective method to heat stress as it helps move heat away from the bird's body. Backyard hobbyists have devised a number of other methods to help chickens "beat the heat." While some methods may help make the hens more comfortable, they have minimal impact on egg production and quality.

Heat Stress and Ambient Temperature[2]	
55° to 75°F	Thermal neutral zone. The temperature range in which the bird does not need to alter its basic metabolic rate or behavior to maintain its body temperature.
65° to 75°F	Ideal temperature range.
75° to 85°F	A slight reduction in feed consumption can be expected, but if nutrient intake is adequate, production efficiency is good. Egg size may be reduced and shell quality may suffer as temperatures reach the top of this range.
85° to 90°F	Feed consumption falls further. Weight gains are lower. Egg size and shell quality deteriorate. Egg production usually suffers. Cooling procedures should be started before this temperature range is reached.
90° to 95°F	Feed consumption continues to drop. There is some danger of heat prostration among layers, especially the heavier birds and those in full production. At these temperatures, cooling procedures must be carried out.
95° to 100°F	Heat prostration is probable. Emergency measures may be needed. Egg production and feed consumption are severely reduced. Water consumption is very high.
Over 100°F	Emergency measures are needed to cool birds. Survival is the concern at these temperatures.

- **DAYLIGHT HOURS**: For maximum production, hens require 16 hours of light per day and anything below 14 hours will cause the reproduction system to decline.[3] Artificial lighting in the form of "soft" or "warm" light (2700K–3000K) bright enough to comfortably read a newspaper (30 lux) is sufficient for laying hens. For best results, use a timer switching on the lights in the morning hours as to not disrupt roosting. Even with an artificial lighting program, egg production will likely decrease as average daily temperatures drop below 52°F.

[1] *J.P. Jacob,et. al, "Factors Affecting Egg Production in Backyard Chicken Flocks,"FACT SHEET PS-35, University of Florida, April 2014*
[2] *Kenneth E. Anderson, "Hot Weather Management of Poultry," Cooperative Services, North Carolina State University, 2007*
[3] *Chad Zadina, et. al. "Proper Light Management for Your Home Laying Flock," NebFacts, University of Nebraska: Lincoln, 2005.*

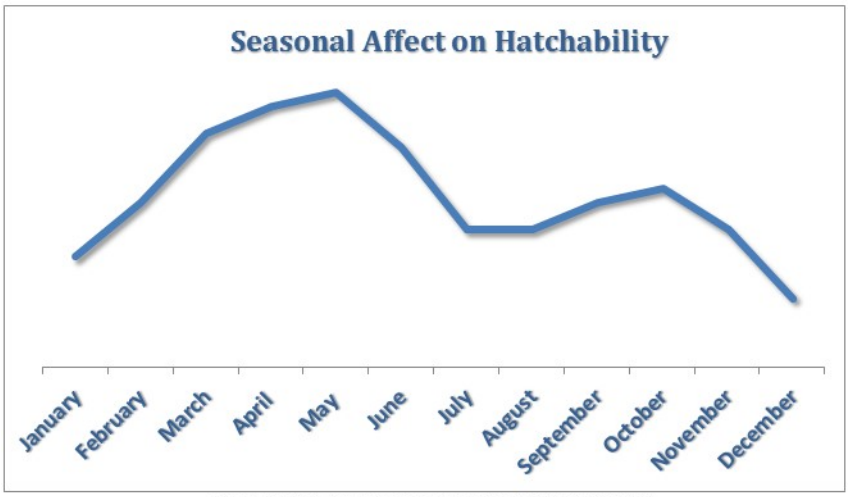
The use of artificial lighting to stimulate egg production can be a contentious topic of conversation with many backyard hobbyists claiming that it is unnatural, harmful, and decreases the number of years that a hen lays. A few of the arguments that they sometimes use are not completely valid:

1. **Chickens are hatched with only so many eggs so if you force them to lay through the winter, then they'll stop laying sooner**: The first part of the argument is true: when chickens hatch, they possess all of the ovum that they will ever have. But, that number is quit high with 2,000 being visible to the naked eye and another 12,000 visible under magnification.[1] A decline in age production is more closely related to age and health than the number of ovum they possess at hatch time.
2. **It is unnatural to force them to lay through the winter**: Modern chicken breeds are the result of thousands of years of selective breeding which grew in intensity during the 19th Century. The birds we have in our backyards hardly resemble the red jungle fowl that thrived in tropical climates. The mere fact that some breeds thrive in cold climates or that some don't go broody provides evidence that man has altered the "natural state" of the chicken. The "natural" resting period for hens consists of a 9-12 week period that includes incubating her eggs and raising her chicks. If the "natural" is important to us, then we probably shouldn't be incubating eggs artificially.
3. **They need a rest**: For those hens that do not go broody and raise their young, there is a secondary annual resting that lasts 8-12 weeks – the annual molt. During the molt, a hen will do more than simply replace her feathers. At this time, a hen stops laying, decreases her feed intake losing excess weight and allowing the reproductive system to regress back to the near pullet stage. The molt provides a "natural" period of rest.

Within my flocks, I use artificial lighting for production birds such as those used to produce laying pullets. I do not use artificial lighting for other birds such as bantams, ducks, and turkeys. To use or not use artificial lighting is a personal preference that largely depends on the intensity and efficiency of the individual program.

- **MOLTING**: Molting is an annual, natural process that usually occurs in the fall after they turn 18 months old. During the molt, a hen not only replaces her feathers but she also loses excess weight and her reproductive organs revert to a near pullet condition. The extent of the molt is highly dependent on the individual hen and breed with the drop in egg production and loss of feathers barely noticeable in some hens and conspicuous in others. The length of molt also varies with most hens being out of production for 8-12 weeks. Following the molt, production levels are unlikely reach pre-molt levels; however, egg size usually increases.

  Molting is a natural part of the life cycle and no effort should be made to stop or "fix" it. Instead, hens tend to benefit from a low nutritional diet (hen scratch, rolled oats, and table scraps) from first signs of molt until they have completely stopped laying. Upon cessation of lay, providing a higher protein diet (20%) will help the hen nutritionally recover.



Milo M. Hastings, The Dollar Hen, National Poultry Publishing, 1911

[1] *See P. D. Sturkie, Avian Physiology, Springer Science & Business Media, Dec 6, 2012 and "Reproductive system," Poultry Hub, 2017, http://www.poultryhub.org/physiology/body-systems/reproductive-system/*

Storage: Mold & Bacteria

Should hatching eggs be washed, dipped, rinsed, sprayed, or simple left alone? A common and often hotly debated topic among hobbyists. The best answer? Unfortunately, there is no single correct answer and the best answer rests in a complex web of details. In developing this article, I examined a large number of evidence-based papers, considered a backyard hobbyist's limitations, and then formulated a feasible and effective approach for the majority of hobbyists. If a person has a method that works well for them, they should not alter that method.

VERTICAL TRANSMISSION: Vertical transmission is where a hatching egg becomes contaminated with microbes during the egg forming process – the microbes come from inside the hen. This article does not address vertical transmission and deals only with horizontal transmission – contamination from outside the hen.

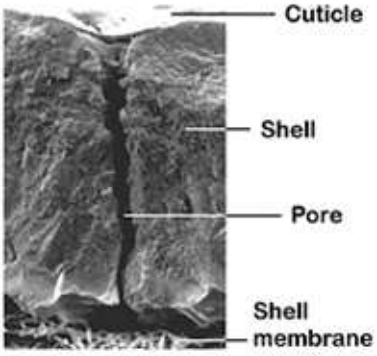
MOTHER NATURE'S DESIGN

Mother Nature created a near perfect self-contained chamber for developing chicks. It contains sufficient water, nourishment, and vascular networking to support the developing chick. It contains a porous shell that permits the escape of excess water and the exchange carbon dioxide for fresh supplies of oxygen. It also contains five layers of protection against invasive microbes:

1. **CUTICLE (Bloom):** a liquid protein layering applied to the outside of the shell. Once dried, the cuticle it the most effective barrier in preventing movement of microbes from the outside the shell to inside. The cuticle, however, is not perfect and its integrity can be compromised:
    a. **Dirty Nests**: Eggs are most vulnerable to bacterial penetration in the first 30 to 60 seconds after lay before the cuticle hardens and caps the pores.
    b. **Hen Age**: Eggs from hens older than 70 weeks have poorer quality cuticles than young hens.
    c. **Wetting**: Any process that wets the exterior of the egg partially dissolves the cuticle decreasing its effectiveness. Moisture also promotes microbial growth on the shell and acts as a media to aid microbe movement through the shell.

> *Bacteria inside the egg may use the nutrients found in the egg to multiply, robbing the embryo of a crucial food source or perhaps producing a toxin harmful to the embryo. During incubation, bacteria can actually prevent embryonic development, ultimately causing the embryo to die. Even if the embryo of a contaminated egg survives hatching, the chick will either die in the broiler house or simply not grow as it*

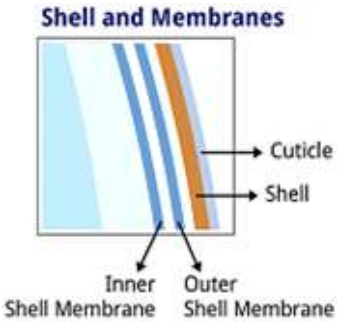
2. **THE SHELL**: Although egg shells appear solid, they have thousands of pores that permit moisture and gases to escape and oxygen and contaminants to enter. Thick shells help reduce contamination, but microscopic cracks, thin shells, and overly porous eggs compromise its effectiveness. Several factors affect shell quality including nutrition, stress, weather, health, and disease. Weather and hen age may be of particular importance:



    a. **Weather**: During the warmer summer months, a hen responds to excess heat by panting changing the blood pH and reducing the available blood calcium. Additionally, hens naturally decrease their feed intake further reducing available calcium.
    b. **Hen Age**: The older the hen, the larger the eggs and the more calcium is required; however, as the hen ages she less able to absorb and mobilize the available calcium… more than a 50% decrease of normal after 40 weeks of age.[2]
3. **INNER & OUTER MEMBRANE**: The egg contains two permeable (penetrable) membranes – the inner membrane attached to the inside shell surface and the outer membrane surrounding the egg contents. These membranes act as filters to discourage microbe penetration into the egg interior.

[1] *"Contamination of Hatching Eggs," North Carolina Cooperative Extension, North Carolina State University, 2007*
[2] *Lokesh Gupta, PhD, "Factors Influencing Shell Quality," Regional Technical Manager, Avitech, March 1, 2008.*

4. **ALBUMEN**: Finally, the chemical composition of the albumen (egg whites) discourages bacterial growth.



Unfortunately, Mother Nature's design is imperfect. Bacteria and mold are endemic – everywhere: in the soil, the nest, the manure, even floating dust particles. ***Contamination remains a leading cause in hatch failure***. While gross infections are easily detected by their pungent smell and oozing exudate, milder forms can be more difficult to identify:

1. Eggs candle clear (appear infertile),
2. Deaths occurring at various stages of development,
3. Fully developed chicks failing to pip, zip, or hatch,
4. Unhealed or wet navels or mushy, soft chicks, and
5. Abnormally small, weak, or fragile chicks.

When an egg is laid, it is warmer than the environment, since the body temperature of the hen is 42°C. The warm egg cools to environmental temperature, and this cooling causes the contents of the egg to contract. Such contraction tends to form a negative pressure within the egg. Bacteria present in the environment or on the egg surface can then be pulled into and through the eggshell and its

FACTORS INFLUENCING EGG CONTAMINATION

- **THE NEST**: The egg is most vulnerable to contaminants when it is first laid. The egg is warm and the cuticle is in its liquid form. As the egg cools and dries, contaminates from the surrounding area are drawn into the interior of the egg. Once inside, no amount of washing and sanitizing will have an effect. *Action*: keep the nest perfectly clean and dry. Avoid using nesting material, such as hay, that promotes the growth of mold. During wet weather, be sure the coop floor has sufficient bedding to discourage the tracking of mud and muck into the nests. Remember, mold and bacteria are microscopic and may not be visible… change nesting frequently during warm, wet weather even if it looks clean and dry.

- **CONDENSATION**: (Sweating) Place a glass of ice water on a cabinet and you will notice condensation (water droplets) form on the exterior of the glass. Under similar circumstances, condensation accumulates on egg shells when moved from a cool to a warm environment – such as from the nest during winter months. *Action*: When moving eggs from a cool to warm climate, avoid exposing cool eggs to warmer air… keep them inside their cartons or tightly cover the eggs with a clean towel until they reach room temperature.

Moisture provides a needed nutrient for microbial growth and might also provide a medium to aid the movement of microbes through the shell... Minimize the number of cracked or broken eggs. Egg contents can provide nutrients for the bacteria to multiply and spread.[4]

- **CROSS-CONTAMINATION**: Cross contamination involves accidentally transferring microbes from one surface to another and can occur several points in the incubation process:

  ✓ **Hands**: Failure to wash hands before touching eggs or inadvertently touching a dirty surface and then touching an egg. This can occur anywhere in the process: collection, storage, setting, candling, and transfer. *Action*: Wash hands before touching eggs and remain aware of what your hands touch.

  ✓ **Collection Basket**: Using the same basket to collect incubation, dirty, or eating eggs and not sanitizing the basket between collections. *Action*: The simplest solution may be to use a new, clean paper towel to line the collection basket and to use two baskets – one for incubation eggs and one for eating eggs.

[1] *M. E. Berring, USDA, et. al. "Bacterial Penetration of The Egg Shell and Shell Membranes of The Chicken Hatching Egg: A Review," Applied Poultry Science, 1999.*
[2] *"Contamination of Hatching Eggs," North Carolina Cooperative Extension, North Carolina State University, 2007*

Dirty, broken, cracked, leaking and dented eggs should be collected in a separate container and should not be used for hatching purposes. Eggs coated in egg yolk are especially dangerous.

- ✓ **Countertops**: Placing incubation eggs on a countertop, especially a kitchen countertop. *Action*: Transfer eggs directly from the collection basket to their storage carton or sanitize the countertop using an antimicrobial cleanser.
- ✓ **Used Egg Cartons**: Using egg cartons from eating eggs and/or reusing incubation egg cartons. *Action*: Use only new cartons to store hatching eggs or use other suitable containers that can be sanitized.
- ✓ **Candling**: Candling usually involves picking up an egg, shining a light into it, looking at the contents, and placing the egg back into the setting tray, and then picking up the next egg. This is an ideal situation for transferring contaminants from one egg to another. *Action*: Candle eggs as infrequently as necessary. Wash and **dry** hands thoroughly before candling and at any time you suspect that a touched egg might be contaminated. Use your nose (smell) instead of candling to locate and identify any "bad" eggs.

REASONS NOT TO WASH

The breeder part of the poultry industry does not want hatchery eggs to even get wet as it is believed that may aid bacteria to enter the pores and may actually increase the number of rotten…
Dr. Craig Coufal, Texas A&M AgriLife Extension Service poultry specialist in College Station.

- **Cosmetic Only**: Washing eggs may be more visually appealing but this only cosmetic… it only looks better. Mold, viruses, and bacteria are microscopic—cannot be seen with the eye – and remain of the egg surface after washing.
- **Wetting Increases Microbial Growth & Movement**: Mold and bacteria need moisture to multiply. Dry dirt and droppings remain relative inert (inactive). Adding moisture not only provides microbes access to the nutrition necessary to reproduce, the liquid also compromises the cuticle and provides the medium that allows the microbes to move into the inner shell. Before wetting an egg, the harms should be carefully considered.
- **The Wrong Focus**: Entry of microbes into the inner shell primarily occurs in the nest before the cuticle fully dries. Egg washing is not capable of addressing microbes already inside the egg but can damage the cuticle allowing microbes to enter other, uncontaminated eggs… ones that have not yet been affected. The primary focus should be on maintaining a clean, dry nest before the problem occurs.

Wetting hatching eggs with or without disinfectants can result in contamination. Any concentration of moisture on warm eggshells evaporates, thus cooling the eggs. This lowers the internal pressure, driving contaminants through the pores into the eggs. Many bacteria use moisture as a vehicle to literally swim into eggs.[5]

- **Washing Damages the Cuticle**: Simply wetting the cuticle can damage it. Rubbing the egg and using cleansers are likely to severely damage, if not completely remove, the cuticle. Remember, the cuticle is the first and best defense in limiting microbes to the outside of the egg.
- **An Inexact Process**: Unlike commercial hatcheries that primarily rely upon fumigation rather than traditional washing, most hobbyists do not have the chemicals or the equipment to thoroughly sanitize the egg surface. An inexact cleansing can cause greater harm than good:
  - ✓ Too cool of water will cause the air in the egg to contract drawing microbes and cleanser inside the egg.
  - ✓ Too hot of water for too long can damage the internal egg composition by changing the characteristics of the albumen and possibly harming the fragile blastoderm.

All sanitizing procedures will remove the outer cuticle from the egg as well as the dirt and may leave the egg at greater risk from bacterial contamination. Any cleaning procedure incorrectly followed can contaminate the egg rather than sanitize it.[6]

[1] *Sue Ann Hubbard, D.V.M. Poultry Specialist, College of Veterinary Medicine, "Keys to Successful Handling of Hatching Eggs," Issue 1638, Mississippi State University, 2002.*

[2] *"Should hatching eggs be cleaned before setting in an incubator?" Brinsea, <http://www.brinsea.com/Articles/Advice/EggCleaning.aspx>.*

- ✓ Using the wrong or too weak of a sanitizing agent can leave microbes on the outer surface while leaving a wet surface better enabling the microbes to move to the inside of the shell.
- ✓ Using the wrong or too strong of a sanitizer agent can change shell characteristics and damage the internal composition.
- ✓ Washing multiple eggs in one setting increases the chances of cross-contamination… transferring harmful microbes from dirty eggs to those that are not contaminated.

- **False Security**: Many people wash eggs to keep contaminates out of their incubator. Unfortunately, incubator contamination is more likely to originate from microbe growth starting inside the egg and then seeping out. Although the eggs appear clean, washing does not sterile the shell and many harmful microbes remain. We develop a false sense of security and may lose focus on the primary means of avoiding problems with harmful microbes – a clean nest and an intact cuticle.

DOES WETTING DAMAGE THE CUTICLE?

Opinions vary among the "experts" as to how much damage occurs by simply wetting the outer shell. Brinsea asserts that simply wetting the shell damages the cuticle and the broiler industry tends to agree:

> *All sanitizing procedures will remove the outer cuticle from the egg as well as the dirt and may leave the egg at greater risk from bacterial contamination. Brinsea Website*

Other sources assert that the cuticle is not dissolved by water, and simply wetting the shell for less than three minutes does minimal harm:

> *The cuticle is the outermost layer, deposited on the palisade layer of the eggshell during the last 1.5-2 hr of eggshell formation in utero. It is a non-calcified, thin,* ***water-insoluble*** *layer composed mainly of glycoproteins with some carbohydrate and fat constituents.*[1]

The vast majority of the material related to sanitizing indicates that simply wetting the egg shell with an approved sanitizer does no physical damage the cuticle, in the absence of surfactants (soaps) or chemical or mechanical abrasion (rubbing). However, we should not forget that microbes thrive in a moist environment and simply wetting the egg shell increases microbial activity and growth.

DOES A BROODY HEN WASH HER EGGS? Well, yes, she does, in a way… Oils, feathers, and movement act as a wash cloth to gently cleanse the eggs from dirt and feces. She doesn't use water but the eggs under my broody hens are always clean and shiny.

IS THE INCUBATOR AN IDEAL ENVIRONMENT FOR MICROBIAL GROWTH?

It is commonly assumed that a poultry egg incubator is the ideal environment for microbial growth; however, this assumption is not necessarily accurate. Microbes, in general, require three key elements for reproduction: warmth, moisture, and nutrients. Incubators certainly provide the ideal temperature, but they generally lack the other two ingredients: moisture and nutrients.

HUMIDITY: Normal incubator humidity is less than ideal for bacterial, virus, or fungal replication.

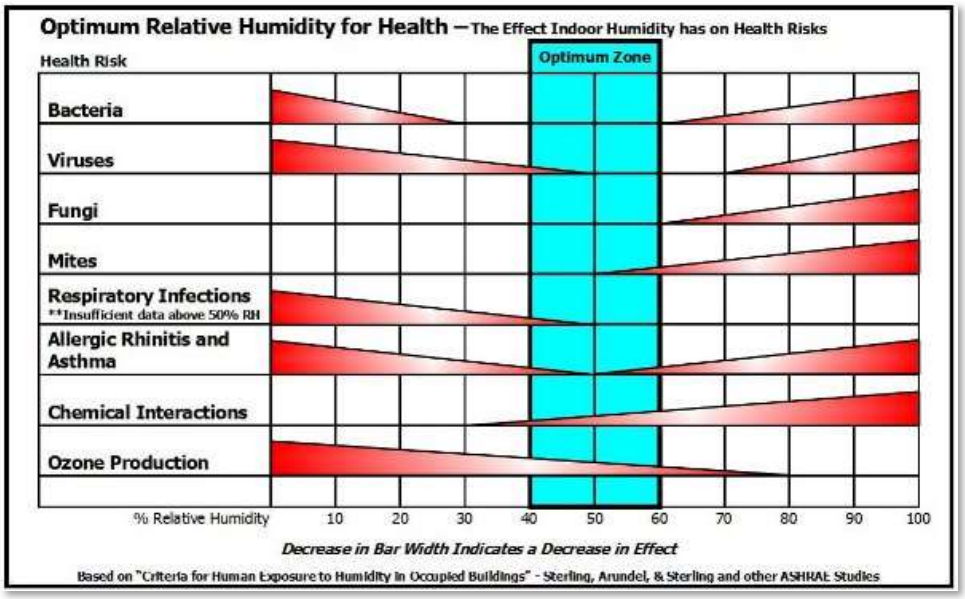
> *Bacteria cells are weakened the most during the 40-60% humidity range. Numerous studies have shown that outside of this range, it's more plausible that bacteria will survive and multiply*.[2]

Since most hobbyist incubate Days 1-18 in the 40% to 60% range, then the poultry incubator provides the least ideal humidity range for bacterial, viral, and fungal reproduction.

Moisture on the egg shell, either by condensation or intentional wetting, does promote microbial growth. It is important to avoid condensation and allow sanitized eggs to dry completely prior to storing or setting.

[1] *S. Samiullah and J.R. Roberts, "The eggshell cuticle of the laying hen," World's Poultry Science Journal, Volume 70, Issue 4 December 2014.*

[2] *Seaira Global, " How Does Relative Humidity Affect Your Health?" Seaira Global, NDA, <https://www.seairaglobal.com/blog/humidity-and-dehumidifiers/health-effects-of-humidity.php>*



Hatching in a multi-stage incubator can be problematic… where eggs at different stages of development are incubated and hatched in the same machine. When humidity levels rise above 60%, microbes begin to reproduce. Unless the unit is emptied and sanitized on a frequent, regular basis, the incubator can indeed provide an ideal environment for microbial growth. However, using a separate hatcher eliminates this potential problem. Dedicated hatchers can be cleaned, sanitized, and dried between batches.

NUTRIENTS: Hatching only clean eggs deprives bacteria of the nutrient necessary for ideal reproduction.

Egg yolk is the perfect nutritional medium for rapid microbe growth. In fact, egg yolk has long been used in the production of many vaccines. A wise person, therefore, will not set eggs exposed to egg yolk, even if that egg has been washed.

There are other potential nutrient sources: eggs contaminated with mud, dirt, or feces, dander and gunk from hatching chicks, and cracked, leaking eggs. Establishing sound nest, collection, cleaning, and storage practices helps reduce contamination from mud, dirt, and feces. Hatching in a dedicated hatcher eliminates the gunk and dander from hatching eggs. And, quickly identifying and removing defective and infected eggs decreases instances cracked and leaking eggs.

CAN MICROBES BE TRANSMITTED THROUGH THE AIR INSIDE AN INCUBATOR?

The most common means of transmitted microbes inside the incubator is through physical contact with a contaminated source such as the surface of a bad egg, a spill, or dirty hands. Microbes can travel through the air on small dust and danger; therefore, the incubator should not reside in dusty locations or where birds are maintained. Hatching chicks produce a great deal of airborne fluff, liquids, and gunk… hatching eggs inside an incubator is discouraged. Microbes can also be spread through the air on small water droplets… not a normal occurrence where the humidity is maintained below 60%.

SHOULD WE MAINTAIN A STERILE INCUBATION ENVIRONMENT?

There is absolutely no point in cleaning and sterilizing your eggs if you are then going to put them in an incubator that hasn't also been sterilized.[1]

If we scrub our eggs and remove or severely damage the cuticle, then microbes can easily cross the cuticle, shell, and membrane barriers. In such cases, it is extremely important that we focus on providing the cleanest environment possible; however, sterilizing (completely free of microbes) is not within our means. Even if we follow

[1] *Tim Daniels, "How To Clean Eggs For Incubation," poultrykeeper.com, September 2018*

the sanitization steps perfectly, some living microbes remain behind. Those with cabinet incubators rarely shutdown and sanitize those incubators except for a few times each year.

There are steps that we can take to minimize cross-contamination of eggs while they are inside the incubator:

- ✓ Using an antiseptic soap, lathering the hands for a minimum of 30 seconds prior to handling eggs or equipment that will come into contact with clean eggs.
- ✓ Rewash hands whenever you suspect that they might have touched a contaminated egg or unclean surface.
- ✓ Store eggs in new, paper cartons. If using setting trays, sanitize the trays before each use.
- ✓ For single-stage incubation (one batch), clean and sanitize the incubator after each batch.
- ✓ For multi-stage incubation (multiple batches), hatch in a separate, dedicated hatcher and clean and sanitize the hatcher after each batch.
- ✓ Sanitize setting trays (turner rails) with each new batch and whenever they become soiled.
- ✓ When bad egg is suspected, place your nose near but not touching each egg. Sniff each egg until the culprit is identified. Once identified, deal only with the suspected eggs and wash your hands before touching any other egg.
- ✓ When encountering a leaking or bad egg, remove the bad egg and any eggs contaminated from the leakage, wash your hands, sanitize a fresh setting tray, and transfer the non-affected eggs to the new tray. For desktop turners, remove the eggs from the affected rail, remove the rail, clean and sanitize, replace the rail, and then move the unaffected eggs back to the original rail.
- ✓ Spills, fluids, shell fragments, and other muck that drop onto the metals shelves or incubator bottom should be cleaned and sanitized as soon as discovered. Use dish detergent and water to remove any muck and then sanitize using the same solution and dilution used to clean the hatching eggs. Do not rinse.
- ✓ The cause of any condensation or water pooling within the incubator should be immediately identified and corrected. The affected area should be sanitize using the same solution and dilution used to clean the hatching eggs. Do not rinse.
- ✓ When rotating eggs to even out temperature variations, do not move the individual eggs from one spot to another. Instead pull the entire setting tray, rotate the tray 180°, and place the tray on a different level. For foam desktop incubator, rotate the lid rather than the eggs.
- ✓ **MOST IMPORTANTLY**: Take steps to preserve each egg's cuticle by using the ***least aggressive*** sanitization method that results in a satisfactory level of egg cleanliness.

WHEN TO RINSE, WASH, DIP, OR SPRAY…

INTRODUCTION: Individual beliefs regarding cleaning and sanitizing eggs vary greatly:

- Some feel that wetting an egg should be avoided and it is best to simply discard a dirty egg – Why risk contaminating the entire batch for a single egg?
- Some feel that sanitizing an egg poses a minimum risk and that all eggs are essentially dirty – It makes no sense to place a dirty egg in an environment that promotes bacterial growth.
- Some feel that if you sanitize some, you must sanitize them all – It makes no sense to mix dirty and clean eggs… the clean eggs quickly become contaminated by the dirty ones.
- Some people simply dislike seeing a soiled egg placed in their clean incubator – Incubating an egg with poop on it is absolutely nasty.
- Some take a minimalist approach wiping away soiled portions of the egg with a Clorox wipe – Addressing the biggest problems helps reduce the largest risks.

If all of my hens were consciousness, wiped their feet before they entered the coop, and laid all of their eggs in a nice, clean, dry nest, then I wouldn't have a dilemma… I'd collect my eggs in nice, clean baskets, store them in nice, new cartons, and set them in nice, newly sanitized setting trays. But, not all of my hens are thoughtful. I have some hens that think a pile of leaves under a fir tree makes a better nest than the one in the coop. I have mallard ducks that like to hide their eggs, turkeys that prefer the floor under the poop board, and peahens that think a pile of

poop makes the softest of cushions. I could discard the dirty eggs, but many of those eggs are quite valuable. I could clean and sanitize all eggs, but I believe that even the mildest form of cleansing compromises the cuticle to some extent. Instead, I have chosen a balanced approach addressing each egg individually and striving to the least harm to the cuticle as possible. If I can preserve the cuticle, I believe, then I can maximize the number of eggs incubated while presenting a minimal risk for all eggs.

WARNINGS: There are several warnings that I think are of maximum importance:

WARNING: **GREAT CARE IS REQUIRED WHEN WETTING HATCHING EGG SHELLS**: The hobbyist can easily do greater harm than good. It is especially important to carefully follow the directions of the chosen sanitizer. Overdosing should be avoided, as this may either cover the pores, which could hamper weight loss and gas exchange during incubation, or damage the protective cuticle.[1] Using a strength that is too weak can compromise the cuticle while leaving lethal bacteria behind.

WARNING: **SANITIZING EGGS DOES NOT STERILIZE THE SHELL**: Sanitizers do not kill all bacteria, molds, or viruses; they merely significantly reduce the colony count. Some contaminants remain on the egg shells, are capable of reproducing, and can cause harm given the proper environment. Protecting the cuticle (bloom) remains an important element in preventing contaminants from entering the egg.

WARNING: USE ONLY SOLUTIONS LABELED SAFE FOR HATCHING EGGS: Trials also showed that some products can be very good disinfectants but may have a negative effect on hatchability. Especially those containing a surfactant which creates a nice layer around the egg but prevent the egg from breathing. The pores are closed and the egg may suffocate causing poor hatching results.[2] If the label doesn't mention "hatching eggs," do not use it.

WARNING: **DO NOT SAND OR BUFF**: Sanding and buffing will remove at least part of the cuticle resulting in eggs that are more susceptible to penetration. The sanding process itself may actually grind the bacteria further into the shell. The general rules for sanding, buffing or wiping is that to: never exceed one wipe to remove material on the shell; and don't do it.[3]

WARNING: IMMERSION IS NOT RECOMMENDED: The recommended time of immersion was five minutes and there were many instances when the eggs were left in the tank too long resulting in elevated yolk temperatures and lower hatchability. Leaving them in the disinfectant solution too short a time causes inadequate sanitation. The lack of proper temperature control was another major drawback… In short, immersion dipping proved to be a very ineffective and even harmful procedure for hatching egg sanitation.[4]

WARNING: LIMIT DIPPING TIME LENGTH: The cuticle is not impenetrable and water on the surface of the egg shell can undermine these defenses because water helps bacteria pass through the shell pores into the egg. If the period of contact between egg and water is short, there will be little microbial penetration into the egg. Therefore, it is important to limit the amount of time that the shell is wet. Soaking eggs in water for as little as one to three minutes can allow microbes to penetrate the shell.[5]

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[1] *Gerd de Lange, "Formalin-free hatching egg disinfection: an achievable goal!" White Paper, PAS Reform, 12 January 2012.*

[2] *Luc Ledoux, CID Lines, Ieper, Belgium, "Hatching egg sanitation beyond the myths!" Poultry World, Elsevier Volume 18, No 10. '02*

[3] *Joseph M. Mauldin, Poultry Science, University of Georgia, "Reducing Contamination of Hatching Eggs," Poultry Industry, June 3, 2008.*

[4] *Joseph M. Mauldin, Poultry Science, University of Georgia, "Reducing Contamination of Hatching Eggs," Poultry Industry, June 3, 2008.*

[5] *"Small-Scale Egg Handling – 1," The Poultry Site, 01 November 2009, <http://www.thepoultrysite.com/articles/1548/smallscale-egg-handling-1/>*

WARNING: APPLY THE SANITIZER AS SOON AS POSSIBLE: Failure to apply the sanitizer in a timely manner will give the opportunity to the bacteria to penetrate into the hatching eggs through the pores of the eggshell and thus reaching the shell membrane. Inside the eggs, the microorganisms will not be exposed to the sanitizer anymore and, during the incubation process, they will find the ideal condition to multiply in the egg's interior.[1]

SANITIZING SOLUTIONS: There are numerous sanitizing products on the market labeled for use with hatching eggs… far too many to examine individually. In deciding which to use, examine the product description and label for the following:

1. Is it labeled safe for hatching eggs?
2. Does it effectively sanitize the eggs?
3. Does it leave residual protection on eggs?
4. Is safe for equipment and personnel?
5. Is reasonable in cost?

Hatching egg sanitizing solutions must effectively reduce surface microbes without being toxic to the developing embryo or blocking pores that will prevent transfer of moisture and gases through the shell. Solutions must be gentle on the shell cuticle and should not contain surfactants (soap) which tend to dissolve the cuticle. Product descriptions and labels must clearly outline proper usage and dilution rates. Solutions that have not been adequately researched, specifically labeled for hatching eggs, or possess adequate dosage should be rejected.

COMMONLY USED HOBBYISTS SOLUTIONS:

- **BLEACH**: (5.25% Sodium Hypochlorite) I love bleach and buy it 5 gallons at a time. I use it to sanitize feeders, waters, brooders, stock tanks, etc. I have read that bleach interacts negatively with the shell calcium. However, I found no such comments in the research dealing with hatching eggs. Sodium hypochlorite was used in numerous studies and those studies indicated that bleach was safe and effective when used in the proper dilution. If you decide to use bleach, be sure that it contains no added ingredients such a fragrances or surfactants (soap).
- **BRINSEA EGG SOLUTION**: (Halogen Tertiary Amines) Brinsea's eggs solution seems to have moderate support among hobbyists, is moderately priced, and is labeled for use with hatching eggs. However, I found no research verifying its effectiveness. Those who do not like bleach and do not want to buy a full gallon of a different type of disinfectant, might find it useful.
- **PEROXIDE:** (Hydrogen Peroxide) Consumer peroxide usually comes in a 3% solution but the best peroxide study used a 5% solution; however, some studies also found that a 1.5% solution was safe and effective. Peroxide may interact with the cuticle resulting an increase loss of moisture during incubation. Personally, I'm don't care for the way peroxide smells and interacts with small cuts on my hands; however, research indicates that it is very effective with hatching eggs. Effectiveness reduced by feces exposure. Peroxide does have the tendency to lose potency once opened and when stored in direct sunlight. Do not use bottles that have been opened more than 30-45 days and do not let a bottle sit out uncapped.
- **LISTERINE GOLD**: (Essential Oils: mint, thyme, wintergreen, and eucalyptol) There are studies that indicate Cumin and Oregano are effective hatching egg sanitizers, but no research was found using Listerine's active ingredients. Listerine Gold contains 29.6% alcohol; however, this level is far below concentrations necessary to kill bacteria (40%). While Listerine Gold may be beneficial as an oral product, it is not labeled for use with hatching eggs, has not proven effective against a wide range of microbes, and ***is not recommended*** for use as a hatching egg sanitizer.

[1] *Dr Vincent TURBLIN, Deputy Regional Market Manager, Poultry CEVA Animal Health Asia, "Disinfection of Hatching Eggs Importance and Practical Aspects," CVE, November 2008.*

- **OXINE AH**: (Chlorine Dioxide) Activated Oxine has proven effective against a wide range of microbes and, unlike bleach, does not require rinsing after applications. Unfortunately, the manufacturer, Bio-Cide, makes no such claims concerning Oxine in a non-activated form. Activated Oxine is approved for "SHELL EGGS INTENDED FOR FOOD OR FOOD PRODUCTS" but hatching eggs are not mentioned. Research indicates that Chlorine Dioxide foam may be safe and effective for hatching eggs; however, since the ppm of available Chlorine Dioxide in unactivated Oxine AH is not known, ***this product is not recommended***.
- **TEK-TROL**: (Orthophenol) TEK-Trol, a phenol compound, is not widely used within the hobbyist community perhaps because it can only be purchase in gallon form and costs about $50.00 after shipping. Phenol compounds are mentioned in several studies and Tek-Trol specifically in at least two. Comparatively it is less effective than peroxide but more so than bleach. It is labeled specifically for use with hatching eggs and studies indicate that it is both effective and safe. Personally, I plan to conduct experiments using Tek-Trol both as a hatching egg and incubator sanitizer.

Sanitizer	Ingredients	Maker	Research	Label	Efficacy	Rate
Bleach 5.25%	Sodium Hypochlorite	Generic	Yes	--	Yes	½ oz per gallon
Brinsea Egg Sol.	Hal. Tertiary Amines	Brinsea	**NO**	Yes	**Unknown**	1 ¼ oz per gallon
Peroxide*	Hydrogen Peroxide	Generic	Yes	--	Yes	1.5% solution
Listerine Gold	Essential Oils	Pfizer	**NO**	**NO**	**Unknown**	50:50 solution
Mannah Pro	Natural Enzymes	Mannah	**NO**	Yes	**Unknown**	2 caps per gallon
Oxine AH	Chlorine Dioxide**	Bio-Cide	**NO**	**NO**	**Unknown**	6 ½ oz per gallon
Tek-Trol	Orthophenol	Bio-Tek	Yes	Yes	Yes	½ oz per gallon

** Can cause an increased loss of moisture from the eggs during incubation.*
***Chlorine dioxide reacts with the protein of the egg shell cuticle which neutralizes it before it can effectively attack the microorganism.*[1]

METHOD FOR SANITIZING EGGS IN THE HOME:

- **WASHING**: Washing eggs involves using a detergent (generally dish soap) and a scrubbing action to remove dirt, mud, and feces. While commercial hatcheries have the professional equipment to safely and effectively wash hatching eggs, washing is not a good idea in the home environment. The soap will largely dissolve the cuticle leaving the egg vulnerable to bacteria and it does NOT kill all of the microbes on the shell. The interior egg is the perfect growth medium for microbes and, without a cuticle, microbes can move out of the egg and contaminate nearby eggs. Washing, in my opinion, poses greater risks than potential benefits.
- **IMMERSION**: Immersion eggs involves placing them in a tub of warm sanitizing solution and allowing the solution to seep partially into the shell. If done perfectly, immersion can be more effective than dipping or spraying. However, immersion requires great precision in timing and temperature… something most hobbyists don't achieve on a daily basis. Because lack of precision ultimately causes greater harm than potential benefits, immersion at home is not recommended.
- **DIPPING**: Dipping eggs involves dipping them into a warm sanitizing solution just long enough to coat the entire shell. Dipping is usually more effective than spraying because spraying may leave a portion uncoated. Unfortunately, it also involved placing all eggs in the same container and possibly spreading contamination from a bad egg to the others – remember a sanitizing solution is not 100% effective. If all eggs are free from dirt and feces, then cross-contamination is minimal; it's more of a problem with dirty eggs. Because of this potential risk, I prefer spraying over dipping.
- **SANDING**: Using sandpaper to sand away dried dirt and feces is a common practice. Unfortunately, a person can accidentally damage the cuticle in the process and give microbes a window to enter the egg. Sanding is not something that I would consider… my hands are not that precise.
- **SCRAPING**: Scraping involves using a finger nail to dislodge chunks of feces from an egg. Scraping usually leaves a layer of feces next to the shell so is imperfect; however, there is less risk of damaging the cuticle

[1] *Henry R. Wilson, professor, Dairy and Poultry Sciences Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, "Hatching Egg Sanitation," Engormix, July 15, 2009.*

than sanding. Scraping, in conjunction with rinsing, can remove the vast majority of the feces, provide less nutrients for microbes, and allow better penetration of the sanitizing solution.

- **RINSING**: Rinsing involves placing the egg under a stream of warm water and gently using the thumb to dislodge dirt and feces. The motion should attempt to move the impurity away from the shell and not press it into the shell. As a rule, no single area of the egg should be rubbed more than once else there is an increased likelihood that the cuticle will be damaged. The water should be at least 10°F warmer than the egg, ideally between 105-110°F. No soap or detergent should be used. Once the egg has been rinsed, use a patting motion (no rubbing) and clean paper towels to dry the egg and then set it in a basket to air dry. Never store a wet egg in a sealed container.

- **SPRAYING**: Spraying is my current preferred method for sanitizing eggs. It involves placing eggs in a setting tray small end up, misting with a warm sanitizing solution, flipping the eggs so the large end is up, misting again, and permitting the eggs to dry. No attempt is made to remove any debris on the shell surface. The flipping of the egg ensures that all surfaces are covered. This method is similar to dipping except the eggs are not placed into a common container.

REMINDER: **EVEN WARM WATER RESULTS IN EGG COOLING**: Any concentration of moisture on warm eggshells evaporates, thus cooling the eggs. This lowers the internal pressure, driving contaminants through the pores into the eggs. Many bacteria use moisture as a vehicle to literally swim into eggs.[1]

CHOOSING THE LEAST AGGRESSIVE METHOD FOR INDIVIDUAL EGGS:

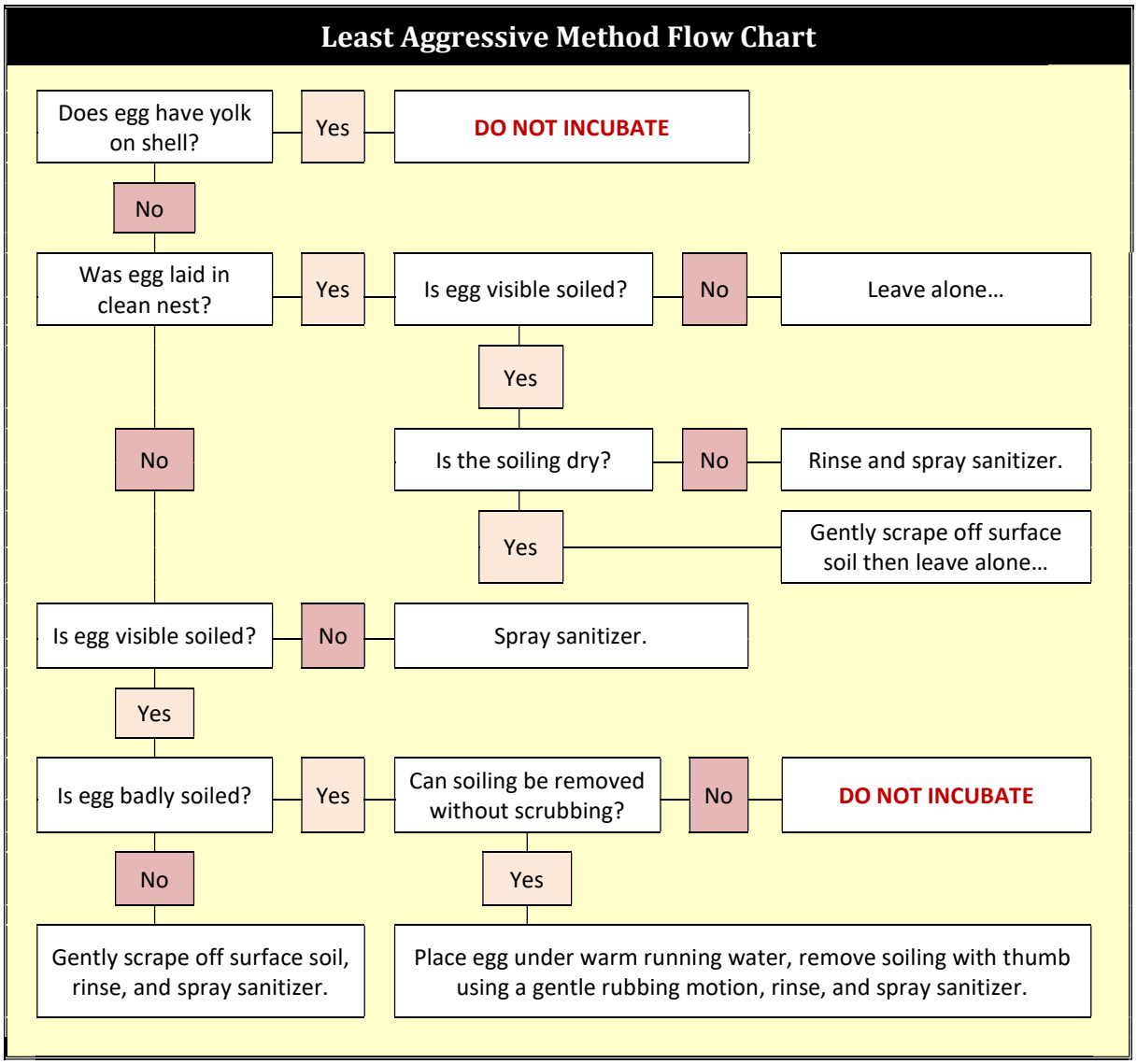
Many people strongly believe in uniformity and that the same method used on one egg should be used on all eggs. There are solid, important reasons for believing this way; however, I take a different path. Instead, I believe in examining the needs of the individual egg and utilizing the least aggressive but effective method for addressing those needs. Some eggs will be left alone. Some will be scraped, rinsed, and sprayed. And some, hopefully only a few, will be discarded. This approach, I believe, minimizes damage to the cuticle while significantly minimizing instances of damage due to internal contamination.

EXAMPLE 1: Weather conditions are dry and Rhode Island White Betty lays her pretty brown eggs in a clean dry nest. Her eggs are free from soilage and fecal matter. Her eggs are collected and stored without intervention.

EXAMPLE 2: Weather conditions are damp and Cream Legbar Lady lays her pretty blue eggs in a clean nesting box but she also poops at the same time she lays. Her eggs are generally clean buy have a small amount of wet feces on the shell. Her eggs are collected in a separate basket, rinsed briefly, sprayed, dried, and then stored.

EXAMPLE 3: Weather conditions are wet and Brown Chinese Gertrude lays her extra-extra-large white eggs in a nest filled with muddy water. Her eggs are coated in mud. Her eggs are placed under warm running water, a gentle rubbing motion is used to remove the mud, it is rinsed, sprayed with sanitizer, dried, and then stored.

[1] *Sue Ann Hubbard, D.V.M. Poultry Specialist, College of Veterinary Medicine, "Keys to Successful Handling of Hatching Eggs," Issue 1638, Mississippi State University, 2002.*



THINGS TO REMEMBER WHEN SANITIZING EGGS:

1. **WASH HANDS FREQUENTLY**: Using an antiseptic soap, lathering the hands for a minimum of 30 seconds prior to handling eggs or equipment that will come into contact with clean eggs. Rewash hands whenever you suspect that they might have touched an unclean surface.
2. **SANITIZE AS SOON AS POSSIBLE**: Under ideal conditions, microbes begin reproducing as soon as the encounter the egg. The sooner the sanitizing solution can be applied, the lower the microbe population both before and after sanitizing.
3. **PRODUCT LABEL**: Carefully read and follow the instructions on the product label. Using too strong a concentration can block the pores and damage the fragile embryo. Using too weak of a solution allows dangerous microbes to remain.
4. **SOLUTION TEMPERATURE**: The sanitizing solution should be at least 10°F warmer than the egg, ideally 105-110°F. This will reduce the effects of negative pressure and lessen the number of microbes moving into the interior of the shell.

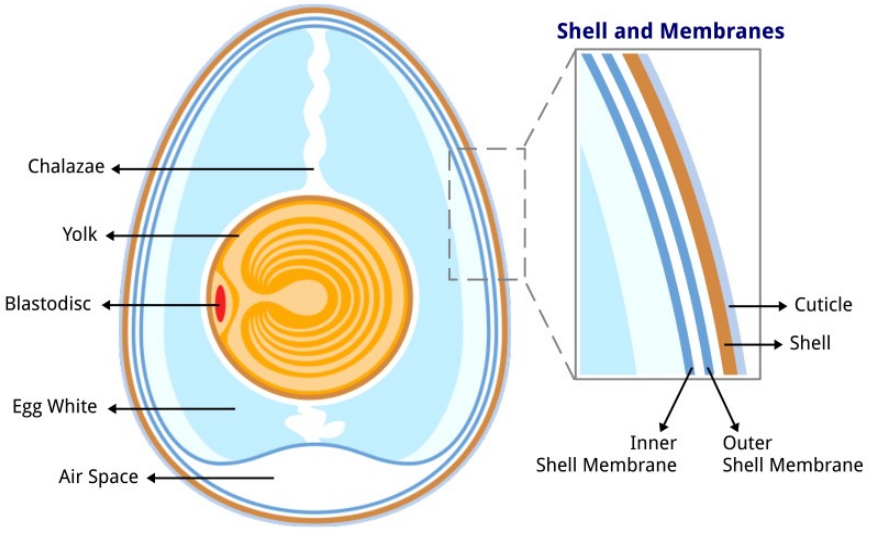
***WARMING SANITIZERS**: For solutions that do not require dilution, pour the amount needed into a separate, clean bottle and place in the incubator 4-6 hours prior to use. Discard any solution that remains after treatment.*

5. **DISTILLED WATER**: For best results, use distilled or filtered water in areas where dissolved solids exceed label recommendations or creates a layer of film on the egg shell.
6. **ALLOW COLD EGGS TO WARM**: During cold weather, allow eggs to reach room temperature prior to sanitizing to prevent condensation forming. Condensation dilutes the sanitizer strength and slows drying time.
7. **DOUBLE-CHECK COVERAGE**: When spraying sanitizer, be sure all surfaces are covered paying particular attention to the bottom of the eggs.
8. **DO NOT RINSE**: Sanitizers labeled for use with hatching eggs provide additional protection once the solution dries; rinsing eliminates this additional protection. Products labeled for use with hatching eggs have been tested and the dried film does not harm the embryo.
9. **ALLOW EGGS TO DRY COMPLETELY BEFORE STORING OR SETTING**: Remember, sanitizers only reduce the microbe population, they do not eliminate them. Microbes will continue to grow as long as there is warmth, moisture, and nutrients. Allowing the eggs to dry completely before storing or setting, robs the microbes of the necessary moisture for reproduction.

When the egg is laid its temperature is slightly less than the hen's body temperature, approximately 40°C (104.0°F). It will take the egg 4-6 hours (depending on the external temperature) to attain ambient temperature. It is during this period that the air cell is created and that eggs should be disinfected.[1]

EFFECT OF EGG STORAGE UPON SHELL SURFACE CONTAMINATION[2]			
	Day 1 of Storage	Day 7 of Storage	Day 14 of Storage
Number of Bacteria/Egg	154,446	254,228	310,444

TOTAL BACTERIA COLONIES ON SHELL SURFACE[3]		
Non-Sanitized Controls	Inadequate Misting	Thorough Coverage with Sanitizer
121,263 colonies/egg	43,830 colonies/egg	331 colonies/egg



[1] *"Incubation Guide," Hubbard Breeders, NDA, pg. 12.*

[2] *Michael Wineland, Extension Poultry Specialist, "Spray Sanitizing Hatching Eggs," North Carolina State University. 6/96, PS Facts #23.*

[3] *Michael Wineland, Extension Poultry Specialist, "Spray Sanitizing Hatching Eggs," North Carolina State University. 6/96, PS Facts #23.*

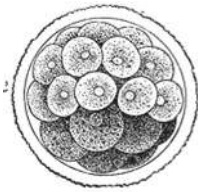
Anatomy of an Egg

https://en.wikipedia.org/wiki/Eggshell#/media/File:Anatomy_of_an_egg_labeled.jpg

Storage: Extended

- **QUESTION**: How long can I safely store my hatching eggs before setting them in the incubator?
- **BEST ANSWER**: Seven days when stored below 68°F in new cartons (10 days at the most) tilting the eggs 45° to the left or right once a day. That answer is the best answer; however, the best answer may not necessarily be the only correct answer.
- **OBSERVATION**: It can easily take a broody chicken 14 days to lay a clutch of eggs… my turkeys take about 16 days, and my mallard ducks up to 21. Under ideal conditions, those hens do a pretty good job hatching those eggs. What do they know that we don't? Perhaps an egg is designed to last longer than 7 days?

- **BENEFITS OF EXTENDED STORAGE**: I have only a small number of hens for some breed and species; however, I don't like brooding mixed batches, e.g. mallard ducks and bantams. I prefer to incubate and brood in batches larger than what a 7 day period can provide. Therefore, I routinely collect for 15 days.
- **EMBRYO DEVELOPMENT**: The embryo starts to develop within five hours of fertilization inside the hen and this development continues for approximately 11 hours.[1] By the time the egg is laid, the embryo consists of approximately 60,000 cells.[2] Personal observation reveals that turkey and duck hens often remain in the nest for 3 to 4 hours after laying a fresh egg possibly extending this initial developmental period. Experiments with pre-incubation, heating the egg to incubation temperature before storage, increases the hatch rates by 4.1%.



It may not be wise to gather hatching eggs as soon as they are laid but rather allow the egg to naturally cool before collecting and storing. When hens share the same nest, this additional heating pre-incubates the eggs and can be beneficial.

- **PHYSIOLOGICAL ZERO**: Physiological zero – the temperature where the embryo stops developing – is 68.9°.[3] Storing eggs above 69° allows the embryo to continue to grow and can lead to an extended hatch window – chicks hatch at different times.

  It may not be wise to store hatching eggs on the counter in your kitchen or other similar warm places. Since the hatch window is one of the most important tools in evaluating a hatch, we should strive to make that window as small as possible.
- **COST OF STORAGE**: Once an egg is stored, embryonic cells begin to die, the egg's chemical makeup changes, and the egg begins to deteriorate: (a) one day's storage adds one hour to incubation time, (b) after the initial six-day period, expect a loss of 0.5 to 1.5% per day with the percent increasing as storage extends, and (c) chick quality will be affected from eggs that have been stored for 14 days or more.[4] There is a cost to storing eggs beyond six days even if they are stored under optimal conditions.

- **STORAGE TEMPERATURE**: Cooler temperatures minimize the negative impact storage has on the egg. The longer the egg is stored, the cooler the temperature should be. Eggs stored for less than 7 days should be held at 61-63°F, while eggs stored longer than 7 days should be held at 50-54°F.[5]

  Backyard hobbyist rarely has the facilities to store eggs at different temperatures and, therefore, might do well by selecting a medium range. Household refrigerators rarely have settings that within the acceptable range and usually require an external thermostat ($15.00 on Amazon).

[1] *"Incubation Guide," Hubbard Breeders, NDA, pg. 12.*
[2] *Jacob Hamidu, "Biological Factors Affecting Poultry Embryo Quality," University of Alberta, 2011.*
[3] *"Egg storage: good practices," Petersime, 2017, http://www.petersime.com/hatchery-development-department/egg-storage/*
[4] *"Hatchery Management Guide," Cobb Hatcheries, 2008, pg. 7.*
[5] *Jacob Hamidu, "Biological Factors Affecting Poultry Embryo Quality," University of Alberta, 2011.*

- **STORAGE HUMIDITY**: During storage, moisture is lost through the egg shell into the atmosphere. If humidity levels in the air are high, less moisture will be drawn from the egg. Therefore, a relative humidity target of 75-80% is required to prevent eggs from losing too much moisture before incubation starts.[1]

  Eggs stored in an open container on the kitchen counter may not be a good idea as older eggs become drier than newer eggs complicating humidity settings during incubation.

  > Just like inside an incubator, humidity for egg storage should be monitored using a calibrated hygrometer. Humidity levels are controlled by water surface area. If the humidity is too high, use a smaller bowl. If the humidity is too low, use a larger bowl.

- **SWEATING**: Set a glass of ice water on the counter and water will form on the outside of the glass – condensation. Moving eggs from a cool environment to a warm one will cause condensation. Condensation on hatching eggs is a really bad thing as it provides a moist environment for mold and bacteria development.
  - Use great care when moving eggs from cool environments (a cold hen house) to a warm environment (the kitchen counter).
- **PRACTICE**: Understanding the risks of storing eggs for more than seven days, the following storage practice is designed to minimize the harms of storage while allowing larger, more efficient batches:
  1. Collect eggs daily (more frequently in cold or hot weather) bring them inside and allow them to rest and cool/warm for 3-4 hours.
  2. Using a small fridge controlled by an external thermostat or a wine cooler, refrigerate the eggs at 58-59° F with the humidity between 70-80%.
  3. Store the eggs in new, paper cartons – one breed or species for each carton with the large end up. Once a carton is filled, begin tilting the cartons 45° to the left or right on a daily basis.
  4. 24 hours before setting, remove the eggs, set them in an incubation tray, and wrap them in a large towel allowing them to warm to room temperature.

- **USING A REGULAR REFRIGERATOR**: The temperature within a regular kitchen refrigerator is usually too cold and has had a significant negative impact on my hatch rate, as much as a 20% decrease.

Duration and conditions for storage *Hubbard Hatchery Management Guide*

	Period of storage						
	1-2 days	3-4 days	5-6 days	7-8 days	9-12 days	13-16 days	17-20 days
Temperature	19.0°C (66.2°F)	17.0°C (62.6°F)	15.5°C (59.9°F)	14.0°C (57.2°F)	12.5°C (54.5°F)	12.0°C (53.6°F)	11.5°C (52.7°F)
Relative Humidity (%)	70.0	80.0	85.0	90.0	90.0	90.0	90.0
Turning	No	No	No	No	Yes	Yes	Yes
Small end up	No	No	No	No	No	Yes	Yes
Bagging	No	No	No	No	No	Yes	Yes

- **STORING EGGS POINTY END UP**: Tradition dictates that hatching eggs should be stored with the pointy end facing down; however, there is evidence demonstrating this practice may limited for longer storage periods.
  - Dr. Anthony Macharia King'ori, Egerton University, 2011, "Eggs stored with the small end up have higher hatchability as compared to the large end up."
  - J.C.S. de Lima, Federal University of Uberlândia, 2012,"Storing eggs with the small end up is an alternative method to improve hatchability and to reduce egg weight and hatchling weight losses in eggs derived from young and old breeders stored up to 14 days."
  - O. Elibol, University of Ankara, 2008, "the detrimental effects of a long storage period may be practically ameliorated by either storage in the SEU position or by an increased turning frequency during subsequent incubation."

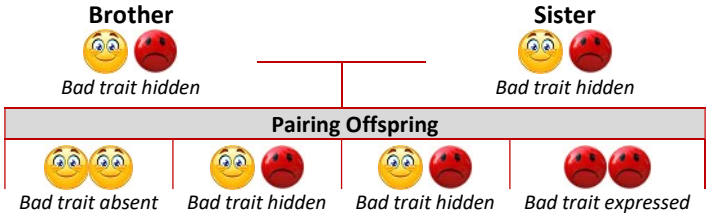
[1] *"Egg storage: good practices," Petersime, 2017, http://www.petersime.com/hatchery-development-department/egg-storage/*

- Dr. Inge van Roovert-Reijrink, Senior Researcher at HatchTech, 2011, "the decline in hatchability can be reduced by 15% when eggs are stored in the small end up position instead of the large end up position."

Genetics: Inbreeding

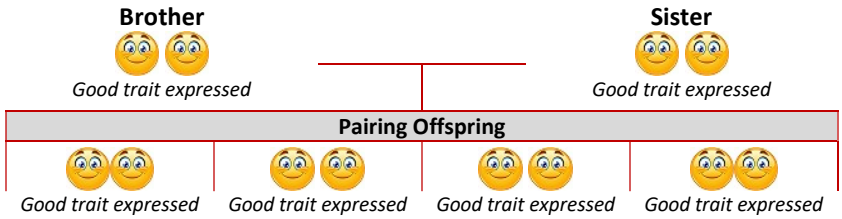
The term "inbreeding" is frequently considered taboo… something repulsive, forbidden, particularly offensive… an act that creates horribly disfigured monsters. Yet, 20% of marriages around the world are between first cousins – Charles Darwin and Albert Einstein both married first cousins.[1] In poultry, line-breeding (organized inbreeding) has long been used in husbandry to create new breeds, improve exhibition qualities, and improve livestock uniformity, vigor, and productivity.[2] When used haphazardly, inbreeding can have undesirable results; however, when used cautiously, it can be beneficial.

- **A FEW STATISTICS**:
  1. Some 90% of the genetic diversity in chickens has been lost since domestication. Loss of diversity means that modern chickens are less able to adapt to environmental changes and disease evolution. This is not a significant problem in managed flocks with adequate care and housing.
  2. Some 10% of the genetic material within modern chicken breeds is identical and this percent increases to 15% within commercial breeding industry… they are more closely related than aunts and nieces in a typical human population – 12.5%.[3] In simple terms, finding breeding stock that is completely unrelated is not possible.
  3. Many believe that mating siblings (brother and sister) is much more intense that parent-child (father-daughter or mother-son); however, the inbreeding coefficient (F1 25%) and the cumulative effect (F5 67.19%) are the identical.[4]
  4. Experiments of the early 20th century frequently demonstrated rapid inbreeding resulted in a significant loss in hatchability, viability, and productivity. However, those experiments were flawed because "they were developed primarily to illuminate the process of inbreeding and not for the express purpose of obtaining viable highly inbred lines." Other experiments resulted in viable lines for up to 22 generations at levels up to 95%.[5]
- **GENETIC DIVERSITY**: In sexual reproduction, two parents contribute genetic information to produce unique offspring allowing a species to adapt to changes in weather, disease, parasites, and food supply. Through the blending of genetic material, the chance that an offspring will inherit an unfavorable trait is reduced by half; and of those unfavorable traits inherited, many are masked by a more dominant gene. Unfortunately, diversity is the adversary to poultry breeders… diversity dilutes desirable traits such as uniformity, body type, and color.
- **DRAWBACKS**: The act of inbreeding does not create bad genes or bad traits – the genes themselves do not mutate (transform). Rather, since closely related birds share many of the same genetic alleles (markers), inbreeding increases the odds that two undesirable, recessive (hidden) alleles will be paired allowing the undesirable trait to be expressed (unmasked)…. traits such as micromelia, dwarfism, crossed beak, crooked toes, and others. Considering the thousands of alleles involved, managing these possible flaws can be difficult.



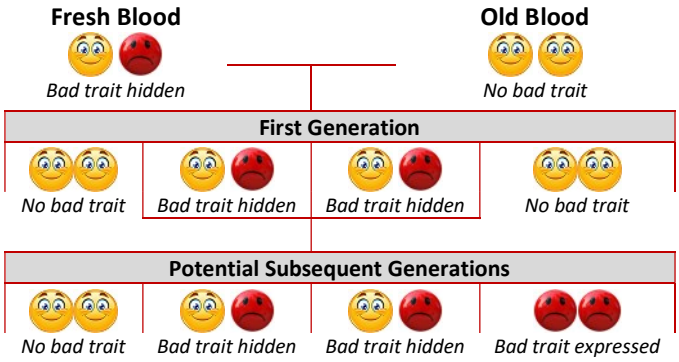
- **BENEFITS**: Conversely, desirable traits are also controlled primarily through genetic selection. The best way to replicate desirable traits is to pass the genes responsible for those traits down to the offspring. Naturally, if both parents share the same traits, odds are great that the offspring will also possess those traits.

[1] *William Saletan,"What's wrong with marrying your cousin?," Slate, Apr. 10, 2002.*
[2] *L.E. Keyser, "Standard Poultry and the Making of the Breeds," Poultry Success, 1950, page 12*
[3] *Debora MacKenzie, "Chicken genome plucked bare by inbreeding," New Scientists, 4 November 2008.*
[4] *Douglas Tave, "Inbreeding and brood stock management," Food and Agriculture Organization of the United Nations, Rome, 1999*
[5] *Dr. Hans Abplanalp, et. al. "Inbreeding For The Genetic Analysis And Improvement Of Poultry Populations," University of California, Poultry Science, 1973*



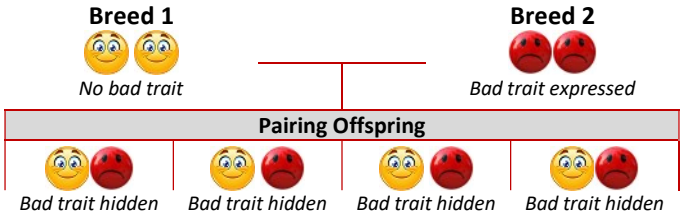
Utilizing a closed flock system with standard Bronze turkeys over a four year period, I was able to increase the hatch rate for all eggs set from 82.4% to 91.0% while concurrently reducing the cull rate from 8.4% to 0.7% and the juvenile loss from 20% to 0%.

- **OUTCROSSING**: Outcrossing involves bringing in "fresh blood" in order to improve genetic diversity and avoid the effects of inbreeding. Outcrossing may be necessary if there becomes a problem inbreeding depression. However, bringing in "fresh blood" can also be problematic. Since many genetic traits are recessive (hidden), the "perfect" appearing male may very well introduce a number of undesirable, hidden traits into the flock… many of those traits may not physically appear until the second generation and may be especially difficult to eliminate completely once they enter a flock.



Fearing inbreeding depression, I once introduced new drakes to my mallard flock to "freshen" the blood. Unfortunately, one of those drakes possessed a recessive crested gene and 10% of the ducklings hatched during the subsequent year were crested. Apparently, one or more of my hens also had the recessive gene. While some love crested ducks, it's an undesirable trait in ranch pond ducks – my target customer base.

- **HYBRID VIGOR**: A hybrid is the offspring of two plants or animals of different species, varieties, or breeds. The hybrid vigor phenomenon has been used in both plants and animals to increase fertility, hatchability, offspring vigor, and both quantity and quality of production (meat or eggs). Technically, breeding two genetically dissimilar parents greatly increases the odds that an undesirable, recessive (hidden) allele will be paired with a more desirable, dominant allele causing the undesirable trait to be masked (concealed). Since this can occur across multiple systems, the production results can be significant. Within the backyard poultry world, the sex-link is the most common hybrid that can be sexed at hatch as well as demonstrate increased productivity.

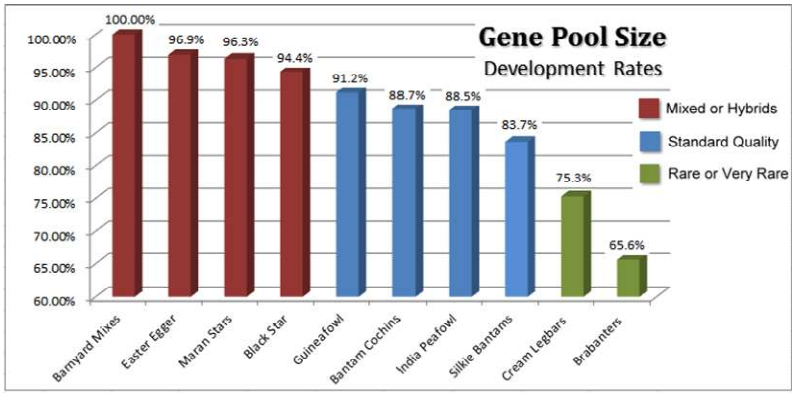


- **INBREEDING DEPRESSION**: Inbreeding depression is similar in nature to hybrid vigor but with opposite effects. It occurs primarily in "exhibition quality" stock or rare breeds with an extremely small genetic pool. Inbreeding depression results in an increase in chick deformities and a decrease in fertility, hatchability, vigor, and both quantity and quality of production.

How much inbreeding is too much? Opinions vary with much depending on the size of the breed gene pool, relationship of the original breeding stock, intensity of inbreeding, and the diligence of culling efforts. Careful monitoring of fertility rates, hatch rates, chick quality, instances of defects, and adult productivity will reveal when the intensity reaches unacceptable levels. With a carefully considered, systemic approach, close breeding has been effective to multiple generations.

Inbreeding Coefficient for Related Pair Matings[1]	
Full siblings, Parent-child, Double first cousins	25%
Half siblings, Grandparent-grandchild, Uncle-niece, Double first cousins	12.5%
First cousins	6.25%
Half cousins	3.13%
Second cousins	1.56%
Half-Second cousins	0.78%
Third cousins	0.39%
Shoffner, 1948, found that for every 10% increase in the inbreeding coefficient, chickens lost an average of 4.36% in egg hatchability and a 9.26% eggs per year decrease in production.	

Cumulative Inbreeding Coefficient[2]				
Generation	Parent-offspring	Full-siblings	Half-siblings	Double first cousin
0	0.00	0.00	0.00	0.00
1	25.00	25.00	12.50	12.50
2	37.50	37.50	25.00	18.75
3	50.00	50.00	34.38	25.00
4	59.38	59.38	42.97	31.25
5	67.19	67.19	50.39	36.72
6	73.44	73.44	56.84	41.80
7	78.52	78.52	62.45	46.48
8	82.62	82.62	67.23	50.78
9	85.94	85.94	71.58	54.74
10	88.62	88.62	75.28	58.37
∞	100	100	100	100



- **FURTHER READING**:
  1. "Line Breeding, Inbreeding & Outcrossing," *The Classroom @ The Coop,* http://www.the-coop.org/forums/ubbthreads.php?ubb=showflat&Number= 28027
  2. "Line Breeding via a Spiral Breeding Program," *Iowa Blue Chicken Club*, http://www.iowabluechickenclub.com/line-breeding-via-spiral-breeding-program.html
  3. Heather Nicholson, "GMS6: Sex-Linkage," scratch cradle, August 5, 2012.https://scratchcradle.wordpress.com/2012/08/05/gms6-sex-linkage/

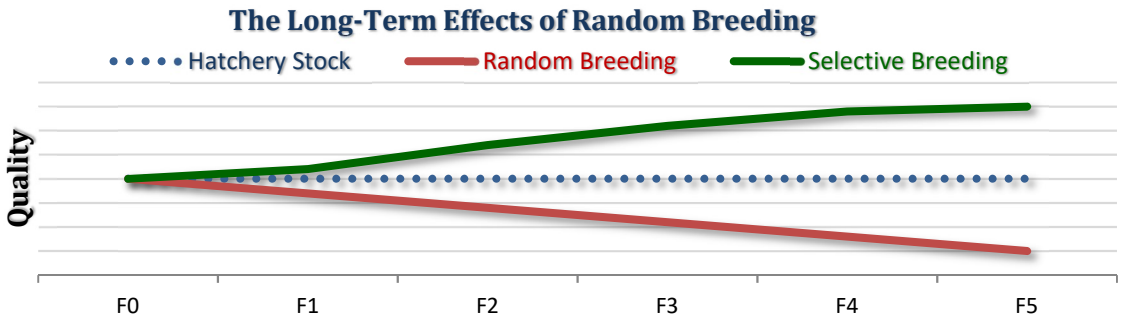
[1] *F. M. Lancaster, "The Coefficient Of Inbreeding (F) and Its Applications," Genetic and Quantitative Aspects of Genealogy, February 2015*
[2] *Douglas Tave, "Inbreeding and brood stock management," Food and Agriculture Organization of the United Nations, Rome, 1999*

Genetics: Selective Breeding

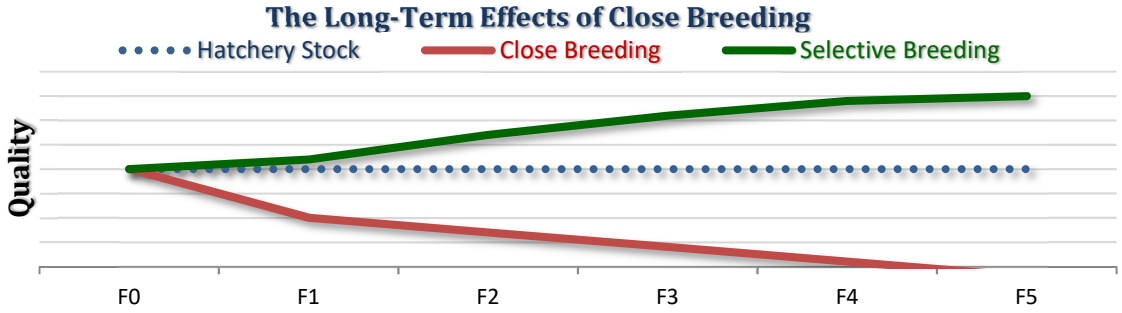
Your fowl are either improving or degenerating with each passing generation. Selective breeding is the only means whereby a flock can be improved… if not, then they are multipliers and not breeders.

-- Dr. Charles R.H. Everett[1]

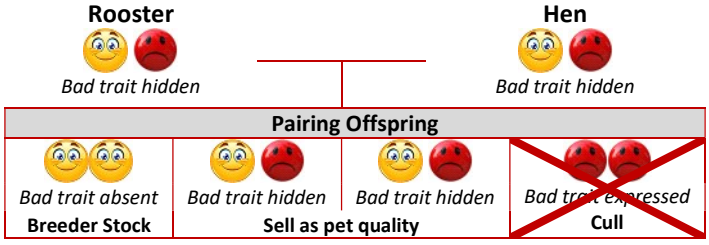
RANDOM BREEDING: Each of us has an inherent instinct to cultivate crops and husband livestock. It's in our nature… it's what separates us from the animals… it's what permitted us to establish permanent settlements and civilizations. Yet, advances in agricultural practices have removed most of us from the land. For those of who have discovered (or rediscovered) the joys of raising poultry, incubating and hatching eggs helps fulfill this natural inclination. However, city folk turned country folk are not privy to poultry breeding secrets once handed down from generation to generation; but rather, must acquire those secrets through books and personal experience. While our nurturing nature encourages us to save every chick we hatch, doing so is an unhealthy practice that leads to a decline in our flock quality:



SMALL GENE POOLS: If our original stock originate from small genetic pools or we allow unrestrained breeding of close relatives, then flock decline will proceed at a more rapid pace. This sharp quality reduction probably accounts for the reluctance of many to incorporate line breeding into their breeding programs:



WHAT IS SELECTIVE BREEDING? Selective breeding (artificial selection) is the process by which humans use animal breeding and plant breeding to selectively develop particular phenotypic (displayed) traits by choosing which typically animal or plant males and females will sexually reproduce and have offspring together.[2] Within a commercial setting, selective breeding involves a great of money, time, and science. Within the backyard setting, selective breeding involves simply producing offspring from the best of one's flock. For the hobbyist, selective breeding means focusing on quality rather than quantity.



[1] *Dr. Charles R.H. Everett, Selective Breeding: How to Breed Chickens," Countryside Daily, December 5, 2016*
[2] *"Selective breeding," Wikipedia, 16 October 2017, https://en.wikipedia.org/wiki/Selective_breeding*

STEP 1: DETERMINE YOUR PURPOSE FOR BREEDING:

Once we realize that placing eggs in the incubator results baby hatchlings, then we realize that we'll need to do something with all those hatchlings… some will hatch to show their birds, others to make a little money, others to replenish their flock, and still others just to give them away. Since everybody will have a different focus, there is no single "best" way of doing things.

Personally, I don't care to leave our little farm so breeding birds for exhibition is not for me. I also do not cook and my wife doesn't care for home grown meat so meat production is simply not a consideration. I do enjoy a bold, pretty bird pecking around in the yard. I also like producing eggs for the lowest possible cost, and I need a way to pay the feed bill so my three main points of focus are (1) pets, (2) eggs, and (3) hatchery stock. Determining your purpose will determine which path will work best for you.

Purposes for Breeding and Hatching

Pet	Exhibition	Eggs	Dual	Hatchery
Focus on appearance and personality.	Focus on breed standards for show or exhibition.	Focus on egg quantity, quality, and size.	Focus on egg and meat production for consumption.	Focus on reproduction for commercial sales.

STEP 2: SOURCE YOUR ORIGINAL FLOCK:

- **AUCTIONS**: In my opinion, a person should never purchase birds from an auction. There is rarely an opportunity to view the parent stock or evaluate flock health issues and auction birds can be a dangerous source of parasites and disease. Birds sold in auction are rarely of high quality and are usually rejects or extras. Additionally, unscrupulous dealers frequently travel about the countryside buying birds from various sources with the purpose of a profit…. quality or sanitation is not a priority When obtaining birds from an auction, use extreme care and isolate them for no less than 30 days.

- **HATCHERIES**: Acquiring your original flock from a large hatchery is advantageous because chicks are relatively cheap and usually have a great deal of genetic diversity. Unfortunately, hatcheries focus on production rather than quality. Some hatcheries claim to offer "show or "4-H" quality birds but the actual quality of these birds is questionable. Hatchery birds are unlikely ever to produce exhibition quality offspring even after several generations of selective breeding. They can, however, result in good quality pet and production flocks through selective breeding.
- **RECOGNIZED BREEDERS**: Acquiring your original flock from nationally recognized breeders is advantageous because chicks are likely to be of high quality and conform to American Poultry Association or American Bantam Association standards. Unfortunately, they are likely to be expensive, especially those of exhibition quality. Additionally, birds from recognized breeders more than likely closely related and originate from small gene pools. For best results, either ask specifically for unrelated birds or use two or more sources.
- **LOCAL BREEDERS**: Acquiring your original flock from local breeders is advantageous because you can physically view the parents, assess quality, tour facilities, and visit with the breeder giving you a source of information should questions arise. Unfortunately, although there are some excellent local breeders, many are focused on making a quick dollar and not quality – use great caution and isolate birds for no less than 30 days. Remember, the stock you acquire from local breeders will likely be related and unlikely to be their very best; spend time talking with the breeder so you'll understand how they the select birds they sell… ask for unrelated birds or acquire your flock from two or more sources.
- **SHIPPED EGGS**: Acquiring your original flock from shipped eggs is advantageous because you have access to just about any breed. Unfortunately, you have no control over quality, health, or genetic lines. Seller reviews may be helpful but are not always accurate. I ordered eggs from an on-line seller with a 100% rating, but the eggs sent were old and genetically mixed. Additionally, shipped eggs do not always perform well in the incubator. A friend in Oklahoma sent a dozen Icelandic eggs through the mail, they were packed extremely well, but none developed when incubated. Buying eggs through the mail can be fun but it's not a route that I would take in adding a line to my flock.

STEP 3: SELECTING YOUR BREED STOCK:

- **INITIAL QUANTITIES**: Regardless of the route used to acquire your original stock, always buy several more hatchlings than you intend to keep. As a general rule, I keep about 15-25% of the hatchlings purchased. Of the remaining balance, defective birds are culled and the rest sold as "pet" quality. Many are reluctant to reduce their flock so drastically because of their financial investment. However, it is one of those "Pay me now or pay me later" scenarios… the more selective you are at the start, the fewer culls you will have in the future.

For those with limited funds and who are not focused on exhibition, hatcheries place specific breeds on sale towards mid-summer and into the fall. At the time of this writing, Ideal Poultry has straight-run Buff Orpingtons on sale for $1.20 each with the purchase of 25 or more. For $48.00 and $7.00 shipping, you'd get 40 chicks that should give you a decent start – two good cockerels and six good pullets. By selling the "pet quality" birds you'll recover most of your original investment and perhaps earn a few extra dollars. Again, you'll not get exhibition quality chicks from a hatchery, but hatcheries can provide an avenue for starting a decent production or pet quality program.

Wouldn't it be easier and cheaper in the long-term to simply buy from a reputable breeder? Yes, probably but not necessarily. First, breeders are unlikely to sell the best of their best. You're more likely to get chicks straight out of the hatcher so not all the chicks are select quality. Second, unless the breeder is exceptionally large, the chicks likely have a small gene pool and may experience inbreeding depression. Ultimately, you'll need to purchase from two different breeders or, at minimum, two different lines… both avenues require purchasing extra birds. Third, birds from recognized breeders are usually 10 times more expensive than those from a hatchery. This additional cost may be prohibitive to a person with limited financial resources especially where potential predator problems add to the financial risk.

- **SELECTION CRITERIA**:

1. **QUALITY #1: EGG QUALITY**: To produce healthy, vigorous chicks we not only need good genetics, we also need high quality eggs… the quality of an egg's content directly impacts the quality of the chick hatched. Egg shape, color, texture, and size help indicate which eggs are suitable for incubation and which are not. Discolored, misshaped, roughly textured, and unusually large or small eggs all indicate that something is not quit right and that perhaps the egg would be more suitable for eating. Additionally, eggs laid on the ground, in dirty nests, or otherwise potentially contaminated should be avoided as infections may not necessarily kill the chick but will certainly compromise its quality.
2. **QUALITY #2: VIGOR & DEVELOPMENT**: Many backyard hobbyist form an emotional attachment to their chicks and adopt will attempt to "save" chicks that are struggling. Many claim that these weak chicks grow up to be just as "good" as those that don't display a problem. This approach, I believe, is a mistake. Lack of vigor and development are signs that there is heredity, immunity, or developmental issues that should not be passed on to future generations. Some people set these chicks aside and sell them as "pet quality." Personally, I'm reluctant to less vigorous chicks because I wouldn't want someone selling me a "defective" chick.

    - **ASSISTING HATCHLINGS**: I do not assist hatchling hatch. Once you've established a solid incubation protocol – temperature, humidity, and turning – then chicks that do not hatch under their own strength demonstrate a heredity, immunity, or developmental issue.

    > *A chick's failure to progress normally at hatching stage can be caused by genetic problems resulting in malpositioning, deformities or weakness, in which case assistance may promote the survival of birds with deleterious genes.*[1] *Debra Bourne MA VetMB PhD MRCVS*

[1] *Debra Bourne MA VetMB PhD MRCVS, Senior Veterinary Editor, Wildlife Information Network, "Management of Hatching Bird Eggs," Wildpro, NDA.*

- **21 DAYS OF INCUBATION**: I end my hatches at the end of day 21. Once you've established a solid incubation protocol – temperature, humidity, and turning – chicks should begin to hatch at the start of Day 21 and finish hatching no later than the end of Day 21. There are exceptions… some breeds, such as Marans and game fowl, may require an additional 6-12 hours of incubation. In such cases, I'll add the specific number of hours to the end of Day 21. Chicks that do not hatch within set limits possess heredity, immunity, or developmental issues and should be culled.
- **BROODER VIGOR**: Hatchlings should be up, running around, eating and drinking 24 hours after hatch – turkeys and a few other species may take 48 hours. With careful observation, chicks that are weak or slow to start can be identified and removed – quality over quantity.

> *The constitutional vigor or vitality of a chick determines its capacity for growth... the majority of evidence indicates that constitution is fundamentally a matter of inheritance and initial selection is, therefore, of considerable importance.*[1] *L. E. Card and W. F. Kirkpatrick, 1919*

- **PHYSICAL DEFECTS**: When moving chicks from the hatcher to the brooder, they should be carefully checked for physical defects such as splayed legs, crooked toe, wry neck, abnormal size, scissor or parrot beak, exposed organs including the yolk sac, or other defects. Some of these defects are not noticeable at first but will become more readily apparent as the chick grows. Again, some people are tempted to "save" or "fix" chicks with physical defects. Within any selective breeding program, we need to remember that there is a reason that these defects occur and keeping these chicks in our flock is an unhealthy practice.

> *Most malformed chicks have a poor chance of becoming healthy, productive members of a backyard flock. Many, but not all chick malformations can be inherited traits, so malformed chicks who survive should not be used for breeding because they can pass on the trait to future generations. For these reasons, euthanizing a malformed chick is justifiable, if done humanely.*[2]
>
> *Julie Gauthier and Rob Ludlow, Raising Chickens*

- **ILLNESS**: A sick bird indicates either poor management practices by the breeder or a weak immunity system within the bird. If an illness is caused by poor management, then correct the problem. If an illness is caused by a weak immunity system, then do not use the bird forbreeding. This criterion is especially important when the original stock comes from a different geographical location… the genetics of a bird may be well suited for the bugs in the Northeast United States but unsuitable for the Southwest. Use of antibiotics and home remedies may cure the individual bird but it does not fix a less than perfect immune system. Selecting only those birds that demonstrate resistance to the bugs in your area should be of primary importance.

> *Here in East Texas, young turkey poults have a high mortality rate when placed on ground where older birds reside. Raising poults in raised pens or fresh ground allows their immune system to mature before they face the onslaught of microbes hiding in the ground… but such management practices are only partially effective. Mortality among juvenile birds remains significant. But by using only birds that demonstrate a strong resistance to local microbes, subsequent generations display greater resistance and lower mortality than the original flock.*

3. **QUALITY #3: DEVELOPMENT & PRODUCTIVITY**: The Livestock Conservancy produces the publication *The Heritage Chicken Manual* that outlines recommendations desirable production traits in chickens and provides more information than can reasonably be presented here. Digital copies are available on-line at: https://livestockconservancy.org/index.php/heritage/internal/chicken-manual.
   - ✓ Chapter 1. Selecting for Meat Qualities and Rate of Growth
   - ✓ Chapter 2. Selecting for Egg Production
   - ✓ Chapter 3. Ongoing Selection of Breeding Stock

[1] *L. E. Card and W. F. Kirkpatrick, "Improved, Profitable rearing Methods," Poultry Herald, Volumes 31-32, page 207, 1919*
[2] *Julie Gauthier, Rob Ludlow, "How To Spot Problems Of Newly Hatched Chicks," Raising Chickens, NDA, http://www.dummies.com/home-garden/hobby-farming/raising-chickens/how-to-spot-problems-of-newly-hatched-chicks/*

4. **QUALITY #4: CONFORMITY TO APA BREED STANDARDS**: While not all breeders chose to exhibit their birds, established breed standards provide an excellent source as to each breed's expected appearance. These standards can be found in The American Poultry Association's *Standard of Perfection* and American Bantam Association's *Bantam Standard*.

STEP 4: DETERMINING YOUR BREEDING METHOD: Please remember that I keep a total of about 150 adult birds but that number consists of several different breeds and species. My practices discussed in the *text boxes* below do ***NOT*** reflect best practices but illustrate compromises a backyard hobbyist with limited resources may adopt.

- **FLOCK**: (Closed Flock) All breeding birds are located in a single pen and allowed to mate freely. Each cycle the best males and females are selected as replacements. No new birds are introduced into the system. This method is the simplest to maintain. The number of generations a flock is able to attain without experiencing inbreeding depression depends on the flock size – most sources tend to recommend a flock of no less than 100 for reasonable sustainability. Flock breeding is generally used for flock maintenance rather than improvement and is probably the method most used by hatcheries. Flock breeding can be used for flock improvement with smaller number but should not be continued for more than three or four generations to avoid inbreeding depression.

  I use this method with my "Tinks" bantams – a Serama and Old English mix. I basically keep four roosters and ten hens, allow all birds to free range, and am currently on my third generation (F2). Replacements are selected primarily on size (super small) and color (variety). Breeding stock is replaced every three to four years. Despite having far fewer birds than recommended, this methods works for me because (1) the original birds were unrelated, (2) the F1 generation were hybrids, (3) they have a replacement cycle of only 3-4 years, and (4) I'm not breeding to APA Standards. Eventually, I'll probably divide the flock into two groups of females, place Serama roosters with one group, and place Rankin roosters with the other.

- **OUT AND OUT**: Outcrossing or out-breeding is the practice of introducing unrelated genetic material into a breeding flock, usually "fresh" males. It increases genetic diversity and reduces the chances of inbreeding depression. Outcrossing can be used to improve a flock if the new males are of better quality than the existing flock and the preferred method for the hobbyist because it does not require a large number of birds. Unfortunately, this method can also cause problems as it can introduce undesirable recessive genes that may not be noticeable for two or three generations.

  I've had negative experiences in the past with outcrossing with fresh males bring in undesirable recessive traits. Therefore, I'm outcross as rarely as reasonably possible. Generally, I'll breed any new males to a new batch of my own pullets. If the results are positive, then I'll breed that same male to his daughters in the next generation. I use males for outcrossing primarily because males are generally more available and cheaper. When acquiring new males, I'll buy at least six males for every one that I need for breeding – keeping the best for breeding and selling the remainder as pet quality.

- **SPIRAL**: (Clan Mating) Spiral mating requires setting up and labeling three or more separate breeding pens. Each cycle, the best of the females are selected and placed in their original pen – pullets from pen A go into pen A, pullets from pen B go into pen B, and so forth. The best of the males are selected and rotated to the next pen – males from pen A go into pen B, males from pen B go into pen C, and so forth. Over time, selective breeding will result in an overall improvement in the flock. This system can be maintained for several generations before experiencing inbreeding depression or the need for new stock.

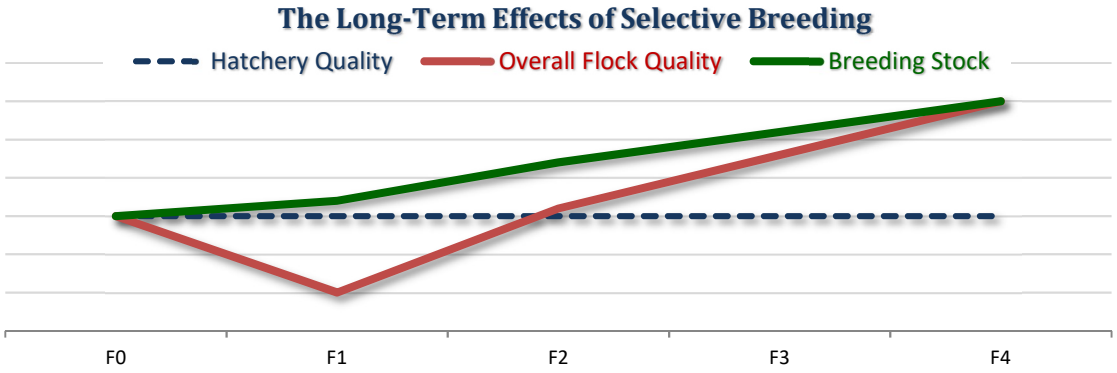
  Spiral breeding enables fairly rapid results with a minimum investment and is probably best method for backyard hobbyist who desires to breed a specific breed for exhibition. It is also suitable for individuals who sell enough hatchlings and/or hatching eggs to financially justify the cost of maintaining several pens.

  Since my goal is to maintain a sustainable flock of peafowl for my lifetime without the need to outcross, this is the method that I use with peafowl. Initially, I acquired my original birds from five different sources, grew them out, and then selected the three males and nine females that I wanted to keep for breeding. The three males were placed in three separate flight pens and then for each pen three unrelated females were chosen. The excess males and females were sold. Peafowl mature at only 1/6th the rate of chickens and their replacement cycle is 8-9 years instead of the usual 2 years for chickens. I've not yet had a need to rotate replacement. I did replace one hen using a young female from an unrelated pen.

- **LINE**: (Pedigree) Line breeding usually involves breeding closely related birds such as daughter to father. Such mating systems require great care and much more research than can be presented here.

> *In East Texas, the winters rarely get cold enough to kill off bacteria and parasites in the ground. Thus, poultry need to have a strong, natural resistance to the bugs in the area. This isn't the case with heritage turkeys brought in from outside the area. Mortality from Blackhead in turkeys can be over 70% for turkeys placed on the ground where older birds have been… something that I experienced firsthand. To combat the problem, I took the best of my surviving F1 turkeys and breed them to each other despite them being full or half siblings. Ultimately, I was able to produce a line with up to 100% survivability.*

INITIAL DECLINE: From personal experience, selective close breeding results in a drop in the ***overall*** flock quality in the first generation (red line). This is probably the result of undesirable, hidden recessive genes pairing off in the offspring. However, a number of individuals (10-15%) demonstrate good or excellent qualities. By only using the best of the flock and culling (removal) lesser quality birds, the overall flock quality eventually catches up with the breeding stock (green line). This year in my F4 Bronze turkeys, there was no significant difference between the juveniles that I kept for breeding and those that I sold as extras.



SELECTIVE BREEDING EXAMPLES: I am a very small producer who focuses on "pet" and "production" rather than "exhibition" qualities. The primary purpose of my Dominique flock is to produce high quality black sex-link laying pullets so egg quantity and size are of primary importance. Within my geographical area, turkey poults tend to have a high mortality rate when placed on the ground so survivability became my primary focus with my Bronze turkeys.

Dominique Flock						
	Cull Rate	**Flock Quality**	**Egg Quantity**	**Egg Size**	**Egg Quality**	**Hatch Rate**
F0	23.0%	★★☆☆☆	72%	Medium	★★★★★	79.3%
F1	12.0%	★★★☆☆	76%	Medium-Large	★★★★☆	62.2%
F2	2.6%	★★★☆☆	80%	Medium-Large	★★★★☆	78.2%
F3	1.4%	★★★★☆	85%	Large	★★★★☆	--

Standard Bronze Turkey Flock					
	Cull Rate	**Mortality Rate**	**Flock Quality**	**Egg Quality**	**Hatch Rate**
F0	20.0%	10%	★★★★☆	★★★★☆	82.4%
F1	14.3%	70%	★★★★☆	★★★★☆	87.9%
F2	10.9%	30%	★★★★☆	★★★★★	86.3%
F3	4.1%	10%	★★★★☆	★★★★★	91.0%
F4	1.0%	0%	★★★★★	--	--

ADDITIONAL READING:

- "Poultry Farming For Beginners and Breeding the Home Flock," *Countryside Daily*, February 7, 2013: http://countrysidenetwork.com/daily/poultry/chickens-101/poultry-farming-for-beginners-and-breeding-the-home-flock/
- "Using the Clan Mating System," *The Modern Homestead*, August 2016, http://www.themodernhomestead.us/article/Clan+Mating.html
- Farhan Sheikh, "Breeding of Poultry," *The Poultry Guide*, October 14, 2012, http://thepoultryguide.com/breeding-of-poultry/

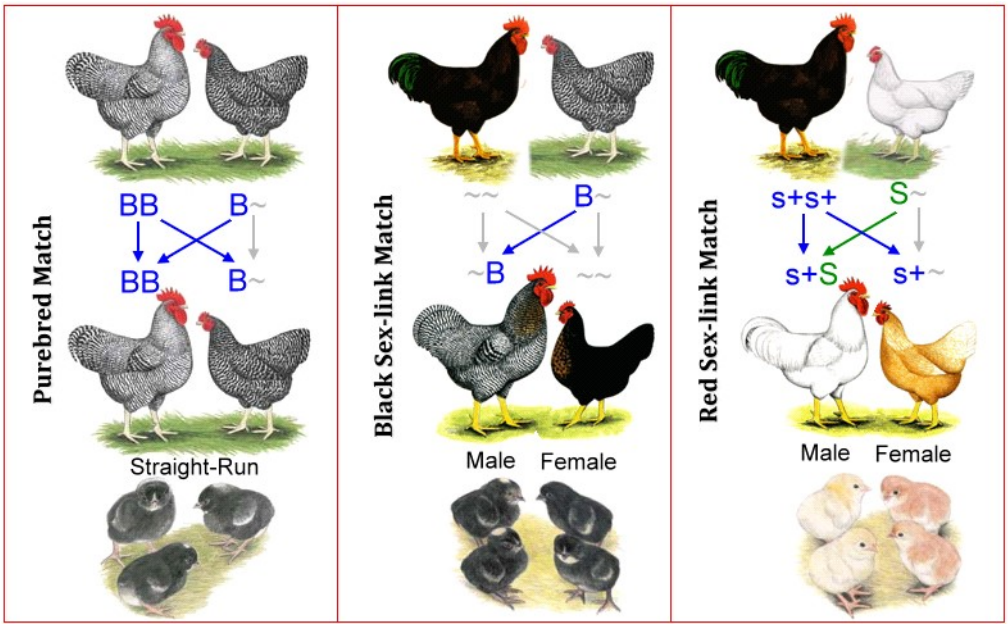
Genetics: Sex-Link Hybrids

Sex-links are the result of first generation crossing of two different **pure** breeds where the genetic mix enables chicks to be sexed at hatch. Hybrid vigor makes them better and more efficient producers of eggs, meat, or both.

- **AUTOSEXING BREEDS**: Autosexing breeds are similar to sex-links in that male and female chicks can be separated at hatch; however, autosexing breeds are pure breeds that breed true – the succeeding generations of offspring resemble their parents, grand-parents, and great-grand-parents. For the backyard, autosexing breeds may be a good choice because they do not require the hobbyist to maintain two different flocks required for breeding sex-links. Unfortunately, autosexing breeds do not enjoy widespread popularity probably because they lack the benefits of hybrid vigor. Autosexing breeds include:

Amrock	Ancobar	Barnebar	Bielefelder	Brockbar
Brussbar	Buffbar	Cambar	Cobar	Cream/Gold Legbar
Dorbar	Hambar	Niederrheiner	Norske Jaerhon	Oklabar
Polbar	Rhodebar	Welbar	Whealbar	Wybar

- **Z and W CHROMOSOMES**: Unlike humans, gender in poultry is determined by the female – females carry one "Z" chromosome and one "W" chromosome while males carry two "Z" chromosome. In addition to gender, Z chromosomes also carry several other alleles (markers) such as color and feathering traits. Mixing and matching dominant and recessive traits on the Z chromosome allows the breeder to produce male chicks that look different than female chicks at hatch.

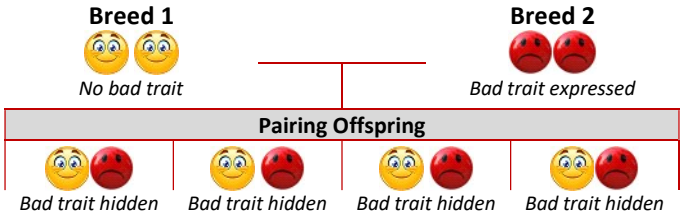


Popular Sex-Link Hybrids				
Common Name[a]	**Rooster**	**Hen**	**Female Chicks**	**Male Chicks**
Black Star	Rhode Island Red	Dominique	all black	yellow headspot
	Rhode Island Red	Barred Rock	all black	yellow headspot
Marans Star	Black Copper Marans	Cuckoo Marans	all black	Yellow headspot
Gold Star	Rhode Island Red	Rhode Island White	buff	white
Gold Comet	New Hampshire	White Rock	buff	white
Cinnamon Queen	New Hampshire	Silver Laced Wyandotte	buff	white
Red Star	Production Red	Delaware	buff	white
Brown Star	Rhode Island Red	White Rock	buff	white

[a] *Common names and breeding combinations differ from breeder-to-breeder.*

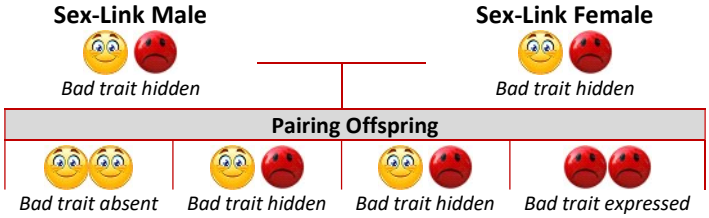
For a more detailed description on the various breeds that can be used in creating sex-links, visit "Sex- linked Information," in the Backyard Chicken Forum: https://www.backyardchickens.com/threads/sex-linked-information.261208/

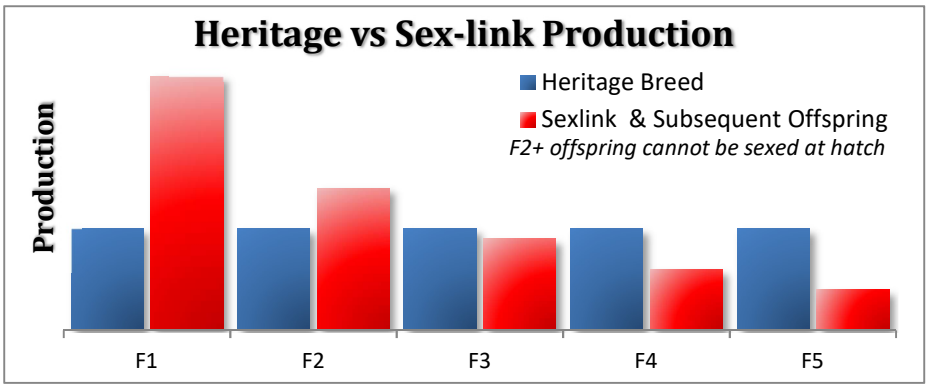
- **HYBRID VIGOR**: A hybrid is the offspring of two plants or animals of different species, varieties, or breeds. The hybrid vigor phenomenon has been used in both plants and animals to increase fertility, hatchability, offspring vigor, and both quantity and quality of production (meat or eggs). Technically, breeding two genetically dissimilar parents greatly increases the odds that an undesirable, recessive (hidden) allele will be paired with a more desirable, dominant allele causing the undesirable trait to be masked (concealed). Since this can occur across multiple systems, the production results can be significant.



The sex-link focus is frequently on the ability to sex chicks at hatch; this is a mistake. The masking (concealing) of undesirable traits occurs not only on the sex chromosomes but on all 36 pairs of chromosomes and affects multiple systems resulting in the benefits of hybrid vigor.

Sex-link chickens are not a true breed and do not breed true – their offspring do not retain the same traits as their parents. Second generation (F2) chicks cannot be sexed at hatch and undesirable, recessive (hidden) traits begin to emerge. Since the mixing occurs across all 36 chromosomes, subsequent generations (F3+) are likely to demonstrate further decline because the diversity of physical traits makes selective breeding difficult.



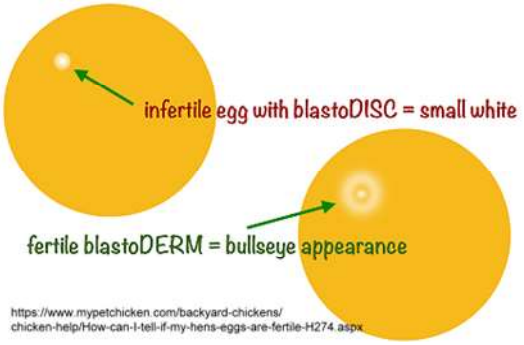


- **CHOOSING BREEDS FOR CREATING SEX-LINKS**: While there are several combinations that can be used to create sexable hatchlings, not all combinations are valuable productively. Simply creating sex-links because you can serve no real purpose. Instead, determine the production qualities desired and then select two breeds that already display those qualities and that crossing will create a sexable chick. Thus far, I have bred three types:
  1. **BLACK STARS**: Rhode Island Red rooster + Dominique hens produces beautiful black, rose comb hens that are superb layers of large, cream colored eggs. Since they are smaller hen, a higher percentage of feed goes into egg rather than meat production. They lay through the winter, free range well, and are predator aware – they are hard to catch and because they resemble crows the hawks leave them alone.
  2. **MARANS STARS**: Black Copper Marans rooster + Cuckoo Marans hens produce beautiful black, single comb hens that lay a large, darker brown egg. They are only fair layers and go broody frequently.
  3. **GOLD STARS**: Rhode Island Red rooster + Rhode Island White hens produces beautiful gold, single comb hens that are superb layers of extra-large, brown eggs averaging nearly 95% lay their first season. However, such high production takes a significant physical toll with production dropping significantly after their first season. Additionally, the gold coloring attracts hawks and overhead cover is recommended.

Fertility: Factors Influencing

- **EGGS CANDLE CLEAR**: Among hobbyist, the term "non-fertile" eggs generally refer to the number of incubated eggs that show NO development upon candling on day seven. However, that use is probably inaccurate… Lack of signs of development may reflect a problem with true fertility or may indicate early embryonic death:

  1. **TRUE INFERTILITY**: (eggs candle clear) True infertility occurs when the hen's eggs are not fertilized by the rooster's sperm. True infertility can be caused by too few or too many roosters, young or old males, males too heavy, females under or overweight, poor nutrition, drugs or toxins in feed, disease, poor legs or feet condition, stress, or extreme climate change.



  2. **EARLY EMBRYONIC MORTALITY**: (eggs candle clear) Eggs that candle clear on day seven can also be caused by early embryonic death – the chick dies very early during the incubation process. Early embryonic mortality can be caused by a number of factors such as improper storage, excess jarring, extreme high or low temperature, blocked pores, poor egg quality, etc.

> ***Turning makes a difference***. *Development rates on Day 7 of eggs turned every hour can be up to 5% higher than those turned every 4.*

  The only accurate way to distinguish between true infertility and early death is to break the egg open and examine the blastodisc – the white spot lying on top of the egg yolk. The infertile blastodisc will be a simple white spot while fertile blastoderm will have a ring surrounding it (bullseye) or will show signs of development – such as enlargement or small blood vessels.

- **SPERM STORAGE**: Birds store a large amount of sperm internally inside Sperm Storage Tubules and release a portion of that sperm each time they ovulate – hens need not mate daily in order to achieve a high fertility rate. Once insemination occurs, maximum fertility is achieved by day five. The average length of time the sperm remains viable inside the female varies by species and can vary greatly among individual birds.[2]
  - Peafowl: 26 days
  - Turkeys: 45 days
  - Ducks: 10 days
  - Chickens: 12 days
  - Japanese Quail: 6 days

> ***Most eggs that candle clear are actually fertile***: *"…most of the unfertile eggs tested out during incubation, are in reality dead germs in which death has occurred before the chick became visible to the naked eye."*[1]

- **IMPROVING FERTILITY**:

  1. **HEN–ROOSTER RATIO**: In general, a young healthy rooster can successfully mate with up to 12 hens. However, most hobbyist utilize a smaller ratio:
     - Light Breeds (Leghorns): 1:12
     - Bantams (Silkies): 1:6
     - Domestic Ducks (Mallards): 1:5
     - Heavy Breeds (Rhode Island Red): 1:10
     - Heritage Turkeys (Royal Palms): 1:5
     - Domestic Geese (Chinese): 1:3
  2. **YOUNG ROOSTERS**: Males tend to mature sooner than females and young roosters are often too aggressive to be successful in the mating process.
  3. **SOCIAL ROLES**: Stimulate mating by sprinkling grain on the litter in the afternoons. Let the males play the role of landlords, so they have the chance to show their leading position in the flock.[3]
  4. **SPIKING**: Exchanging roosters between pens creates a new social order and increases interaction between rooster and hens.
  5. **KNOCK-OFF-SYNDROME**: Avoid having too many roosters; competition may result in roosters knocking each other off the hens before the breeding sequence is complete.
  6. **REPLACE AGING ROOSTERS**: Roosters continue to be fertile long after most hens have passed their prime. However, increased age may result in lower mating interest requiring the introduction of younger males.

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[1] *Milo M. Hastings, The Dollar Hen, National Poultry Publishing, 1911*
[2] *"Ejaculate features and sperm utilization in peafowl: Pavo cristatus," T. R. Birkhead, Department of Animal and Plant Sciences, The University, Sheffield and M. Petrie, Department of Zoology, South Parks Road, Oxford. The Royal Society, 1995.*
[3] *Maciej Kolanczyk, "FAQ: Managing fertility: good breeding shows," Pas Reform,https://www.pasreform.com/academy/frequently-asked-questions/ hatching-eggs/128-managing-fertility-good-breeding-shows.html.*

Humidity: Hygrometers

- **DIGITAL HYGROMETERS**: Digital hygrometers are easy to read, easy to find, and generally inexpensive. Quality, however, is heavily dependent on the quality of its electronic sensor. Most digital hygrometers are "factory set" and not capable of being manually calibrated or adjusted. Humidity is a key component to successful incubation and most digital hygrometers that can be purchased locally are completely inadequate. When purchasing a digital hygrometer, ***if it doesn't specifically state its accuracy, do not buy it***!

> There is a huge difference between *READOUT PRECISION* and *ACCURACY*. Although a hygrometer may read 45%, it may not be accurate to that 1%... the actually humidity may be much higher or lower than the reading. Carefully check the package and be sure it specifically states that it is accurate to ± 1% and user calibratable.

- **ANALOGUE HYGROMETERS**: Analogue hygrometers are mechanical, have a dial and dial indicator (similar to a clock face with hands), and require fine tuning from time-to-time, usually using a small screw. Much like digital hygrometer, the quality of analogue hygrometers is heavily dependent upon the quality of material used and most devices that can be purchased locally are inadequate for incubation purposes. For best results, examine the packaging to ensure that it can be calibrated and that it is accurate to ± 1%.

  Personally, I have a strong preference for analogue hygrometers and utilize the one pictured. If I ever begin to doubt their accuracy, I simply re-calibrate them. It most instances, they only require adjusting once per season.

- **CALIBRATING A HYGROMETER**:[1]

  Step 1: Determine that your hygrometer can be hand calibrated. To check this, look for a small screw head or a hole with a small screw head inside. You'll need to locate a screwdriver small enough to turn this screw.

  Step 2: Evaluate the accuracy of the general reading. Wrap the hygrometer in a moistened hand towel or napkin. After a period of about 30 minutes, check the reading. It should read approximately 95%. If it does not, turn the calibration either clockwise or counter clockwise until it reads between 95-100%.

  Step 3: Gather the following materials: (1) a clean, dry, quart size zip lock bag, (2) a clean, dry water bottle cap (or other similar sized container), (3) sufficient table salt to fill the container, and (4) distilled or filtered water.

  Step 4: Fill the cap with salt. Wet the salt until it is saturated but not pooling (the salt is not expected to dissolve).

  Step 5: Place the salt filled cap into one side of the bag.

  Step 6: Place the hygrometer in the bag on the opposite side and zip the bag closed.

  Step 7: After 6 hours, check the hygrometer. It should read exactly 75%. If it does not, turn the calibration either clockwise or counter clockwise until it reads 75%. Repeat Steps5-7 until the hygrometer is reading accurately.

- **WET/DRY BULB METHOD**: A method that measures relative humidity by comparing the dry-bulb temperature (a regular thermometer) to the wet-bulb temperature (bulb covered with a wet, cotton muslin). Once the two readings have been obtained, a chart is used to find the relative humidity value.

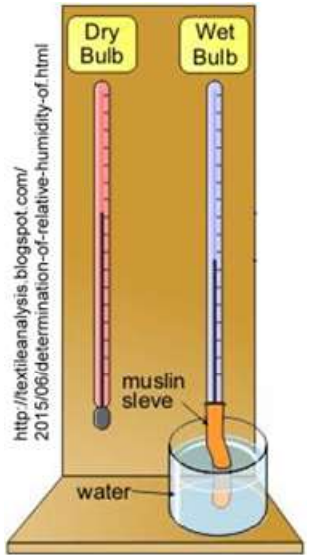
  - **BENEFITS**: When used correctly, the wet/dry bulb method is the most accurate means of measuring relative humidity, especially when the temperature varies greatly. Unfortunately, this advantage tends to disappear under an incubation environment – the temperature (dry-bulb) should remain constant throughout incubation.

[1] *"Calibrating Your Analog Hygrometer, "Cigar Manor, 2017. https://www.cigarmanor.com/pages/calibrating-your-analog-hygrometer*

- **DRAWBACKS**: Unfortunately, the wet/dry bulb method is cumbersome and many people fail to use them correctly frequently such as using a shoelace for a cotton sleeve and/or taking the dry-bulb reading above the eggs and the wet-blub reading under the eggs. Use the following to ensure an accurate reading:
    1. Both the wet and dry bulb thermometers should be the same type and both must be calibrated.
    2. The bulb of both thermometers must be in close proximity to each other and the readings must be taken at the same time to avoid measuring regular temperature variations within the incubator.
    3. The cotton sleeve should be made of thin cotton muslin and use distilled water. Alternatives introduce variables that compromise the method's accuracy.

1. **RECOMMENDATION**: The wet/dry method is cumbersome and prone to error in many hobbyist incubation environments. Considering that incubation humidity generally falls within a range of values (e.g. 40-43%), then a good, calibrated analogue hygrometer is sufficiently accurate and much easier to use.

Dry Bulb →	98 °F	99 °F	100 °F	101 °F
↓ Wet Bulb ↓	↓ Relative Humidity (Percent) ↓			
90 °F	72%	70%	68%	65%
89 °F	70%	67%	65%	63%
88 °F	67%	65%	63%	60%
87 °F	65%	62%	60%	57%
86 °F	61%	59%	57%	54%
85 °F	58%	56%	54%	51%
84 °F	55%	53%	51%	49%
83 °F	53%	51%	48%	46%
82 °F	50%	48%	46%	44%
81 °F	48%	45%	43%	41%
80 °F	45%	43%	41%	39%

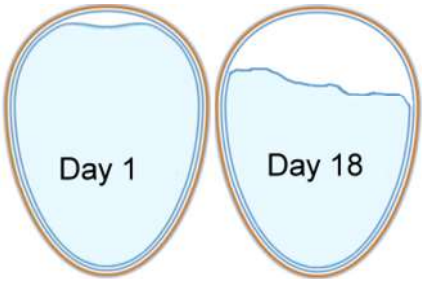


Humidity: Settings

Humidity – the amount of moisture in the air – plays a significant role in incubation. Too high of humidity during the first two-thirds of incubation, the air cell is too small to support respiration and the hatchling grows too large to comfortably turn within the egg. Too low of humidity during the first two-thirds, the hatchling can become weak due to dehydration and the lubricating fluids that help the chick turn inside the egg will dry. Unfortunately, finding the perfect humidity setting can be difficult and will vary from situation-to-situation.

NOTATION: Humidity during hatch time is discussed within the hatching section of this guide.

- **VARIABLES**: During incubation, an egg must lose between 11-12% of its weight primarily in the form of water. How much water is lost depends on a number of variables:
    1. **Shell Thickness & Pore Size**: Some breeds such as Marans, produce thick shells with small pores; they tend to lose less water than average.
    2. **Cuticle**: (bloom) The cuticle tends to block pores and reduce moisture loss. Washed eggs without a cuticle lose more moisture than unwashed eggs.
    3. **Air Movement**: The less air movement (still air incubators) the less the drying effect; the greater air movement (cabinet incubators) the greater the drying effect.



    4. **Ambient Humidity & Ventilation**: Incubators draw in fresh air and release stale air. The combination of ambient (room) humidity and how much fresh air enters the incubator affects water loss.
    5. **Humidity**: The higher the humidity = less water loss; the lower the humidity = greater the water loss.

- **RESULTS OF HIGH HUMIDITY (Days 1-18)**: The effects of too high of humidity during incubation are not usually seen until hatch time. If the humidity is too high, the air cell will be small and the chick may have difficulty placing its beak into the air cell. In such cases, the chick never takes it first breath. Frequently, hobbyists will claim that these chicks drown but this is not technically correct. Additionally, the chick will grow to fill the available fluid space often becoming too large to comfortable turn inside the shell. In these cases, the chick may not pip externally or, if it does, may not completely zip the shell. Signs of too high of humidity during incubation include:
  - No internal pip with full tem embryo
  - Malpositioning
  - Small air cell
  - Membrane incompletely broken
  - Herniated egg sac
  - Delayed hatch
  - Sticky chicks smeared with albumen
  - Red hocks or unhatched chicks
  - Large chicks
- **RESULTS OF LOW HUMIDITY (Days 1-18)**: Hobbyists are often quick to blame low humidity during hatch time on numerous hatching problems. However, this is frequently an error as a healthy chick is likely to hatch even if the hatch humidity is relatively low. Low humidity during incubation (days 1-18) is more likely the culprit and "dry incubation" the likely cause. For the hobbyist, a *lower* humidity during incubation can improve hatch rates; however, if the humidity is too low, then a number of ill effects can occur:
  - Abnormalities of aortic arches
  - Premature death
  - Internal pipped full term embryo dead in shell
  - Chick stuck in shell; shell fragments stuck to down
  - Early hatch, noisy chicks
  - Thin, weak, or small chicks
- **RECOMMENDED HUMIDITY (Days 1-18)**: What is the best humidity to use days 1-18? A simple question; unfortunately, there is no simply answer. Brinsea Products lists 40-50% as idea while Mississippi State University promotes 58-60%. Many backyard enthusiasts promote "dry incubation" (no added water) while still others swear anything less than 60-65% will lead to dried out chicks. There does not appear to be a consensus among the "experts."

Humidity & Temperature Recommendations					
	Still Air	**Circulated Air**	**Humidity Days 1-18**	**Humidity Days 19-21**	**Total Wgt Loss**
North Carolina State	99.5-101°F	99.5-101°F	40-45%	-	-
Brinsea Products	-	99.3-99.6°F	40-50%	65%	13-15%
Hubbard Hatcheries	-	99.8-99.9°F	50-55%	55-60%	11%
Murray McMurray	-	99.5-100°F	50-55%	65%	-
Pas Reform Academy	-	-	50-55%	-	12%
U. of Illinois	99-103°F	-	50-55%	65%	11%
U. of Minnesota	100-101°F	100-101°F	50-55%	65%	-
Brower Equipment	-	99.5°F	50-55%	75%	-
Mississippi State U.	102°F	100°F	55-60%	90%	12%
Penn State	100°F	99-100°F	60%	65-70%	-
U. of Connecticut	100-101°F	-	60-65%	70%	-
Virginia Tech.	100-101°F	99-99.5°F	60-65%	70-75%	-
Cobb Hatchery	-	-	-	-	12%
Ross Technology	-	-	-	-	12%
		Mean	**51-56**	**Average**	
		Median	**50-55**	**Middle**	
		Mode	**50-55**	**Most Common**	
		High	**60-65**	**Highest**	
		Low	**40-45**	**Lowest**	

Why so much variation in recommendations? Remember, there are a number of variables involved – shell thickness, pore size, cuticle condition, air movement, ambient humidity, and ventilation. The humidity setting in a small, still air desktop incubator using unwashed eggs will be different than that of room size incubator using washed eggs. What works for one incubator in one part of the country will not work for a different incubator in a different part of the country. Each situation requires unique settings.

Where, then, should I start? For best results, start with the median recommended humidity setting of between 50-55% for days 1-18. Routinely monitor both the humidity and the size of the air cell. Once the chicks hatch, evaluate the results of that hatch and then either raise or lower the humidity depending on what you find.

> ***Never*** attempt to incubate expensive, precious, or rare eggs until you have had a number of successful hatches. It takes both time and experience to become familiar with your incubator and what works best in your situation. Always start with a batch of barnyard mixes.

- **ADJUSTING HUMIDITY**: The humidity within an incubator is affected by the air flow, ventilation volume, ambient humidity, and water surface area. While the air flow remains constant, ventilation volume should increase with development and ambient humidity will change with the weather. To compensate for these variables, increase the water surface area to increase the humidity or decrease the surface area to lower it.

> ***Never*** adjust the humidity level by closing ventilation ports. Developing embryos and hatching chicks are living creatures taking in fresh oxygen and expelling carbon dioxide – the shell has more than 7,000 pores. Reducing ventilation to increase humidity is a dangerous practice.

1. **Desktop Incubators**: Desktop incubators usually have a number of channels in the bottom section. Begin by filling one channel and then increasing the number of channels filled until the desired humidity level is achieved. Using an oven baster, large needle and syringe (available at most feed stores), a funnel with attached tubing, or transfer pipette can ease adding and removing water without the need to remove the eggs. Alternatively, when eggs are hand turned, using wet kitchen sponges on top of the grill can make controlling the humidity easier; simply adjust the size or number of sponges as needed.

2. **Cabinet Incubators**: In my GQF, I cover the water pan with aluminum foil and adjusting the area exposed to increase or decrease the humidity. In my Brinsea 380, I've removed the original water pan completely and use a plastic Tupperware bowl in the bottom of the incubator – the larger the pan, the higher the humidity. For hatching in my hatcher, I use a large plastic pan containing numerous large kitchen sponges to raise the humidity to 60%. These methods may seem tedious, but they are simple, inexpensive, and generally need not be adjusted once the desired humidity is achieved.

3. **Humidity Pumps**: A number of commercial humidity pumps and controls are available for purchase or can be fabricated using various components. They are rumored to make the task of controlling the humidity level worry free – simply connect the components, fill with water, set the desired humidity, and let the device do the work. Personally, I've never had difficulty maintaining the desired humidity and another gadget would add expense and provide another potential point of failure. However, several people claim that they have improved their overall hatch rates.

> ***Never*** use ventilation holes to attach a humidity pump. Ventilation holes are intended for one purpose only – to permit fresh O_2 to enter and stale CO_2 to escape. Blocking these ports can result in death of an embryo or impede hatching. Keep ventilation holes clear of obstruction.

- **DRY INCUBATION**: Classical "dry incubation" includes adding no water to the incubator days 1-18 and not monitoring humidity levels. This method has often proven beneficial over traditional settings primarily because desktop incubators have (1) small fans with minimal air circulation and (2) small ventilation holes which are frequently plugged – eggs lose less water than in incubators with stronger fans and greater ventilation. However, because ***humidity is not monitored, the results can be unpredictable*** working well during humid months such as March while having disastrous results in dry months such as August.

How can you tell if dry incubation is not working for you? If the humidity was too low days 1-18, the classical signs appear at hatch time: fully formed chicks dead in the shell, chicks that pip but get stuck, and abnormally small, weak or noisy chicks. If you find a need to assist in hatching, then your humidity days 1-18 was likely low.

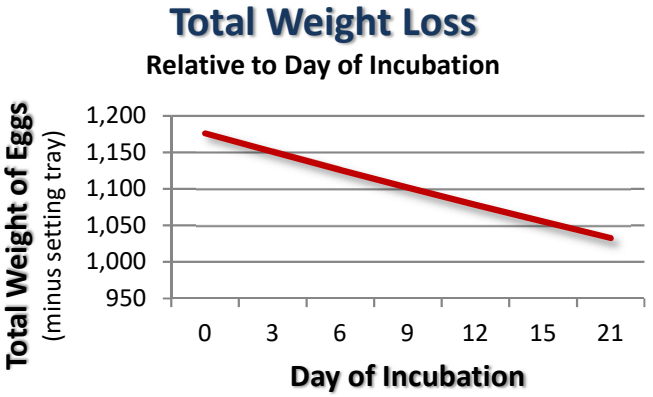
Successful incubation should focus on producing as many healthy, vibrant chicks as possible. Low humidity may produce a slightly higher hatch rate but hatchlings experiencing some levels of dehydration may not perform well in the brooder and be less productive later in life.

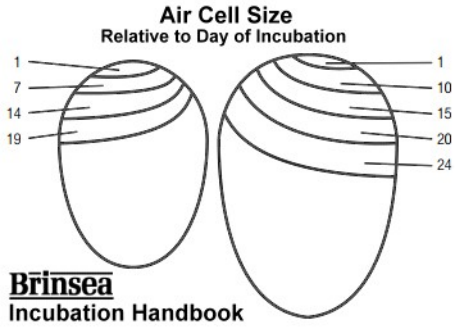
Using a "dryer incubation" approach is preferential to "dry incubation." Lower humidity settings in desktop incubation seem to have a positive correlation with higher hatch rates. But, finding the setting that works best for you takes time, observation, and experience. Closely monitoring your humidity and maintaining a steady humidity during days 1-18 allows you to evaluate the effects of your humidity setting. Was my humidity too high or too low?

- If you see no internal pip with full tem embryos, small air cells, membranes incompletely broken at hatch, or sticky chicks, then you can ***lower*** your humidity during the next batch.
- If you see fully formed chicks dead in the shell, chicks that pip but get stuck before hatching, and abnormally small, weak or noisy chicks, then you can ***raise*** your humidity.

- **MONITOR WATER LOSS DURING INCUBATION**: The most accurate method of monitoring water loss during incubation is to weigh the eggs every three days. Using this method, the entire batch of eggs including the setting tray before setting the eggs and then every third day during incubation. After subtracting the weight of the setting tray, the entire batch of eggs should about 97.86% of its weight relative to the previous weighing. Unfortunately, few hobbyists have the means to accurately weigh eggs in such a manner and removing eggs from the incubator can potentially damage the eggs through bumping/jarring or excess cooling.

  Alternatively, a simpler and safer method is to simply candle a sampling of the eggs, examine the relative size of the air cell, and compare to diagram below. If the air cell is growing too slowly, lower the humidity. If the air cell is growing too rapidly, increase the humidity. Although less accurate than weighing eggs, monitoring humidity by air cell size can be effective – with time and experience.





The Master Hatcher

Master hatchers know the rules.
Master hatchers don't follow the rules.

Hatching is more of an art than a science. A person can follow all the rules exactly to the letter and still have bad hatches. You see, Mother Nature doesn't provide a broody hen with a rule book. She instinctively knows how much material to pull up around her nest and how much to push away. She doesn't candle her eggs but she knows which ones to kick out of the nest. She knows when she can safely leave the nest and how long she can be gone. She listens to her eggs and knows when they will hatch. And, she does a pretty good job... all without a rule book.

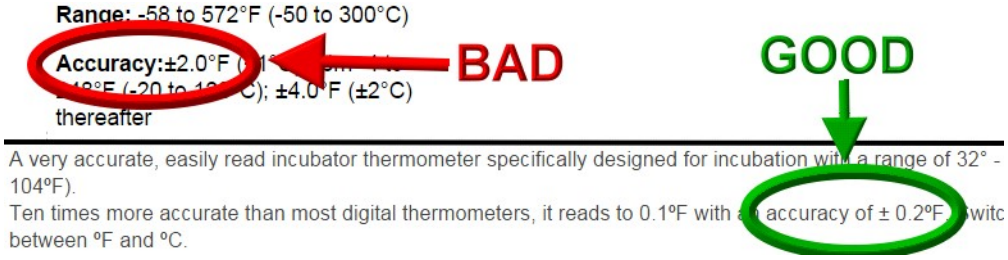
There are people who hear something in a hatching group and they adopt that something as a golden rule, never to be broken. These people never become Master Hatchers because they never deviate from the rules... they never get a sense... they never get a feel... they never develop an instinct that the eggs need something a little different.

Be a Master Hatcher!

Temperature: Thermometers

Temperature is one of the four key components of successful incubation and failure to maintain the correct temperature accounts for the vast majority of hatch failures... and ***poor thermometer selection is among the leading causes of incorrect temperatures***.

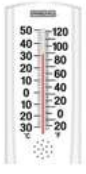
- **OBJECTIVE**: Chickens should hatch on day 21. If they hatch early, then your temperature is too high. If they hatch later, then your temperature is too low. While early and late chicks may survive, they are not among the healthiest or vigorous. It is important that you get your incubation temperature correct.
- **INCUBATOR GAUGES**: ***Do Not Trust the gauges that came with your incubator***. Verify that both the temperature and humidity readings are correct with a calibrated thermometer and hygrometer. It is recommended that this verification be repeated periodically. If there is a reading difference between the incubator panel and the calibrated thermometer, trust the calibrated thermometer.
- **DIGITAL SENSITIVITY**: Most digital thermometers are inadequate for incubation. While they may read to 0.1° F, they are only sensitive to 2.0° F – while the readout may display 99.5° F the temperature will range anywhere from 98.5° F to 100.5° F. Before purchasing a digital thermometer, read the packaging. If it does not specifically list an accuracy of ±0.2° F, do not buy it…



> **CAUTION**: All digital thermometers appear to be accurate but most are grossly inadequate for incubation. A digital thermometer must be capable of calibration and must have an accuracy (sensitivity) of no less than ±0.2° F.

- **RESPONSE TIME:** When the heating element comes on, the temperature will rise and continue to do so for a short time after the element switches off. Some digital thermometers will incorrectly register this rise as a temperature spike and cause concern… "Why does my temperature seem to bounce all over the place?" Digital thermometers encase in plastic frequently continue to register this increase long after the air temperature has returned to normal. For best result, buy only digital thermometers with a probe type sensor where the probe can be slipped into one of the vent holes.

- **THERMOMETER TYPES**:

STEM	RED, SPIRIT GLASS	DIGITAL PROBE	DIGITAL
			
PRO: Slips thru vent May be calibrated CON: May be difficult to read Not readable to 0.1°	PRO: Easily calibrated Inexpensive CON: Difficult to read Not readable to 0.1°	PRO: Slips thru vent Easily to read CON: Can be Expensive Most not accurate ±0.2°	PRO: Easy to read Inexpensive CON: Cannot be calibrated Most not accurate ±0.2

- **MERCURY THERMOMETERS**: Silver mercury glass thermometers are the most accurate thermometers but are not readily available because of toxicity associated with mercury.

Why are common digital thermometers: *inadequate for artificial incubation?*

Digital dual-purpose hygrometers/thermometers are popular among backyard hobbyists. They are readily available, inexpensive, and easy to use. However, they are a very poor choice for artificial incubation:

1. **They cannot be calibrated**: The easiest method for calibrating home instruments is submerging the thermometer in either a ice water or boiling water bath. Most digital thermometers would be destroyed by such baths. Additionally, even if they could be submerged, they do not have a calibration setting... their readout cannot be altered.

   "I have model 00613. When the temperature in the house is 69 degrees it says 72. When the temperature is 75 in the house it says 73."

2. **They are inaccurate**: They have an accuracy error rating of ±2.0°F meaning that while the readout displays 99.5°F the actual temperature can range anywhere between 97.5°F to 101.5°F.

   "My Acurite 00309SBDI is reading 72°F but it is actually 75°F (verified 75 using a Fluke Multi-meter) I would think a device that is supposed to tell temperature would be more accurate."

   This accuracy error is in ADDITION to any calibration error. If there is a 1.0°F calibration error and a 2.0°F accuracy error, the incubator temperature can be off by a full 3.0°F.

3. **They have a poor response time**: How quickly a thermometer registers a change in temperature is referred to as "response time." Sensors encased in plastic have poor response time... it can take up to 30 minutes for some thermometers to respond to a change in temperature.

   "It only takes about 1/2 an hour to reflect the temp."

WARNING: Problems associated with high or low temperatures are often not seen until hatch time. Poor temperature control produces weak chicks that do not have the stamina to hatch. Far too often, people blame the humidity when the real problem was temperature Days 1-18.

Effects of Temperature Variations

Prolonged High Temperature

- early embryonic death
- blood ring (early death)
- death of embryo days 7-17
- early hatch
- extended hatch window
- small, weak chicks
- chicks with unhealed dry navel
- malpositioning
- deformities
- short wiry down

Prolonged Low Temperature

- blood ring (early death)
- death of embryo days 7-17
- dead in shell, not pipped
- dead in shell, pipped
- partially zipped, membrane partially torn
- late hatch
- extended hatch window
- chicks with unhealed wet navel, soft bodies
- malpositioning
- deformities

Inaccurate and variable temperature is the major cause of hatch failure.
Chicks can develop all the way to hatch time and pip but fail to finish.

Digital Thermometer Selection Criteria

1. **Calibration Setting**: Can the thermometer's reading be altered?

   Most thermometers do not provide a correct reading straight out of the box... this includes thermometers that are calibra results, choose a thermometer that can be calibrated and the reading adjusted.

2. **Submersible**: Can the thermometer be submerged in an ice water bath?

   Within the home environment, using an ice water bath is the best method for checking a thermometer's reading. If a ther submerged in an ice water bath, then the reading cannot be verified.

3. **Temperature Range**: Does the thermometer read down to 32.0°F?

   Within the home environment, using an ice water bath is the best method for checking a thermometer's reading. If a ther down to 32.0°F, then the reading cannot be verified.

4. **Accuracy**: Does the thermometer have an accuracy of ±0.5°F?

   A thermometer's accuracy rating reflects its acceptable error range meaning if a thermometer has an accuracy of ±2.0°F a actual temperature may be anywhere between 97.5°F and 101.5°F. For best results, choose a thermometer with an accura

5. **Response Time**: How quickly does the thermometer reflect temperature changes?

   Thermometers encased in plastic often respond very slowly to temperature changes... we do not get an immediate respon the more accurate thermometers respond too quickly to changes resulting in readings that bounce around. We want some quickly, but not too quickly.

WARNING: Do not confuse the difference between Celsius and Fahrenheit. Some manufacturers list their accuracy as ±1° likely meaning ±1.0°C that translates into ±1.8°F. 0.5°C translates into 0.9°F. If the specifications are not perfectly clear, do not purchase.

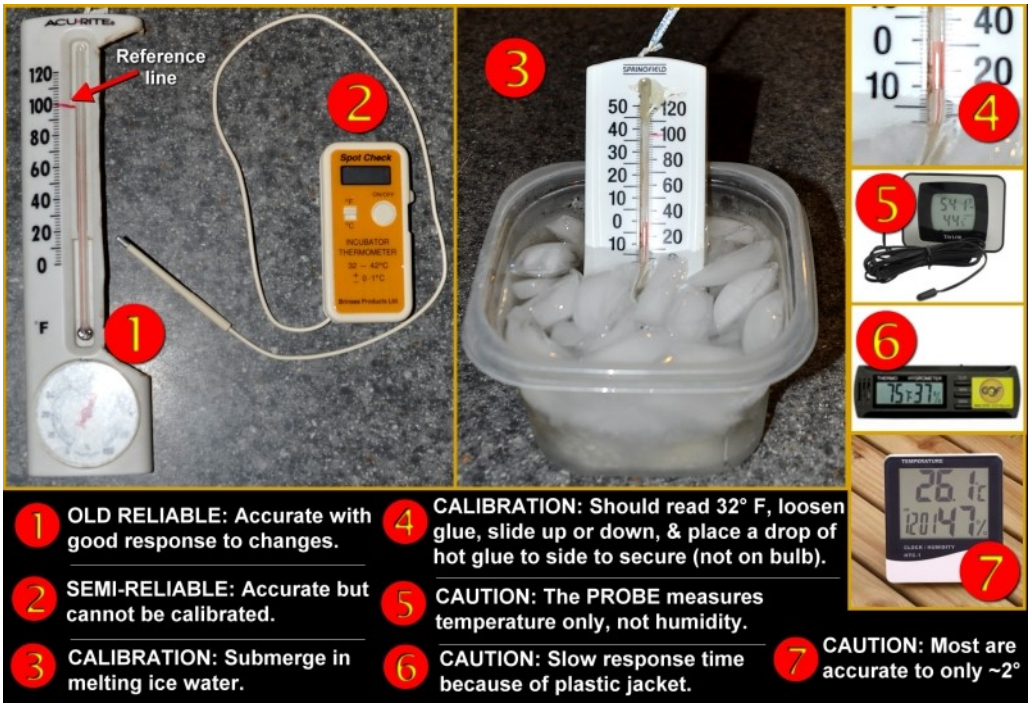
	AcuRite 00613	AcuRite 01083	Brinsea Spot Check	IncuTherm	CheckTemp 1	SensorPush
						
Calibration:	No	Yes	No	No	Self	No
Submersible:	No	No	Yes	No	Yes	No
Temp. Range:	32° to 122° F	-4° to 158° F	90º to 104ºF	Unknown	-58.0 to 302.0°F	-40°F - 140°F
Accuracy:	± 2°F	± 0.5° F	± 0.2ºF	Unknown	±0.5°F	±0.5°F
Response:	Up 30 minutes	Up to 8 Minutes	Rapid	Unknown	Instant	1 Minute
	★☆☆☆☆	★★☆☆☆	★★★☆☆	★☆☆☆☆	★★★★☆	★★★☆☆

- **CALIBRATING A THERMOMETER**:

FREEZING POINT	BOILING POINT
1. Fill a glass with crushed ice cubes and cold water. 2. Stir the water and let sit for 3 minutes. 3. Stir again, then insert your thermometer into the glass, making sure not to touch the sides. 4. The temperature should read 32°F (0°C). 5. If it doesn't, loosen the glue holding the glass to the scale, move the glass up or down as needed. 6. Recheck accuracy and secure tube with a drop of glue.	1. Boil a pot of distilled water. 2. Once the water has reached a rolling boil, insert your thermometer, making sure not to touch the sides or bottom of the pot. 3. The temperature should read 212°F (100°C). 4. If it doesn't, loosen the glue holding the glass to the scale, move the glass up or down as needed. 5. Recheck accuracy and secure tube with a drop of glue.

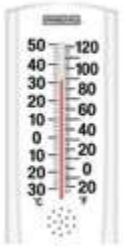
- **REMINDERS**:

1. NEVER trust the gauges on your incubator. ALWAYS use a separate, calibrated thermometer.
2. ALWAYS calibrate your thermometer before using. If your thermometer cannot be calibrated, do not use it. If your thermometer was calibrated at the factory, recalibrate it yourself. You don't need three or four thermometers – use only one that has been carefully calibrated.
3. ALWAYS be sure that your thermometer is accurate to ±0.2°F… most digital thermometers will read to 0.1°F but are only accurate to ±2.0°F. Read the package carefully before purchasing. If it doesn't say accurate to ±0.2°F then do not buy it.
4. ALWAYS measure the air temperature at the top of the eggs – this includes circulated air and cabinet incubators. This task can be difficult in cabinet incubators but can be accomplished using a thermometer with a long probe.
5. NEVER take a temperature reading while the heating element is on… there will be a little light that turns on when the heating element is on.



Temperature: Glass Thermometers

A CASE FOR GLASS THERMOMETERS: Lately, there's been a great deal of focus on the best humidity settings for incubation and hatch. Unfortunately, far too many novices seem to blame humidity for poor hatch results. The more experience I gain, the more I believe that a healthy, vigorous chick will hatch regardless of the humidity settings…. temperature remains the most important key to a successful hatch.



- **AIR TEMPERATURE**: the air temperature within the incubator. Even with the most expensive incubator, air temperatures will consistently fluctuate (vary). The temperature will rise when the heating element comes on and then it will drop when the element goes off – frequently as much as a full degree (even more so with cheaper incubators). The more insulation and effective the air flow, the less the air temperature will vary. However, these variations only have a minimum impact on the developing embryo.
- **REALIZED TEMPERATURE**: the temperature physically experienced by the embryo. The developing chick is insulated from the air temperature by its cuticle (bloom), shell, inner and outer membranes, and the albumen (egg white). Just as it takes time to boil a pot of water or freeze water in an ice tray, it takes time for the embryo to physically experience a rise or fall in air temperature. How quickly an egg's temperature changes depends on factors such as humidity, air speed, and egg size.
- **BROODY HEN EXAMPLE**: When a broody hen sits on a clutch of eggs, she is using conduction (touch) to transfer heat to the eggs with only one side being warmed at a time. A hen's internal body temperature runs between 105-107°F and we can assume that the temperature of heated side of the egg is well above the 99.5°F that we commonly use in artificial incubation. That broody hen will turn her eggs up to 50 times a day so that no one side is heated/cooled for an extended period of time. From her example, we can learn that temperature variation is of less importance than the **AVERAGE** temperature physically experienced by the developing embryo – the "realized" temperature.
- **THE PROBLEM WITH DIGITAL THERMOMETERS**: When I started back incubating a few years ago, I spent quite a bit of money on thermometers. Unfortunately, those expensive thermometers were useless in an incubation environment. In fact, most were detrimental (damaging) especially the most responsive ones like the renowned *Brinsea Spot Check*. You see, accurate and responsive digital thermometers react to even the slightest change in air temperature. When the heating element comes on, the reading rises. When the heating element cuts off, the reading drops. These variations caused me to fiddle with my thermostat… and fiddling with the thermostat with eggs in the incubator can cause all sorts of problems.
- **THE SOLUTION**: Expensive digital thermometers do not work well for me. They accurately and precisely measure the "air" temperature but they aren't very helpful in measuring the "realized" temperature. What I needed was a thermometer that reacted to changes in air temperature more slowly… one that measured the average air temperature… one that better represented the "realized" temperature. My solution was to return to the inexpensive, calibrated, red spirit filled thermometer (old faithful) I had first purchased at Tractor Supply shortly after my wife gave me a Little Giant incubator for Christmas. That thermometer responds to changes in air temperature but more slowly… more in line with what the embryo actually experiences. Since I returned to using old faithful, my babies hatch when they are they are scheduled – and that is the true measure of a good thermometer.
- **LESSON LEARNED**: Newer and more expensive does not mean better. Since my Little Giant days, I've moved on to bigger and more expensive incubators; however, my good and faithful glass thermometer remains the cornerstone of my temperature monitoring. At this very moment, she sits in my hatcher constantly keeping vigilance over my hatching babies.

A glass thermometer need not be expensive. However, it MUST read down to 32°F do that it can be calibrated and it must be large enough to easily read. You can easily judge the accuracy of the glass thermometer… If chicks begin to hatch on day 21, then your thermometer is spot on.

Temperature: Settings

Nothing has a stronger influence on a successful hatch than temperature. Most hobbyists know to set the temperature to 101.5°F for still air incubators and 99.5°F for circulated air; but there is more…

We often think in human terms – our normal body temperature is 98.7°F, a temp of 101.2°F indicates a serious infection, and a temp of 105° can be deadly. However, a chicken's internal body temperature is between 105° to 107°F and 103.5°F for newly hatch chicks.[1] While humans dislike high humidity because it decreases the effectiveness of sweating (heat index), chickens, however, do not sweat and benefit from higher humidity. When we incubate eggs, we need to think in chicken terms, not human ones.

It is not uncommon for temperatures within desktop incubators to spike to 104-105°F. The cause is not always clear; however, as long as the temperature does not stay too high for too long, the eggs may experience only a minimal negative impact… chickens can tolerate higher temperature than humans. Don't give up hope. Simply candle in a few days to evaluate the effect.

- **BROODY HEN VS INCUBATOR**: If a hen's internal body temperature is 105-107°F, why do we set 99.5°F as the ideal air temperature? As parents, we know that our normal body temperature depends on how we measure that temperature. If we take the temperature under the arm, 96.6°F is normal; if by mouth, 98.6°F; or if rectally, 99.6°F – heat dissipates (scatters) the closer it gets to the external air temperature. So although the hen's body temperature is between 105-107°F, the temperature physically felt by the eggs is only about 101.5°F on one side at a time with frequent turning averaging that temperature to around 99.5°F.

It is an error to directly compare broody hens and artificial incubation. Hens heat eggs through conduction (touch) – incubators through convection (air). Hens control water loss through skin moisture and physical contact; incubators through relative humidity and air flow. Hens know what to do by instinct – humans through directions. We can't match a broody hen and shouldn't try.

- **METABOLIC WASTE**: Metabolism is a chemical process that uses oxygen to convert raw materials into usable substances. This chemical process produces two waste byproducts – heat and CO^2. In incubating eggs, these byproducts pass through the shell into the surrounding air and are eliminated from the incubator through ventilation. During the early phases, waste byproducts are few because embryo metabolism is minimal; however, as the chicks approach hatch-time, both byproducts – heat and CO^2 – can build up within the incubator and pose significance health risks to the developing chicks.

Never block ventilation ports. Near the end of incubation, a chick's internal body temperature rises to 103.5°F – four degrees above the set temperature for forced air incubators. Without adequate ventilation, air temperature can spike to above 105°F causing heat injury or death. Additionally, blocking air holes deprive chicks of the oxygen necessary for the physical exertion needed to hatch.

- **REALIZED TEMPERATURE**: The air temperature within the incubator does not accurately reflect the temperature physically experienced by the embryo. The realized temperature is the temperature physically experienced by the embryo. The developing chick is insulated from the air temperature by its cuticle (bloom), shell, inner and outer membranes, and the albumen (egg whiteAs the embryo develops, it increasingly produces its own heat through metabolism. Around days 11-12, the egg's internal temperature will be greater than the air temperature of 99.5°F and will steadily rise to 103.5°F by hatch time.

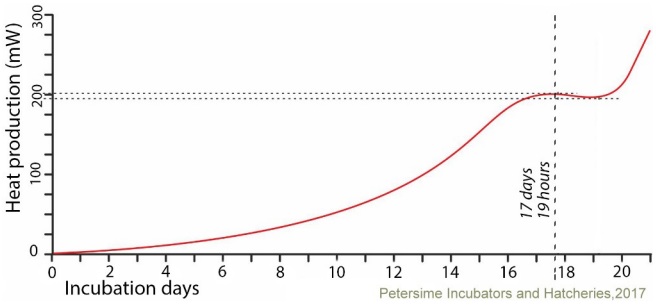
Do not permit the thermometer bulb or probe to touch an egg. Near the end of incubation, a chick's internal body temperature rises to 103.5°F – four degrees above the air temperature in circulated air incubators. If the temperature bulb or probe is touching an egg, then you'll be measuring the shell temperature not the air temperature.

[1] *"Chapter 7 - Ventilation principles: Air Temperature," Poultry Production Manual, University of Kentucky, College of Agriculture, October 2, 2017.*

- **IDEAL TEMPERATURE**: The air temperature for a forced air incubator is normally set at 99.5°F; however, this is only an average, not the ideal temperature for incubation… the ideal temperature will change as egg development advances:

  – When set, the egg generates no heat. By hatch, a lot of heat is generated.
  – When set, the egg is at room temperature. By hatch, it is at 103.5°F.
  – When set, the ideal incubation temperature is 100.5°F is ideal. By hatch, the ideal is 98.0°F.

  BOB'S RESPONSE: "Are you telling me that a hen decreases her body temp over 21 days?"



  Well, yes, of course… If you watch a broody hen, you'll notice that she has ways of regulating the temperature of her nest. If the eggs need more heat, she'll build up the nesting material and sit tight on the eggs. If the eggs need less heat, she'll spread her wings, stand up slightly, and/or leave the nest for longer periods of time. During the latter portions of incubation, I've seen hens off the nest for up to four hours at a time – and the eggs hatch perfectly fine.

  In the old days, when the temperature of all incubators was controlled by either bi-metal or wafer thermostats, fiddling with the thermostat was dangerous. Turn the screw knob to the left or right too much, and you could increase/decrease the temperature by several degrees... not a good thing. Keeping the temperature at the same temperature throughout incubation was the safest, most productive route. Not fiddling with the thermostat became a cardinal rule – a rule that should never be broken.

  However, with the advent of accurate, reliable digital controllers, fiddling with the thermostat is far less dangerous, and we can begin to consider deploying more ideal temperature settings depending on our method of incubation:

  1. **MULTI-STAGE INCUBATION** (Batch Incubation): Eggs within the incubator were set at different times and are expected to hatch at different times. There is just no practical way to calculate all the different ideal temperatures for eggs at various stages of development. Those who use batch incubation will need to stick with a temperature of 99.5°F.
  2. **SINGLE STAGE INCUBATION**: All eggs within the incubator were set at the same time and are expected to hatch at the same time. For those using single stage incubation, the attached chart reflects the ideal temperatures during the various stages.
  3. **COMBINED APPROACH**: Those of us who have multiple incubators can take a combined approach. I start eggs off in my Coca-Cola incubator with a setting of 100.2°F. After candling on day 7, I move them to my Brinsea 380 cabinet with a temperature of 99.9°F. After about a week, I move them to my GQF 1500 with a temperature of 99.3°F. At the end of day 18, I move them to my hatcher with a temperature of 98.5°F.

Ideal Air Temperature & Ventilation[1]

Incubation Day	Air Temperature	Embryo Temperature	Ventilation
1-4	100.0-100.5	100.0-100.0	0-10%
5-8	99.8-100.0	100.0-100.2	10-20%
9-10	99.5-99.9	100.0-100.5	30-40%
11-12	98.5-99.6	100.0-101.0	40-50%
14-16	98.0-98.8	100.0-101.0	50-60%
17-18	98.0-98.5	100.0-101.0	60-70%
19-20	98.0-98.5	-	30-50%
21	97.0-98.0	-	50-70%

Use great caution when fiddling with the thermostat while eggs are in the incubator. Adjusting temperature according to stages of development is ONLY suitable with single stage incubation and ONLY with advanced digital equipment. Fiddling with a tricky thermostat while eggs are in the incubator can have disastrous results. Beginners should NOT consider altering temperatures.

[1] *Adapted from "Incubation Guide," Hubbard Breeders, <http://www.hubbardbreeders.com/managementguides/Incubation%20guide%20(english).pdf>*

Temperature: Warm & Cool Spots

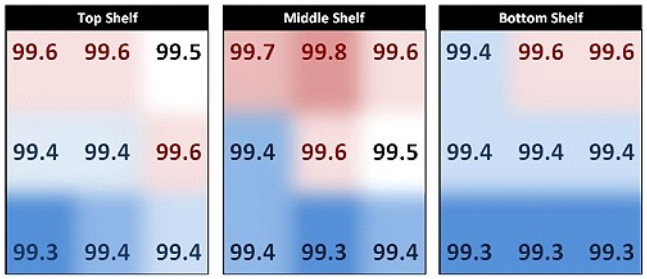
I tested various spots in both my new cabinet incubator and hatcher. There is over a 1.5 degree temperature difference thru-out. The fans are running. Would some please give me advice on how they've modified theirs to get better distribution of heat? I am very handy and have lots of tools. Thank you in advance!

Bree G. – Hatchaholics Anonymous

- **THE PROBLEM**: ALL incubators that are within most hobbyists' budget have both warm and cool spots… temperatures that are consistently warmer or cooler than the average. This includes higher-end incubators such as those made by Brinsea. Variations under 0.5°F are tolerable; greater variations are problematic:

Effects of Temperature Variations	
Prolonged High Temperature	**Prolonged Low Temperature**
early embryonic death blood ring (early death) death of embryo days 7-17 early hatch extended hatch window small, weak chicks chicks with unhealed dry navel malpositioning deformities short wiry down	blood ring (early death) death of embryo days 7-17 dead in shell, not pipped dead in shell, pipped partially zipped, membrane partially torn late hatch extended hatch window chicks with unhealed wet navel, soft bodies malpositioning deformities

- **DIAGNOSIS**: Before using for the first time, ALL incubators should be carefully checked to identify temperature variations and location the warm spots and the cool spots. For small incubators, this can be achieved by simply moving the thermometer around to the various locations. For larger incubators, a thermometer with a long probe is need. I use a calibrated Willhi Temperature Controller and generate a temperature map for reference:

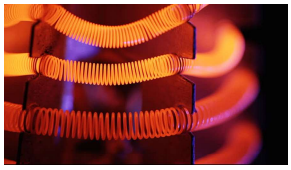


*Proper **incubator placement** has a significant impact on temperature stability*. All incubators should be placed in a room with minimal temperature and humidity variations. Place incubators away from windows, doorways, vents, and drafts. Tuck small incubators away in a corner of the room.

- **MODIFICATIONS**: If there are temperature variations greater than 0.5°F, then modifications to the incubator are required. The simplest modification would be simply adding a fan to moves more air. Intermediate modifications may include adding insulation around the incubator and exchanging the current fan for one that moves more air. Extensive modifications may include adding baffles, ducts, and/or fans to alter air circulation. For my GQF Sportsman 1500, I added an insulation jacket (½" foam board and ½" hardwood plywood) and installed an exterior air duct with axial fan ultimately reducing the temperature variation from 1.2°F to 0.5°F.
- **EGG ROTATION**: Once variations have been reduced to 0.5°F then a simple egg rotation will reduce the ill effects of minor variations:
  1. Placing the newest eggs in the warmest and the oldest eggs in the coolest spots provides more of an ideal temperature for the eggs in their stage of development. (*See Ideal Temperature in the previous section*.)
  2. For desktops, periodically shuffle egg position usually moving eggs from the center to the edges and those on the edges to the center.
  3. For cabinets, periodically remove each setting tray, turn the tray around, and place on a separate shelf.

Temperature: Heat Sinks

A common question asked in poultry groups is, "What incubator should I buy?" Within the responses, we'll almost always see, "Buy a Brinsea. They're the best." Unfortunately, most people cannot afford a Brinsea -- those things are expensive. Some people can barely afford one of those cheap Little Giants sold in Tractor Supply. (I own a cheap Little Giant and think of it as gold.) Successful incubation of chicken eggs need not be an expensive endeavor. Those cheap foam incubators can do a good job if we adopt practices to help them out a little bit.



- **DEFINITION**: A heat sink is an inert substance used to absorb excess heat when the temperature rises and release heat when the temperature decreases. In desktop foam incubation, a heat sink is an important component is maintaining a stable temperature.
- **HEAT RETENTION**: In simple terms, air has a low Heat Capacity – air does a poor job of holding heat – air warms up very quickly and air cools very down quickly.

  This is not a big problem for large cabinet style incubators because they have powerful heating elements (225-250 watts coil). When additional heat is needed, the coil turns red hot quickly and heats the air quickly. When no longer needed, the coil cools down quickly. The latency (wait time) of coil heating elements is small.

  This is not true for smaller, desktop foam incubators. They have weak heating elements (25-40 watts rod) that take time to heat up when needed and time to cool down when no longer needed. The latency of rod elements is large. This leads to greater temperature instability... not good.
- **INCUBATOR PLACEMENT**: For desktop foam incubators, we first combat temperature instability through careful placement -- placing the incubator in the corner of an environmentally controlled room away from doors, windows, vents, and drafts. If possible, we place it between tall furniture to block air from flowing over it. If necessary, we place it in a small bathroom or we construct cardboard walls to place around it. (A closet is not a good spot because of the lack of fresh air.)
- **USING A HEAT SINK**: A second tool we can deploy to combat temperature instability is a heat sink. Heat sinks take up space... the less empty air space, the less temperature instability. Heat sinks also absorb excess heat when the temperature goes too high, and heat sinks release some of that heat when the temperature drops too low. Heat sinks help balance out flaws with the heating element.
  1. **EGGS**: The best heat sinks are the eggs themselves. Since they are mostly water, they have a high Heat Capacity... they hold heat well. Whenever possible, fill your incubator to capacity. If necessary, use infertile, store bought eggs to fill up the empty spaces... simply throw them away when you are done.

  2. **WATER BOTTLES**: Sealed water bottles make superb heat sinks. They consume a good deal of empty space and have a good deal of surface area to absorb/release heat. When using automatic turners, remove one or two of the unused rails to make room for a couple of water bottles.
  3. **ROCKS**: Some people fill the bottom of their incubators with small aquarium type rocks to serve as a heat sink. While not ideal, rocks decrease the amount of empty air space and do absorb/release excess heat. However, using rocks does require special care: (1) the rocks must be washed and sterilized periodically to avoid the growth of mold/bacteria, (2) the rocks should not impede air flow under and around the eggs, (3) moist rocks can play havoc with humidity, and (4) the rocks should not be placed in the water channels.
- **SUMMARY**:
  1. Incubator placement is extremely important in reducing incubator temperature instability.
  2. We want to decrease the amount of empty space without blocking air flow.
  3. We can assist weak heating elements by adding heat sinks that absorb excess heat when the temperature rises and release heat when the temperature falls.

We can be successful incubating chicken eggs even with cheap incubators if we take steps to improve temperature stability.

Turning Eggs

Why do eggs need to be turned during incubation? The most frequent response usually involves, "So the chick will not stick to the shell." Unfortunately, this simple answer is INACCURATE and tends to permit poor practices to creep into our incubation protocols.

- **BENEFITS OF TURNING**: A broody hen will turn her eggs as often as four time per hour, that's up to 96 times per day.[1,2] The primary reason she does this it to ensure all sides of the eggs are equally heated. This turning has a number of other positive effects necessary for proper embryonic development:[3]
  1. **Adhesion**: Prevents *premature* adhesion of the embryo to the inner shell membrane… the chick should not stick to the side before day 6-8.
  2. **Growth**: Embryos in unturned eggs grow at a lower rate compared to embryos in eggs turned each hour over 90˚.
  3. **Yolk**: Stimulates the rate of development of the area vasculosa (the membrane which grows around the yolk and is rich in blood vessels).
  4. **Albumen**: Allows normal transfer of albumen proteins into the amniotic fluid, promoting optimum use of the albumen.
  5. **Blood Vessels**: Supports the growth of the chorio-allantois (blood vessels under the shell) to maximize oxygen absorption.
  6. **Positioning**: Facilitates movements of the embryo into the normal hatching position and reduces the incidence of malpositions in unhatched embryos.

> *As the egg is turned the embryo is swept into fresh nutrients, allowing the embryo to develop. This is critical for the first week when the embryo has no circulation system. After the first week, eggs still need to be turned but not as often.*
>
> *Brinsea Incubation Handbook*

- **ILL EFFECTS OF INADEQUATE TURNING**: The effects of inadequate turning during the first half of incubation is only seen during the second half of incubation, but by then it is too late to take corrective actions.
  1. **Early Death or Weak Chicks**: The embryo simply does not have the access to the nutrients, proteins, and oxygen necessary for optimal development. Inadequate access to the necessary building blocks can result in early death or weak chicks. Weak chicks that survive until hatch time may fail to hatch or lack vigor.
  2. **Malpositioning**: The chick is not situated in the correct position come hatch time.

Inadequate turning, along with improper temperature and humidity, is a leading cause of hatch failure.

- **OPTIMUM TURNING DAYS, ANGLE, & RATE**:
  1. **Initial Resting Period**: Not turning for the first 12 hours after setting permits the egg to rest and restore its internal balance. Some advocate not turning shipped eggs for 24-48 hours to allow the shell membranes to re-attach in eggs with detached air cells.
  2. **1st Week Critical**: Turning eggs is most critical during the first week of incubation. During this time, the embryo is very, very small and can only access the nutrients in its immediate vicinity. Turning helps "churn" the nutrients making them more readily accessible as well as providing the benefits listed earlier. Even though it is generally accepted that turning is not essential after day 15, studies indicates that continued turning improves metabolism and air cell $C0_2$ content both having a positive effect on the hatch rate.[4]
  3. **Optimum Turning Angle**: Numerous studies have demonstrated that tilting eggs a full 45° from the horizontal plane every hour generally provides for satisfactory results. For devices that do not tilt a full 45° or with eggs from older hens, increasing the frequency of turning can produce similar results.

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[1] *Okan Elibol and John Brake, "Turning frequency during incubation," Poultry World, May 26, 2017. http://www.poultryworld.net/Eggs/Articles/2017/5/Turning-frequency-during-incubation-137498E/?cmpid=NLC*

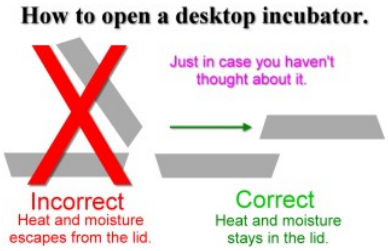
[2] *"Poultry Facts," Purdue Agriculture, Purdue University, NDA, http://www.ansc.purdue.edu/faen/poultry%20facts.html*

[3] *Gerd de Lange, "Relevance of turning," Pas Reform, NDA, https://www.pasreform.com/academy/frequently-asked-questions/incubation/141-relevance-of-turning.html*

[4] *"Incubation Guide,' Hubbard Breeders, <http://www.hubbardbreeders.com/managementguides/Incubation%20guide%20(english).pdf>*

4. **Hand Turning**: The practice of hand turning eggs has largely disappeared with the advent of automatic turners. This is unfortunate for a few of reasons. First, desktop auto-turners only tilt eggs a relatively small degree – there's just not much churning going on. Second, hand turning promotes bonding between the hobbyist and the egg – the entire experience becomes more personal. And, third, briefly opening the incubator for short periods of time better replicates the cooling cycles of the hen periodically leaving the nest.

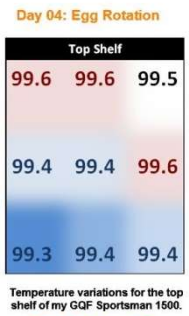
Hand turned eggs should be turned at least three spacing the intervals as evenly as possible. In still air incubators, turning five or more times per day promotes more even heating of both sides of the egg. Developing a routine may be helpful – turn once in the morning upon getting up, once in the afternoon upon getting home from work, and turning once in the late evening before going to bed. For best results, wash hands before turning, move the eggs from the center to the edges and roll the eggs on the edge to the center. Placing an "X" on one side of the egg and an "O" on the other helps to ensure that each egg has been adequately turned.



5. **Desktop Turners May Be Inadequate**: Desktop turners have become commonplace and have greatly eased the burden of hand turning eggs three or five time per day. Unfortunately, most desktop models tilt the eggs only 30-35° from the horizontal plane. While this degree may produce satisfactory result, it is far from ideal. Experimentation by Funk and Forward, 1953, with similar results by Cutchin, 2009, demonstrated that turning eggs at a 45° angle increased the overall hatch rate by 5.9% over a turning angle of 30°.[1,2] If you are using a desktop turner and experiencing less than ideal results, consider hand turning the eggs or purchasing an alternative desktop turning devices, such as Incubator Warehouse's *IncuTurn*.[3]

6. **Cabinet Incubator Tilt Trays**: Not all cabinet incubators tilt eggs a full 45° from the horizontal plane. For example, the newer GQF Sportsman 1502 only tilts eggs about 35°. If possible, increasing the turning time to once at least every 60 minutes may help correct this deficiency. Alternatively, incubating eggs on their side and flipping them 180° at least once a day has proving helpful with larger or more difficult eggs such as goose, duck, and peafowl. Additionally, personal experience demonstrates that early development rates are significantly increased with cabinets that turn once each hour (Brinsea Ova-Easy 380) compared to those that turn only every four hours (GQF Sportsman 1500).

- **EGG ROTATION & TWISTING**: Unfortunately, even the most expensive incubators contain areas that are warmer (hot spots) or cooler (cold spots) that the average incubator temperature. If an egg remains in a hot spot for the entire incubation period, that chick will hatch early – an egg in a cold spot will hatch late. As we know, chicks hatching early or late have greater risk of health problems, consume more feed, and produce less eggs/meat than those that hatch on schedule.



Temperature variations for the top shelf of my GQF Sportsman 1500.
Illustration #1

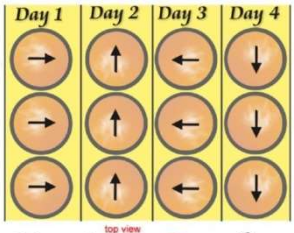


Illustration #2

To combat this flaw in technology, pull each tray daily beginning on day 4, turn it around, and place it on a different shelf. This rotation system ensures that no individual egg sits in a hot or cold spot for an extended period of time. Additionally, the embryo traditionally experiences turning on only two axes (side-to-side). To combat this flaw in technology, periodically twisting each egg 30-45° to the left permits the embryo to experience turning on multiple axes.

Does rotation and twisting have a significant impact on hatchability and chick quality? Anecdotal, personal evidence suggests that it does… to the extent that both are included in my incubation protocol.

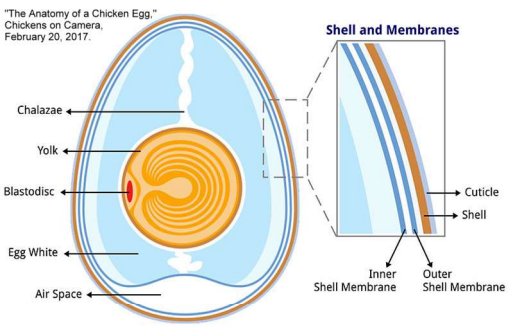
[1] *E. M. Funk and James Forward , "The Effect of Angle of Turning Eggs During Incubation on Hatchability," University of Missouri, June, 1953.*
[2] *H. R. Cutchin, et. al. "Embryonic development when eggs are turned different angles during incubation," Poultry Science Association, 2009.*
[3] *"Incuturn™ Automatic Egg Turner For Hovabator Egg Incubators," Incubator Warehouse, 2017, http://incubatorwarehouse.com/incuturn-egg-turner-hb.html*

Hatching: Shrink-Wrapped & Drowning

Frequently, metaphors (symbols) are used among hobbyists to help beginners understand complex processes. Unfortunately, these metaphors are often taken literally (factually) and lead to an inaccurate understanding. This section is intended to clarify two such metaphors: "shrink-wrapping" and "drowning."

It is perfectly normal and desirable for a chick to be shrink-wrapped prior to hatch.
Very rarely does a chick physically drown within its shell.

- **ANATOMY**: The egg shell contains two membranes – an outer and inner membrane. The outer membrane clings to the shell and protects from the loss of excess moisture and hinders mold, bacterial, and viral penetration. The inner membrane clings to the egg contents (albumen) and serves a similar purpose. The air gap between these two membranes is the air space; it is normally located towards the large end of the egg. As incubation progresses, moisture is lost and the gap between these two membranes increases.



- **SHRINK-WRAPPED**: By day 20, most of the amniotic fluid is gone, the chick has grown to fill the available space, and the inner shell membrane is tightly wrapped around the chick. If we were to open the egg, the chick would appear to be *shrink-wrapped*… this is perfectly normal and does not indicate a problem. The membrane should fit snuggly around the chick.

  When someone says that a chick is "shrink-wrapped," what they truly mean is that the chick failed to pip internally (place its beak into the air cell) and that the inner membrane has dried out – turned white, tough, and leathery. ***The problem is not likely low humidity during hatch time***. Rather, the problem is that the chick is too weak to complete the physically demanding task of pipping, zipping, and hatching. The membrane dries out because the chick takes too long to hatch. Increasing the humidity the final three days slows the drying process but it does not correct the main problem – a weak chick. Instead of focusing on humidity days 19-21, you should focus on what caused a weak chick such as poor ventilation, too much or too little humidity days 1-18, inadequate turning, poor egg quality, temperature too low or too high, or bacterial contamination.

- **DROWNING**: I've never seen a healthy egg with free fluid inside the egg. The term "drowning" is rarely mentioned in academic literature and references high humidity days 1-18. It is not related to the humidity at hatch time. By day 20, most of the amniotic fluid is gone, the chick has grown to fill the available fluid space, and the inner shell membrane is snuggly wrapped around the chick. The remaining internal fluid coats the chick and serves as a lubricant to assist the chick in turning within the egg and eventually pushing its way out of the shell. The air cell is large consuming nearly 1/3 of the total egg space and remains fluid free.

Not all eggs are created equally. Some eggs may have a thick cuticle, thick shell, and/or thick membranes. Such eggs only reluctantly surrender their internal moisture even if the humidity is perfect days 1-18.

  There should NEVER be fluid within the air cell. If there is fluid within the air cell, then a serious problem exists unrelated to humidity… most likely a bacterial infection resulting in a compromised inner membrane. Regardless of the cause, fluid within the air cell results in a gloomy prognosis.

  Rather than drowning, it is more likely that the chick was unable to place its beak into the air cell and take its first breath – it suffocates. If the humidity was too high days 1-18, then the chick grows too large and the air cell is too small. The chick has difficulty turning and may not locate the small air cell. If the humidity was excessively high, then there may also be excessive amniotic fluid within the inner membrane. In such cases, the problem is unrelated to the humidity levels days 19-21. To correct this problem, lower the humidity days 1-18.

  Some people have mistakenly associated this "drowning" with an excessively high humidity during hatching, days 19-21. They claim, "Your humidity is too high. You're going to drown those chicks." This is unfortunate because reducing humidity during hatching increases drying and gives the chick less time to escape.

Excessively high humidity during lockdown can present a problem in the form of heat exhaustion. A combination of excessively high humidity, high temperature, and low ventilation can lead to heat exhaustion – hatching takes a lot of physical labor.

Hatching: Eggs Position

- **GENERAL PHILOSOPHY**: Many individuals see the incubation of poultry eggs as a science and believe following guidelines established by experts is the best path to a successful hatch. In general, I agree BUT also believe that incubation is partially an art form. While I believe that my current methods are effective, I recognize that others may have good ideas and attempting some those ideas may improve my technique.
- **BACKGROUND**: Some hobbyists have taken to placing chicken eggs inside egg cartons during the last phase of incubation. They claim that the cartons hold the egg in a desirable position and prevent unhatched eggs from being bumped by early hatchlings ultimately leading to an improved hatch rate. As a side benefit, the upright shells tend to contain the "gunk" associated with hatching making for easier clean-up.
- **QUESTIONS**:
  1. Does placing the egg in an upright position improve pipping and shell emergence?
  2. Does limiting the bumping of unhatched eggs improve their chances of successfully hatching?
  3. Does placing the egg in an upright position lead to a cleaner hatch requiring less clean-up?
- **CONCERNS:** In Nature, eggs lay on their side during the hatching process and the chick rotates vertically to zip the end of the shell. Placing the egg in an upright position would require the chick to rotate horizontally which seems unnatural. Additionally, with the egg on its side, the hatchling uses its feet to push the shell away. With an upright egg, the bottom of the shell remains stationary while the hatchling must push its entire body out of the shell.

Traditional Placement

- **SETUP**: Fifty eggs – 49 laying hybrids of ¾ Rhode Island Red and ¼ Rhode Island White heritages along with one Serama – were incubated for a period of 18 days on the same tray within a GQF 1500 incubator. No untold events occurred during the first 18 days of incubation. Prior to being transferred to the dedicated hatcher, 25 eggs were placed on their side in a hatching basket (TRADITIONAL) while the remaining 25 were kept in their incubation tray and the entire tray placed in a hatching basket (CARTON). The TRADITIONAL was placed in the hatcher on the third shelf while the CARTON was placed on the second shelf. Prior experience has shown that the second shelf is slightly warmer than the third and that eggs on the second shelf hatch a little earlier than those on the third. Humidity was maintained at ~68%.
- **INITIAL OBSERVATIONS**: The first external pip occurred in the TRADITIONAL. Within two hours a total of five eggs had pipped externally with three being in the TRADITIONAL and two from the CARTON. Within 12 hours of the initial pip, a total of seven hatchlings had fully emerged with five being from the TRADITIONAL and only two from the CARTON. Additionally, multiple pips and nearly emerged hatchlings were observed in the TRADITIONAL with only two additional small pips noted in the CARTON. The initial observations caused concern as the hatchlings from the second shelf were expected to emerge sooner than those of the third.

Upright Carton Placement

- **HATCH SUMMARY**: Forty-one of the total 50 eggs hatched – 23 from the TRADITIONAL and 18 from the CARTON. Three from the CARTON were removed from the carton, the shell over the air cell removed, the eggs laid on their side, and the chicks permitted to exit under their own power. From the TRADITIONAL basket, the Serama egg was under-developed and the other unsuccessful hatchling had pipped and zipped the small end of the egg but failed to emerge. From the CARTON basket, two were under-developed, two had pipped internally but not externally, and the remaining three had failed to pip internally. One leg from a CARTON hatchling had become glued to the carton; the leg was dislodged, and, hopefully, the hatchling will make a full recovery.
- **CONCLUSIONS**: In my opinion, the results are fairly conclusive. ***Eggs placed in an upright position for hatch does not improve pipping or emergence***. In all likelihood, this unnatural positioning tends to inhibit internal and external pipping. Additionally, although the bumping of unhatched eggs may seem disruptive, such bumping does not appear to have a negative impact upon late hatchers. As the "gunk" associated with hatching does remain in the bottom portion of the shell, less clean-up is required when eggs are hatched inside of cartons. However, utilizing porous shelf lining serves a similar purpose without the negative consequences.

Hatching: Hatch Rate

WHAT IS A GOOD HATCH RATE FOR A BEGINNER? A simple question; unfortunately, there is no simple answer. Many people claim 95%, 96%, even 100% hatch rates but those figures may be slightly exaggerated and certainly are not the average.

- **FERTILITY RATE** is the number of eggs that show development upon day seven candling compared to the number of eggs originally set: *85 show development ÷ 100 eggs set = 85% Fertility Rate.*
- **HATCH RATE**: The term "hatch rate" is used in two different manners:
  1. **HATCH RATE FOR ALL FERTILE EGGS**: The number of hatchlings compared to the number of eggs that show development upon day 7 candling: *75 hatchlings ÷ 85 show development = 88% of All Fertile Eggs*
  2. **HATCH RATE FOR ALL EGGS SET**: The number hatchlings compared to the number of eggs originally set *75 hatch 100 ÷ total number of eggs set = 75% of All Eggs Set*

> *A natural hatch using a hen generally has a 50 to 75 percent hatch rate; commercial operations may get up to a 92 percent.*[1]

- **PERSPECTIVE**: Mother Nature is not perfect, and even if the incubation environment is perfect, not all eggs will hatch. Human mothers only have a birth rate of 69% of all fertile eggs (*New England Journal of Medicine*). Commercial hatcheries only set their expectations at 90% of all eggs set... even lower with ducks at 70-75% (*Metzer Farms*). If commercial hatchers – with the best science, genetics, feed, and equipment – only have an expectation of 75-90%, then we should be careful about setting our expectations too high.
- **REALISTIC HATCH RATE**: What then is a realistic hatch rate? In reviewing a *BackYard Chicken* thread, 20 hobbyists listed their honest results of several individual batches.[2]

Average:	50%	*(normal)*			
Mode:	51%	*(most common)*	Median:	50%	*(middle)*
High:	80%	*(high)*	Low:	24%	*(low)*

From this dataset, it appears that a rate of 50% of all eggs set appears to be a realistic goal.

Would I be happy with a 50% hatch rate? No, but I have a solid investment of time, money, and effort in improving my flock, my equipment, and my knowledge. A good hatch rate for me depends on the species, weather, age of flock, genetic pool, and collection conditions. I'm disappointed if I get a goose hatch rate under 90% in February but thrilled with a 50% rate in June. If my black sex-link rate falls below 90% then I'm sad; however, if I get an 85% rate from those same hens using a Dominique rooster then I'm happy.

- **EVALUATION**: How do I tell if it's my incubation process and not a different factor? I use three factors: hatch timing, hatch window, and broody comparison.
  1. **HATCH TIMING**: (Hatch Start) Chicks should begin to hatch towards the start of day 21 – hour 488 is my target. If they start to hatch earlier, then my temperature was too high. If they start to hatch later, then I need to check my thermometer or evaluate my storage method.
  2. **HATCH WINDOW**: (Hatch Spread) All chicks should hatch on day 21. If the last chick hatches more than 24 hours after the first chick, then I need to evaluate my incubator for hot/cold spots, evaluate my storage method, consider the age/health of my hens, or search for clues of contamination.
  3. **BROODY COMPARISON**: If I establish ideal incubation conditions, then my hatch rate should be the same as a broody hen. Last year, my hatch rate was significant higher than my ducks, geese, and turkeys but significantly lower than my Serama bantams. I had no standard size chicken go broody. I need to figure out how the Serama hens are doing better than me.

> ***Most people have an exaggerated idea of the hen's success as a hatcher***. I have a number of records of hen hatching with large numbers of eggs set, and they are all between 55 percent and 60 per cent.
>
> *Milo M. Hastings, The Dollar Hen, National Poultry Publishing, 1911*

- **A LITTLE TALE**: When I first started incubating duck eggs, I thought I was doing a horrible job – my ducks had a 100% hatch rate. My hatch rate was significantly lower. It puzzled me for a while, but then I discovered their secret. Those girls were cheating… I caught them rolling the bad eggs out of the nest so the turkeys would eat them. They only had a hatch rate of 70%; mine was much better.

[1] *"The Science of Incubation," Poultry Science, March/April 2015, pg. 65*
[2] *"Average Hatch Rate Thread," BackYard Chickens, 2010, https://www.backyardchickens.com/threads/average-hatch-rate-thread.378339/*

Hatching: Hatch Evaluation

Your hatch rate is a tool that can help you evaluate your hatching capabilities, but it is not a measure of success or failure. Any hatchling is reason to celebrate because if you didn't try, you would have no hatchlings at all.

Poor hatches happen; and when they do, a wise person will carefully evaluate the entire incubation process to determine what went wrong. Even those with experience will examine each hatch in an attempt to discover what can be improved in future hatches. After completion of each hatch, consider the following points to determine where improvements are warranted:

- **FERTILITY RATE**: Number of eggs set ÷ Number of eggs begin development = Fertility Rate. The fertility rate varies between breeds and species. Although it is unreasonable to expect a fertility rate of 100%, you can improve your odds by:
    1. **FEMALE: MALE RATIO**. Although a ratio of 8 females to 1 male may be suitable for laying type chickens, fertility rate will be much lower if that rate is used with rare, bantam chickens.
    2. **BREEDER HEALTH**: Poor nutrition, inadequate exercise or ventilation, and using a male or female that is too young or too old will have a negative impact on fertility rates.
    3. **GENETIC DIVERSITY**: Breeds or species from a small genetic pool will have a lower fertility rate than more the more common types. Inbreeding can also lower fertility and hatch success.
    4. **CLIMATE EXTREMES**: Eggs laid during excessively hot or cold weather will suffer a lower fertility rate.
    5. **EGG STORAGE**: Eggs that are stored too long or are poorly handled will suffer a lower fertility rate.
    6. **INCUBATOR CALIBRATION**: Incubators that have not been properly warmed and regulated may experience spikes in temperature killing the embryonic germ prior to development.
- **HATCH RATE**: Number of hatched hatchlings ÷ Number of fertile eggs = Hatch Rate. A hatch rate of 85% is generally considered satisfactory among most breeds of fowl. Some species, such as turkeys and bantams will naturally produce a lower hatch rate than average. Other breeds, such as hybrid laying hens, will produce a higher hatch rate than average. The same factors that influence the fertility rate also play a role in the hatch rate. Other factors include:
    1. **LOW INCUBATION TEMPERATURE**: In general, it is better to incubate at a slightly higher temperature, such as 100° F, rather than a slightly lower temperature, such as 99°F.
    2. **HIGH INCUBATION HUMIDITY**: High humidity during incubation leads to inadequate water loss and a small air cell at hatch. Hatchlings experience difficulty in maneuvering within the shell, locating the air cell, and pipping internally leading to drowning.
    3. **INADEQUATE TURNING**: Routine turning provides the embryo with some exercise, allows the embryo to develop uniformly, and prevents the embryo from sticking to the shell. Failure to turn eggs an adequate number of times or an adequate number of degrees decrease hatchling viability and performance.
    4. **LOW HATCH HUMIDITY**: Once a hatchling externally pips, the hatchlings begins to dry and if it takes too long for the them to emerge from the shell, the membrane can dry out gluing them to the shell.
    5. **INADEQUATE VENTILATION**: While studies indicate that high CO^2 levels during the first several days of incubation can improve fertility rates, high CO^2 levels during hatch can prove disastrous. For best results, be sure that all vents are open during hatch. Open vents work to lower the humidity during hatch, but this effect can be countered by adding as many wet sponges as needed.
    6. **HIGH HATCH TEMPERATURE**: Hatching is an exhausting activity that required a hatchling's full energy. If the temperature during hatch is too high, hatchlings are more likely to exhaust themselves prior to emergence from the egg. I maintain a hatch temperature of 98.5° F to avoid this problem. However, this temperature should only be used with dedicated hatching units. It is unwise to alter temperature settings while eggs are in the unit.
    7. **UNANTICIPATED EVENTS**: Unavoidable events such as power outages, the door accidentally left unlatched or equipment failure happen.
    8. **ENVIRONMENTAL**: Fluctuations in temperature and humidity caused by inadequate placement of incubator, room temperature and humidity variations, and poorly operating or designed equipment.
- **EGGTOPSY**: Not all chicks will hatch. There are multiple reasons why this occurs from hen nutrient deficiencies, cold temperatures during collection, bacterial contamination, genetic flaws, and flaws in incubation methods. Eggs that did not hatch should be opened and examined to determine, if possible, why the chick failed to hatch. The following link from The Chicken Chick provides an excellent look at the stages of development: http://www.the-chicken-chick.com/2012/03/chicken-embryo-developmentviews-from.html.

Hatching: 21 Days of Incubation

Chickens should hatch on day 21 of incubation.
The elapsed time between first chick and last chick should be no more than 24 hours.

While each incubator and each batch of eggs are unique, hatch time should be fairly consistent. Evaluating imperfect hatch results will help us identify flaws in our incubation method, take corrective actions, and ultimately improve our techniques. After each batch, I consider each of the following items to discover how I can make the next batch better:

GOAL 1: THE HATCH SHOULD BE COMPLETE BY THE END OF DAY 21

- **MOST EGGS HATCH LATE: POWER OUTAGE**: If the electricity goes off or the incubator inadvertently becomes unplugged, the temperature will drop. While most eggs can tolerate lower temperatures for several hours, the hatch will be delayed. Small eggs lose heat faster than large eggs and will usually hatch even later.
- **MOST EGGS HATCH LATE: LOW AVERAGE TEMPERATURE**:

> Yep, I had my thermometer in the wrong place (taped in the window at top) first hatch - failed miserably it was a 10° degree difference! *Nichole Hansen, Backyard Chickens*

  1. **THERMOMETER PROBE TOUCHING EGG SHELL**: As the chick grows, it begins to generate its own heat through metabolism. As development progresses, the shell temperature becomes warmer (101° F) than the circulated air. If the bulb or probe is resting on the egg shell, the thermometer will read high.
  2. **THERMOMETER PLACEMENT LEVEL TOO HIGH**: Warm air rises and cool air sinks. The incubator's temperature should be measured at the TOP of the eggs especially for still air incubators. While the fan in desktop forced air models circulates air, they still experience heat layering and the thermometer probe should be kept at egg top level.
  3. **THERMOMETER INACCURATE**: Digital thermometers should be accurate to ±0.2° F. Unfortunately, most are only accurate to ±2.0° F meaning if the display reads 99.5° F the actual temper ature can be anywhere from 98.5° F to 100.5° F. when buying a digital thermometer ensure that it is accurate to ±0.2° F.
  4. **THERMOMETER UNCALIBRATED**: Most thermometers claim to be calibrated at the factory, but almost all thermometers are incorrect. Thermometers should be calibrated by placing its bulb/probe in a pan of crushed ice and water – the thermometer should read 32.0° F.
  5. **THERMOMETER PROBE/BULB IN COOL SPOT**: All incubators have warm and cool spots. If the thermometer is kept in a warm spot, then the overall temperature will be cooler than needed. When regulating your incubator, measure the temperature is several different areas. Place the thermometer in an area that is neither cool nor warm.

- **MOST EGGS HATCH EARLY: HIGH AVERAGE TEMPERATURE**:

> Because overheated chicks hatch earlier than they should, they are often smaller, weaker and more prone to infections as well as a host of other health problems. *Cobb Hatcheries*

  1. **THERMOMETER PLACEMENT LEVEL TOO LOW**: Warm air rises and cool air sinks. The incubator's temperature should be measured at the TOP of the eggs especially for still air incubators. While the fan in desktop forced air models circulates air, they still experience heat layering and the thermometer probe should be kept at egg top level.
  2. **THERMOMETER INACCURATE**: Digital thermometers should be accurate to ±0.2° F. Unfortunately, most are only accurate to ±2.0° F meaning if the display reads 99.5° F the actual temperature can be anywhere from 98.5° F to 100.5° F. when buying a digital thermometer ensure that it is accurate to ±0.2° F.
  3. **THERMOMETER UNCALIBRATED**: Most thermometers claim to be calibrated at the factory, but almost all thermometers are incorrect. Thermometers should be calibrated by placing its bulb/probe in a pan of crushed ice and water – the thermometer should read 32.0° F.
  4. **THERMOMETER PROBE/BULB IN WARM SPOT**: All incubators have warm and cool spots. If the thermometer is kept in a warm spot, then the overall temperature will be cooler than needed. When regulating your incubator, measure the temperature is several different areas. Place the thermometer in an area that is neither cool nor warm.

GOAL 2: ALL CHICKS SHOULD HATCH WITHIN A 24 HOUR PERIOD (HATCH WINDOW)

- **EGGS STORED ABOVE 68° F**: A chicken embryo begins to grow before the hen lays the egg; however, this process ceases at temperatures below 68°F permitting hens to lay full clutches before incubation begins.[1] Common practices allow eggs to be stored at room temperature for seven to ten days; unfortunately, older eggs may experience greater development than newer ones as room temperature approaches 80° F. For best results, store eggs below 68°F (55-65°F) allowing them to warm to 75-80°F prior to setting.

> Cooling at ordinary temperatures will not kill the embryo, and it will begin to develop again when the egg is placed in the incubator. Keeping eggs at temperatures above about 80° F (27 C) prior to incubation will cause a slow growth which leads to a weakening and eventual death of the embryo. *University of Illinois, 1988*

- **HOT & COLD SPOTS INSIDE INCUBATOR**: Few incubators maintain perfectly even temperatures in all areas – some spots will be warmer and some spots cooler – differing as much as one full degree. Fans help circulate the air reducing temperature variations; however, automatic egg turners, covering the mesh flooring, and cramming eggs into a small space decrease air flow and fan effectiveness. Many hobbyist set their eggs in the turner and then hope that the incubator will do all of the work; unfortunately, eggs resting in a cool spot for the entire incubation will hatch later than those resting in a warm spot. For best results, eggs should be shuffled periodically – eggs in the center moved to the sides and those on the sides to the center.

> Broody hens provide optimum conditions for embryos developing in the eggs they are sitting on. The brood patch provides heat from one direction only, and the eggs at the side of the patch are cooler than those in the middle of the nest. However, because the broody hen regularly turns and moves the eggs in the nest, uniform egg temperature is achieved. *Pas Reform Hatchery Technologies*

- **EGGS STORED DIFFERENT LENGTHS OF TIME**: According to Cobb Hatcheries, not only does prolonged storage decrease hatchability (about 1% for each day after the initial six) but it also prolongs incubation time, "On average, one day's storage adds one hour to incubation time."[2] To decrease the storage effect, eggs should be carefully stored using the following recommendations. Warm eggs for 6-12 hours before setting.

Hubbard Hatcheries	Days of Storage						
	1-2	3-4	5-6	7-8	9-12	13-16	17-20
Temperature	66.2°F	62.6°F	59.9°F	57.2°F	54.5°F	53.6°F	52.7°F
Humidity	70.0	80.0	85.0	90.0	90.0	90.0	90.0
Turning	No	No	No	No	Yes	Yes	Yes
Small end up	No	No	No	No	Yes	Yes	Yes

- **EGGS FROM YOUNG & OLD HENS**: Research indicates that eggs from hens 32-45 weeks old produce the healthiest and most vigorous chicks. Unfortunately, most home flocks consist of hens from various age groups. For best results, attempt to avoid eggs from very young or very old pullets. While these may produce healthy chicks, they expand the hatch window and experience more difficulties.

> Maternal age directly affects the rate of embryonic development. Embryos from 'pubescent' flocks (< 32 weeks) require longer incubation periods than embryo's from 'mature' flocks (>32 weeks). *The Poultry Site, 2006*

- **EGG SIZE VARIATIONS**: Within an environmentally stable and consistent environment, small eggs will hatch at the same time as large eggs. When the temperature within an incubator is inconsistent – bounces up and down – smaller eggs will hatch significantly earlier or later than larger eggs – small eggs heat up and cool down faster. If this occurs, consider your incubator placement and move to a location free of drafts, heating/cooling vents, and direct sunlight or a room with a more stable environment.
- **BREED VARIATIONS**: Some breeds require a few more or a few less hours of incubation than the average, for example game fowl average 12 hours and Cream Legbars 4-5 hours longer than standard breeds. For best results, track each of your breeds to identify and breed specific time differences.

[1] *from Gaylene M. Fasenko, "Optimal egg storage conditions," University of Alberta, 2006*

[2] *"Hatching egg storage and transport," Cobb Hatcheries, NDA, <http://www.cobb-vantress.com/cobb-academy/overview/blog/detail/cobb-academy/2012/12/14/hatching-egg-storage-and-transport>*

Hatching: Malpositioning

NORMAL HATCHING POSITION: The normal hatching position is where the spine of the embryo runs parallel to the long axis of the egg and the beak is positioned underneath the right wing. The tip of the beak is directed towards the air cell in the blunt pole of the egg. When the beak is under the right wing, the wing holds the shell membrane away from the face of the embryo and thus gives the beak more freedom of movement. In addition, the wing helps stretch the inner shell membrane and helps the piercing of this membrane by the beak. In this way, the embryo gains access to the air cell of the egg and begins to ventilate its lungs.[1]

COMMON MALPOSITIONS[2],[3]

					
Head between thighs. Largely fatal High temp. Retarded development	**Head in small end of egg.** 50% fatal Assist required	**Head turned to left.** 20% fatal Hen nutrition High temp. Setting position	**Beak away from air cell.** Largely fatal Never breaths	**Feet over head.** Often fatal Assist required	**Beak above right wing.** Often fatal Small eggs Round eggs Heat stress

There are a variety of reasons why malpositioning occurs. If a large number of malpositioning occurs – more than 2% -- then you should take steps to identify and correct the problem:

- **SMALL END UP**: Eggs are placed in the turner or setting tray with the small end facing up. This most frequently occurs in eggs that are more round than pointy. For best results, candle rounder to identify the air cell location prior to setting. There is an 80% chance that eggs set upside down will hatch normally. However, correcting the error by day 8 greatly reduces the chances of malpositioning.
- **POOR EGG QUALITY**: Egg shell quality problems or content problems associated with advancing hen age, nutrition, health, or season.
- **INADEQUATE TURNING**: Turning angle of less than 45° from center and/or turning rate of less than once per hour. Remember desktop turners frequently only tilt the egg 30° with a rate of every two hours. Some cabinets tilt only 35° every four hours. When possible, increasing the turning rate will help alleviate inadequate angle. When hand turning, turn at least three times a day. If malpositioning is frequent, increase hand turning to five time each day.
- **HIGH HUMIDITY DAYS 1-18**: Inadequate water loss (less than 12%) results in a large chick that has difficulty maneuvering within the egg.
- **SMALL AIR CELL**: Frequently related to high humidity days 1-18, improper temperature, and/or inadequate ventilation.
- **MOVEMENT DISRUPTION**: Chicks begin to move into position days 11-14. Low temperatures or rough handling (due to candling) can disrupt this process resulting in malpositioning.
- **TEMPERATURE**: Lack of temperature control – too high, too low, spikes, or dives – can lead to harm, poor develop, or weak chicks that fail to move into the proper hatching position.

[1] Steve Tullett, "Investigating Hatchery Practice: Examining the Hatch Debris," ROSS TECH, October 2009
[2] Images Steve Tullett, "Investigating Hatchery Practice: Examining the Hatch Debris," ROSS TECH, October 2009
[3] Information in this chart was obtained from multiple sources and should not be construed to represent the only cause or outcomes.

Hatching: Result Analysis[1]

Clear eggs found at candling: No signs of embryonic development, eggs are infertile	
• Immature males • Too many hens or not enough males • Extreme climatic conditions • Old breeder flock	• Health problem • Males or females too heavy • Excess or deficiency of nutrients, feed control too strong • Parasites
Clear eggs found at candling: Signs of embryonic development (enlarged germinal disc), eggs are fertile	
• Storage period too long • Inappropriate storage conditions • Heat shock • Pores blocked	• High temperature at the start of incubation • Flock too young or too old • Health problems • Frequency of egg collection is insufficient or incomplete
Clear eggs found at candling: Presence of the blood ring or a dead embryo before 3 days of incubation, no black eye visible	
• Egg storage too long or wrong temperature • High temperature at the start of incubation • Insufficient temperature at the start of incubation • Health problems	• Flock too old • Severe nutritional deficiencies • Contamination
Dead embryos: 3 to 17 days of incubation	
• As above • Insufficient ventilation or blocked pores	• Inadequate turning • Inadequate turning angle
Dead embryos: >18 days of incubation	
• Inadequate temperature, humidity, turning or ventilation • Contamination • Eggs cooled during transfer, or transfer done too late	• Broken eggs • Malposition of the embryo • Hatcher opened too frequently during pipping or hatching
Non pipped eggs, embryos completely formed, a part of the yolk is not completely absorbed	
• Inadequate turning • Humidity too high during incubation or after transfer • Insufficient temperature during incubation	• Hatcher temperature too high • Inadequate ventilation • Prolonged storage
Eggs pipped, embryos completely formed, dead in shell	
• Insufficient humidity or temperature during long periods • Insufficient humidity in the hatcher • High temperature in the hatcher • Insufficient ventilation	• Inadequate turning during the first 12 days • Prolonged storage
Early hatch, noisy chicks	
• Small eggs • Difference between breeds	• Incubator temperature too high • Incubator humidity too low
Delayed hatch	
• Big eggs • Old flock • Prolonged storage	• Insufficient temperature during incubation • Weak embryos • Humidity too high during incubation
Hatch window is too long	
• Mixing of eggs stored for different lengths of time in • Mixing of eggs from both young and old flocks • Mixing of both small and big eggs	• Incorrect egg handling • Hot or cold spots in the incubator or hatcher • Incubation or hatch temperature too high or too low
Poor uniform hatch between the different hatch trays	
• Mixing of small and big eggs • Mixing of eggs from both young and old flocks • Mixing of eggs from different breeds • A part of the eggs were stored for too long	• Inadequate ventilation in either the incubator or hatcher • Health problem in one or more flocks • Different storage conditions

[1] *adapted from "Incubation Guide," Hubbard Breeders, <http://www.hubbardbreeders.com/managementguides/Incubation%20guide%20(english).pdf>*

Sticky chicks, traces of albumen on the fluff	
• Insufficient temperature during incubation • Humidity during incubation too high • Inadequate turning	• Old eggs • Eggs too big
Chicks stuck to the shell, chicks with part of the shell stuck to their fluff	
• Humidity too low during storage, incubation and/or hatching • Inadequate turning	• Eggs broken or poor shell quality
Early hatch, umbilical buttons	
• Temperature too high during incubation or hatching	
Small chicks	
• Small eggs • Insufficient humidity during storage or incubation	• Temperature too high during incubation • Porous or weak shells
Navel not closed, dry fluff	
• Temperature high during incubation • Variation of temperature • Insufficient temperature during hatching	• Humidity during hatch too high • Insufficient ventilation at the end of hatching • Inadequate breeder nutrition
Navel not closed, wet, smelly. Big chicks, lethargic, soft abdomen	
• Insufficient temperature in the incubator • Humidity high in either the incubator or hatcher	• Inadequate ventilation
Weak chicks	
• Temperature high in the hatcher • Ventilation insufficient in the hatcher	• Contamination
Mal-position	
• Eggs incubated with the small end up • Inadequate turning • Temperatures during incubation high or low • Humidity high	• Old flock • Eggs too big • Poor transport and storage conditions
Malformation	
• Inappropriate storage conditions • Poor hatching eggs transport conditions • Nutritional deficiencies • Inadequate turning	• Poor orientation of the eggs (eggs small end up) • Temperatures during incubation too high or low • Health problems • Inadequate ventilation or thick shells
Curled toes, splayed legs	
• Temperatures during incubation high or low • Nutritional problems	• Wet hatcher tray surface
Short fluff, dry, rough	
• Nutritional deficiencies	• High temperature during the first 14 days of incubation
Dwarf like chicks, insufficient growth	
• Contaminated eggs • Contamination particularly during hatching • Health problems	• Nutritional deficiencies • Thyroid anomaly
Exploding eggs	
• Dirty eggs or nests • Floor eggs • Inadequate egg washing, dried or cleaned with dirty cloths • Dust in breeder house or storage room or transport	• Condensation on the egg shell surface • Using a contaminated solution to spray the eggs • Eggs contaminated by other exploding eggs • Handling eggs with dirty hands

Incubating Waterfowl

Much of the information pertaining to hatching chickens applies to ducks and geese, but there are differences.

- **DIRTY EGGS**: Unlike chickens, waterfowl are more likely to lay their eggs on the ground frequently near a water source; therefore, their eggs may be contaminated with bacteria and coated in mud or dirt. Since egg are most susceptible to bacterial invasion before the cuticle dries, washing eggs have little effect on infections. However, if the shell pores are block, the egg cannot "breath" and the developing embryo will die. Under running water at 10°F higher than the egg, use a gentle rubbing motion with your thumb to remove any excess dirt. Be sure that the egg shell is completely dry before storing.

Some hobbyists promote the use of antiseptic solutions to clean and periodically spray the eggs. If used, ensure the solution is at least 10°F warmer than the egg and that the solution does not alter the chemical composition of the egg shell. We cannot kill bacteria that have already entered the egg.

- **DUCK TURNING TRAYS**: Duck eggs, except mallard and call ducks, are large and may not fit comfortably into regular trays. In desktop models, it is probably best to remove the automatic turner, lay eggs on their side, and turn manually. For cabinet, extra-large trays used for turkey, ducks, and peafowl are required.
- **GOOSE TURNING TRAYS**: Goose eggs are large, sometimes very large and require a special incubation tray or set on their side during incubation. For desktop models, I lay the eggs on their side and turn them by hand. For cabinets, I fabricate a goose egg tray using ½ inch hardware cloth by folding the wire in a |_|_|_|_| manner.
- **SETTINGS**: Mallard ducks hatch in 26.5 days, Pekin in 28, Muscovy ducks in about 35, and geese in 30. A humidity of 60% is generally recommended; however, my general setting of 40-43% provides satisfactory results. ***Waterfowl do not tolerate lower temperatures***… a little warmer is better than a little cooler.
- **COOLING & MISTING**: Many waterfowl egg shells are thick and hard making it difficult for the duckling/ gosling to emerge at hatch time. Although the exact mechanism is unknown, allowing the eggs to cool followed by a misting of lukewarm water causes the shell to become more brittle. Personally, following day 7 of incubation, I remove the eggs from the incubator, allow them to sit on a counter at room temperature for 15 minutes, mist one side with lukewarm water, flip each egg 180°, mist the other side, and then replace them in the incubator. If you have an infrared temperature gun, the shell surface should cool to 86° F. Do not cool or mist the eggs once turning stops three days before hatch.

Rigorous turning appears to be vital with waterfowl eggs. Many automatic turners tilt the eggs only 30° and only tilt the eggs every four hours. For waterfowl, this may be inadequate. For best results, tilt trays should tilt at least 35-45° every hour. If this is not possible, turn by hand 5 times a day.

- **HATCHING TEMPERATURE**: If you can do so without affecting other eggs, ducklings and goslings benefit from a lower temperature during hatch – 98.0-98.5° F. Do not attempt to adjust on models where you must turn a small knob to adjust the temperature; the risk of causing excessive temperature swings outweighs any potential benefits.
- **HATCHING**: Normally, the first pip will occur 36-48 hours prior to the hatch date. It can take 24-36 hours for a duckling to completely zip the shell and emerge. They will naturally rest between efforts so resist any temptation to help a tired duck from their shell. Be patient, unless there has been an unexpected incubation event, healthy ducklings will emerge from the shell under their own power.
- **BROODING**: Ducks and geese are excessively messy birds. Do not use water containers that allow them to play in the water as the litter will become damp promoting the growth of mold. Additionally, the down of artificially brooded ducklings and goslings does not repel water; a wet ducklings and goslings chills easily resulting in death. Personally, I brood waterfowl on old, cloth towels for the first three days and then raise them on ½ inch hardware cloth thereafter. I do not allow ducklings or goslings to swim until their down has been largely replaced with feathers.

> *While some birds that are assisted from the shell develop into fine specimens, a large percentage of them are usually handicapped by a deformity or weakness. When it is understood that the hatch is a fitness test given by nature to cull out the weak and deformed-protecting them from facing a life for which they are unprepared, we can take a more realistic view of helping ducklings from the shell.*
>
> *David Holderread,*
> *Raising a Home Duck Flock. 1978*

Incubating Peafowl

Many say that peafowl are especially difficult to hatch. I have yet to find that to be true; however, there is a lot less room for error with peafowl than chickens. Most of the information provided in this guide applies directly to peafowl, but there are a few specifics that need to be considered:

Precision is extremely important with peafowl. A temperature of 99.0° is close, but it is not close enough. A humidity that fluctuates between 40% and 60% will result in a poor hatch. Trusting automatic turners is dangerous. Calibrate your instruments and check your turner. Precision makes a difference.

- **INCUBATION PERIOD**: Peafowl require 28 days of incubation.
- **MALE-FEMALE RATIO**: A study at the Punjab Wildlife Research Institute indicates that a 1:3 mating ratio results in significantly higher fertility (80%) and hatchability (62%) of peafowl eggs when compared to either a 1:1 (34% and 25%) or 1:2 ratio (65% and 40%).[1]

- **SETTING & TURNING**: Peafowl do best when they are set on their side. While chickens do alright if you forget to turn them routinely, peafowl are less forgiving. When turning by hand, turn eggs no less than five times per day. When using cabinet incubators, place on their side, allow the turner to tilt the eggs, and flip the eggs by hand 180° daily starting on Day 3.
- **INCUBATOR PLACEMENT**: Peafowl do better when the incubator is placed where the climate experiences little temperature and humidity variations. Be especially careful to avoid rooms with a low humidity; peafowl eggs seem to be sensitive to low humidity.
- **INITIAL SETTING**: Some breeders initially place their peafowl eggs under broody hens for the first week and then transfer them to an artificial incubator. Personally, I get them started by placing them in my Brinsea 380 on their side with a temperature of 100.5° F. I do not turn for the first 12 hours; thereafter, I engage the automatic turner and manually flip them 180° daily to avoid them laying on one side for an extended period.

Rigorous turning appears to be vital with peafowl eggs. Many automatic turners tilt the eggs only 30° and only tilt the eggs every four hours. For peafowl, this may be inadequate. For best results, tilt trays should tilt at least 35-45° every hour. If this is not possible, turn by hand 5 times a day.

- **SETTING TRAY PLACEMENT**: The temperature within a cabinet incubator can vary by 0.5-1 degrees between the top and bottom shelves. While it may be difficult to correct these variations in temperatures, they can have a significant impact on hatchability. Place newer eggs on the top shelf as they benefit from the slightly warmer temperature. Place older eggs on the bottom as they do better with lower temperatures.
- **HUMIDITY**: Peafowl lose internal water at a faster rate than chicken eggs and require higher incubation humidity; 60% is generally recommended. However, within my incubators, a humidity setting between 43-48% provides good results – some air cells will still be larger or smaller than the average. These variations do not affect hatchability.
- **DAILY COOLING**: Peafowl shells are thicker than chicken eggs making it more difficult for the peachick to emerge at hatch time. Although the exact mechanism is unknown, allowing the eggs to cool causes the shell to become more brittle. Following day 7 of incubation, I remove the eggs from the incubator, allow them to sit on a counter at room temperature for 10 minutes, flip each egg 180°, and then replace them in the incubator. If you have an infrared temperature gun, the shell surface should cool to 90° F. Do not cool eggs once turning stops three days before hatch.
- **BROODING PEACHICKS**: Peachicks hatch by a hen do well when cared for by their mother. For some reason, they seem to avoid the ill effects of Coccidiosis while peachicks artificially hatched and brooded do not. Artificial brooding should involve keeping the peachick off the ground until they are 14-18 weeks old along with feeding medicated feed. Additionally, peafowl mature at a much slower rate than chickens. While chickens will be completely mature by 6 months, it takes 2 years for peafowl. Consequently, peafowl benefit from a longer stay under artificial heating and lighting.

[1] *Mushtaq-ul-Hassan, "Effects of mating sex ratios in Indian peafowl,"Iranian Journal of Veterinary Research, Shiraz University, Vol. 13, No. 2, Ser. No. 39, 2012*

Incubating Turkeys

Many hobbyists report that turkeys are more difficult to hatch than chickens. Many factors may contribute to this perceived difficulty such as smaller genetic pool, inadequate protein feed for parent stock, larger egg size, and incubator temperature instability. Turkeys can be hatched successfully when attention to detail if given to each factor involved in the incubation process.

- **NUTRITION**: Successfully hatching turkey eggs is largely dependent of the health and vigor of the parent stock. Hobbyists frequently confuse "meat production" with "heritage" breeds. While meat production benefits from feed with high protein levels, heritage birds do not and high protein feed has been associated with lower hatchability.[1] Heritage turkey feed should contain only 17% protein. Focusing on quality and freshness provide greater benefits than a focus on protein.

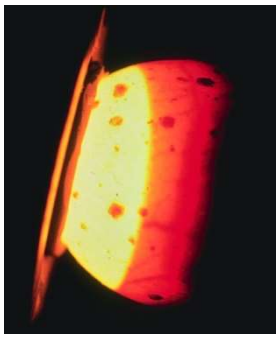
> High energy level feeds are used to grow market birds; however, when feeding potential breeding stock, the feed should contain more fiber so birds do not put on excess body fat. High protein levels in the diet of breeding birds will have negative effects on the hatchability of eggs.
>
> *The Livestock Conservatory*

- **INCUBATION PERIOD**: Turkeys require 28 days of incubation.

> Rigorous turning appears to be vital with turkey eggs. Many automatic turners tilt the eggs only 30° and only tilt the eggs every four hours. For turkeys, this may be inadequate. For best results, tilt trays should tilt at least 35-45° every hour. If this is not possible, turn by hand 5 times a day.

- **EGG SIZE**: Turkey eggs are about 50% larger than chicken eggs; they take up more space in the incubation tray and take more time to warm than chicken eggs. Turkey eggs are generally too large to fit correctly in desktop automatic turners requiring eggs to be placed on their side and hand turned. In cabinets, eggs from mature hens may be too large to comfortably fit into extra-large plastic setting trays. Extra-extra-large eggs set in an upright position may also strike the tray above them causing damage to the shell. For eggs from mature hens, I hand fabricate a special setting tray from ½" hardware cloth using a |_|_|_|_| weave, set the eggs on their side, and flip the eggs 180° daily after day 3.

- **STILL AIR DESKTOP MODELS**: It is very important that the temperature be regulated at the top of the turkey eggs; do not assume that the setting used for your last batch of chickens will be satisfactory for a new batch of turkeys.
- **TEMPERATURE PRECISION**: My hatch rate for all eggs set the first year was about 75%; I was able to increase that rate to 90.4% the second year by focusing on better temperature control during the various stages of development. Turkey eggs are larger than chickens and a turkey embryo will produce more internal, metabolic heat than a chicken. Placement within the incubator seems to have a significant impact on hatchability – newly set eggs are placed on the top shelf where the temperature is warmer, 100.0°F and the oldest eggs are placed on the bottom shelf where the temperature is cooler, 99.0°F. Additionally, lowering the temperature to 98.5° F during the active hatching phase reduces the hatching stress and end-stage mortality.



- **CANDLING EGGS**: Turkey eggs are frequently thicker and darker than chicken eggs making it more difficult to clearly visualize the interior during candling. Frequently, after the first two weeks, only dark and light are visible within the egg. Movement may or may not be visible. In generally, development can be judged by the growth of the dark area rather than visualization of finer details.[2]
- **HATCHING**: Many of my turkeys have pipped internally when I move them to the hatcher at the end of day 25. They usually pip externally by the beginning of day 27 and start hatching by the beginning of day 28. Be patient; they take their time from external pip to hatching.

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[1] *Jeannette Beranger, et. al. "Feeds and Feeding of Free Range Turkeys," Heritage Turkey Manual - How to Raise Heritage Turkeys on Pasture, The Livestock Conservatory, 2007*

[2] *R. A. Ernst, et.al. "Egg Candling and Break Out Analysis for Hatchery Quality Assurance and Analysis of Poor Hatches" Animal Science Department, University of California <http://animalscience.ucdavis.edu/Avian/pfs32.htm>*

Brooding Hatchlings: Artificial

- **BROODER**: A brooder is a heated enclosure in which young fowl or livestock are raised. Brooders need not be sophisticated or permanent structures; they need only to protect young hatchlings from cold, drafts, and dampness. A simple plastic tub with a screen covering placed in a back room is well suited for many beginners. A good brooder has the following traits:
- **LOCATION**: Brooders should be located within a structure with a relatively stable environment free from drafts and moisture. Almost any small building with good ventilation is suitable in the late spring or early summer. Greater protection is required when temperatures are extremely low or high. An insulated or semi-heated garage or shed may be suitable for a brooder during colder weather.
- **SPACE**: Hatchlings need sufficient space to move, when necessary, away from the heat source. A large 30 gallon plastic tote is large enough for 10 chicks for up to 3 weeks. General space recommendations include:

Age of chicks	Floor space per bird	Sample Enclosure for 10 birds
0 to 4 weeks	½ square feet	2 ½ foot x 1 foot
4 to 8 weeks	1 square feet	3 foot x 3 ⅓ foot
Small chick juveniles	1 ½ to 2 square feet	3 foot x 6 ⅓ foot
Large chick juveniles	2 to 2 ½ square feet	3 foot x 8 ⅓ foot

Since chicks tend to push and pile on top of one another, any enclosure with more than 25 chicks should have rounded corners to prevent suffocation.

- **ENCLOSURE**: The brooder should have a wall height of 12-18 inches or more to protect against drafts and to keep hatchlings corralled. A screen or wire lid will prevent older chicks from flying out of the enclosure.
- **HEAT**: A single 250 watt red heat lamp suspended 18 inches above the brooder floor is sufficient to brood 80 chicks. Two 60 watt yellow bug light may provide sufficient warmth for 20 or less chicks within a controlled environment. When possible, avoid bright, white light as it induces picking and may be disrupt sleep. Temperature is very important and the use of a thermometer at floor level is highly recommended. For small birds, such as bantam, the temperature may need to be slightly higher.

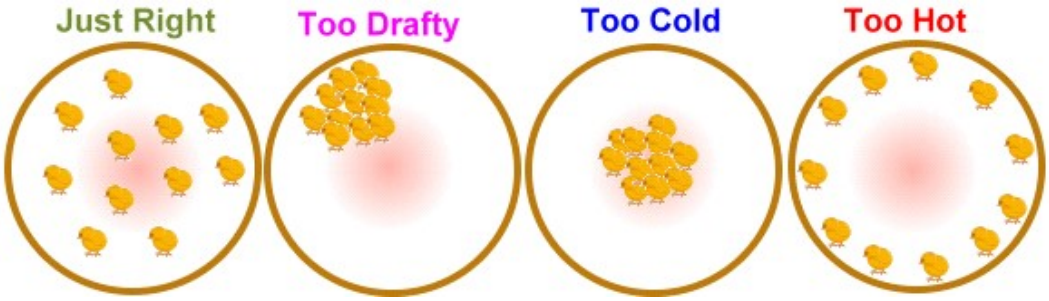
General Heating Requirements													
Week:	0	1	2	3	4	5	6	7	8	9	10	11	12
Temp:	95°	90°	85°	80°	75°	70°	65°	60°	55°	50°	45°	40°	35°

CAUTION: Over time, heat will accumulate in the brooder and bedding. Always ensure that hatchlings have sufficient space to move away from the heat source should they become overheated. Too small of space can result in injury or death.

CAUTION: Heat lamps in brooders and coops are a major source of home fires. Use only ceramic receptacles with an appropriate reflector. When using clamp-on types, secure the lamp with a secondary safety cord in case the lamp falls.

Visual observation best evaluates hatchling comfort.

If the hatchlings bunch up under the heat source, they are too cold. If the hatchlings scatter to the edge of the enclosure, they are too hot.



Two lamps are important. If one burns out in the wee hours of the night, the other will keep the chicks warm until morning. Placing a sheet of cardboard over the brooder helps retain heat, but be very cautious about keeping anything flammable away from hot bulbs.

- **BEDDING**: Large flake pine wood shavings are the favorite bedding for brooders. Rice hulls, dry straw, or hay can also make good bedding. For the first few days, place an old sheet, cloth towels, paper towels, or similar material on top of the shavings. This better enables the hatchlings to gain their feet, move about easily, and find their feed. ***DO NOT USE*** fine shavings, saw dust, or sand as very young chicks may consume these materials which can lead to an impacted craw, decrease consumption of feed, and possibly death. Fine shavings and sand may be suitable after a week or two after the chicks learn to eat. Cedar or cypress shavings should be avoided because many consider them toxic.
- **WIRE FLOORING**: My brooders have ½" hardware cloth wire flooring with a plastic tray underneath to capture and easily remove droppings. For standard size chicks, the wire is covered with old towels for the first two weeks; for bantams for three to four weeks; and mallard ducks for the first week only. Although some claim that hardware cloth flooring may harm a hatchling's feet, I have had no such incidents but rather find the practice more sanitary with less odor than traditional pine shavings.
- **OUTDOORS**: Except in extremely cold climate, most hatchlings can safely be placed in an unheated outdoor shelter once they fully feather (about 6 weeks for chicken) as long as the shelter is well ventilated but draft free.
- **FEEDING & WATERING**: Just before a hatchling emerges from its shell, it absorbs the remainder of its yolk. This absorbed yolk provides the hatchling with sufficient food and water for 48 to 72 hours. A hatchling may be reluctant to eat or drink for the first 24 hours but should actively be doing both by the end of the second day.
- **FIRST DAY**: When moving the hatchlings from their transit box to the brooder, dip each beak into waterer before turning them loose. For the first day, sprinkle feed about the feeder and waterer to make it easy for the hatchling to locate the feed. Avoid sprinkling any feed directly under the heat source. Do place the feeder inside the brooder – the hatchlings should soon locate and use it. Adding smashed boiled egg yolk on top of the feed may help the hatchlings get started and eating right away; remove uneaten boiled eggs after a couple of hours.
- **FEED**: Individual species may require a specific starter feed formula, and different feed companies formulate their feed differently. For best results, follow the feeding instructions found on the bag of the feed you use. The following chart illustrates common recommendations.

General Feed Recommendations

Age in Weeks	2	4	6	8	10	12	14	16	18	20
CHICKENS										
Lone Star	*Chick Starter 20%*				*Chick Grower 18%*				*Layer 17%*	
Agway	*Chick Starter-Grower 18%*								*Layer 16%*	
Purina	*Start & Grow 18%*								*Layena 16%*	
Dumor	*Chick Starter/Grower 20%*					*Grower/Finisher 15%*			*Layer 16%*	
Nutrena	*Chick Starter Grower 18%*								*Layer 16%*	
MIXED FLOCK										
Purina	*Flock Raiser 20%*								*Layena 16%*	
Dumor	*Chick Starter/Grower 20%*				*All Flock 18%*				*Layer 16%*	
TURKEYS										
Purina	*Game Bird Startena 30%*				*Flock Raiser 20%*				*Layena 16%*	
Dumor	*Chick Starter 24%*			*Chick Starter/Grower 20%*					*Layer 16%*	
Agway	*Gamebird/Turkey Starter 26%*				*Gamebird/Turkey Grower 21%*					
Lone Star	*Gamebird Starter 28%*				*50/50 Mix Gamebird & Chick Grower 23%*					*Layer 17%*
DUCKS & GEESE										
General	*22% Protein*			*16-18 % Protein*					*Layer 16%*	
GUINEAS										
General	*24-26% Protein*				*18 % Protein*					*16%*

- **MEDICATED FEED**: Medicated chick feed DOES NOT contain antibiotics but rather most likely amprollium – a thiamine uptake inhibitor. Amprollium does not treat Coccidiosis (a protozoa parasite) but rather discourages its overgrowth… it attempts to prevent an outbreak. The dosage of amprollium in chick feed is small and unlikely to result in a thiamine deficiency in hatchlings. Coccidiosis is naturally occurring and present in all chickens. Overgrowth, however, can be devastating in hatchlings. Unless you have a very specific reason for not using amprollium, it should be seriously considered in all chicken hatchlings.

  Decades ago, some medicated chick starter might have been harmful to waterfowl… such is not the case with modern feeds. Although they do not require medicated starter as they rarely suffer from an outgrowth of Coccidiosis, feeding medicated chick starter to ducks and geese is not harmful.[1]

- **WATER**: Using additives to water is generally discouraged as the taste may discourage drinking. Clean, chemical free water is generally the healthiest choice. I use bottled water for the first few days when the quality of the tap water is questionable. For bantams, I also add a packet of Sav-A-Chick to the first gallon. Before letting a hatchling loose inside the brooder, dip its beak into the water source. Never allow hatchlings to run out of water and keep the waterer as clean as possible.

- **OTHER CONCERNS**:

  - **DROOPY HATCHLINGS**: If hatchlings look droopy upon arrival, adding two tablespoons of sugar in one quart of 100° F water and shaken well may help perk them up. Additionally, adding this solution to a small amount of feed and sprinkling the mixture around may prove helpful. Remove any left-over portions of feed/sugar water mixture after a couple of hours to prevent souring.

  - **GRIT**: Chick grit is unnecessary for hatchlings to properly digest starter or grower crumbles. Once placed on the ground, birds will gather what grit they need from the ground. You will need to add chick grit if you intend to feed hatchlings food that requires "chewing" while they remain in the brooder. Chick starter and grower provides all the necessary ingredients for healthy hatching growth; provide additional "treats" sparingly.

  - **PASTY BUTT**: Stress, overheating, and natural occurrence may result in droppings to accumulate on the hatchling's vent – pasty butt. In most instances, this condition is temporary and results in no harm. However, if sufficient quantities accumulate, it may block the vent. Remove by gently pulling off using a warm moist wash cloth.

  - **PECKING**: Hatchlings may peck each other if they are too hot, too crowded, without fresh air, and even when they are bored. Occasionally, bright lights can cause them to pick and having lights on 24 hours a day can cause stress; changing to a red light may help. An ounce of prevention is worth a pound of cure when it comes to picking. To treat chicks that have been picked, smear some type of menthol ointment on the area that has been injured and keep up the treatment until healed.2

  - **DUCKLINGS & GEESE**: Ducklings and geese mature quicker and require less heat than baby chicks. Medicated feed is not required although the medication will cause them no harm. Waterfowl like to play with water and are messy creatures. Because of this reason, it is not recommended that waterfowl and chickens be brooded together. Special care should be taken with bedding material to ensure that it stays clean and dry. Although tempting, waterfowl should not be allowed to become wet or swim. Wet down may cause chilling and hatchlings can easily drown. Wait until birds are fully feathered before allowing them to swim freely in small pools or ponds.

  - **TURKEYS**: Turkeys require higher protein than baby chicks and their size difference may result in harm to smaller chicks. Chickens may carry diseases and parasites that barely affect them but can be deadly to turkeys, e.g. Blackhead. In general, professional breeders do not recommend turkeys and chickens be raised together or that turkeys be raised on ground where chickens have been in the previous three years. Contact your local county extension agent for further details.

[1] *"Can Medicated Feed Be Used for Waterfowl?" Metzer Farms, November 30, 2011. <http://metzerfarms.blogspot.com/2011/11/can-medicated-feed-be-used-for.html>*
[2] *"The Care of Baby Chicks," Cackle Hatchery, http://www.cacklehatchery.com/pdfs/baby%20chick%20care%20guide2012.pdf*

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