UNIVERSITY OF FLORIDA
IFAS EXTENSION

CIR1112

Hatchability Problem Analysis[1]

H. R. Wilson[2]

Introduction

When a problem occurs in hatchability, usually it can be categorized as a hatchery, egg handling, or breeder flock problem. If the problem has originated within the breeder flock, it is probable that it happened at least 4 weeks earlier, assuming 3 weeks of incubation and 1 week of egg storage. This delay in identifying a problem is costly and may even make it impossible to determine the cause if the effect is of short duration. It is necessary to identify the problem as early as possible, using candling at 1 week of incubation and constantly monitoring unhatched eggs, to minimize the delay in taking corrective measures. Analysis of hatch debris does not yield definitive diagnoses; however, it is a useful tool for determining the most likely areas for further examination.

It is of utmost importance for hatchery, egg handling, and breeder farm personnel to work together as a team to produce top quality chicks and to identify problems when they occur. Very accurate and complete records of the breeder flock (including egg production, mortality, morbidity, egg weight, shell quality, hatchability, feed consumption, and antibody titers) and the egg history from the nest through the hatchery are essential in providing clues to most hatchability problems. Personnel should be trained in recognizing problems, identifying causes, and implementing appropriate corrective measures.

The objective of the following outline is to suggest possible causes, and corrective measures when appropriate, for some of the signs of trouble observed when decreased hatchability occurs.

General Comments

The magnitude of the effects of deviations from recommended incubation conditions (temperature, humidity, turning frequency, ventilation, and egg orientation) is a function of the severity of the deviation, the length of time of the deviation, and the age of the embryo at the time of the deviation. The manifestation of abnormalities and the embryonic age at which mortality peaks occur due to nutritional factors usually depend upon the severity of the nutrient deficiency, how long the deficiency has existed, or how long an adequate diet has been fed to the breeders following a deficiency. Therefore, depletion rate, repletion rate, egg deposition efficiency, interference from inhibitors, and yolk formation time are factors that contribute to the effects manifested in embryonic abnormalities and mortality.

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2. Henry R. Wilson, Professor Poultry Physiology, Department of Dairy and Poultry Sciences, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville FL 32611.

Troubleshooting: General Problems

1. ***Sign:*** **Eggs candle clear; broken out eggs show small white-dot germinal disc; no blood. Infertile.** ***Causes:***

    1. Immature males. Males may need to be photostimulated 2 weeks earlier than females.
    2. Males with abnormal sperm; females with abnormal egg (germinal disc). This occurs most often in very young or very old breeders.
    3. Too few males, resulting in infrequent mating; too many males, resulting in fighting or interference. Ratios of 1:12 to 1:15 for light breeds and 1:10 to 1:12 for heavy breeds are suggested.
    4. Extreme weather conditions.
    5. Old breeders. Spiking with young males may help if the problem is with the male.
    6. Breeder flock disease. This is often indicated by rough, misshaped, or thin-shelled eggs.
    7. Excess body weight, especially in broiler breeder males (>4,800 g, 10.6 lb).
    8. Nutritional deficiencies or excesses; severe feed restriction.
    9. Feet and leg problems, especially in males of heavy breeds.
    10. Certain drugs, pesticides, chemicals, toxins, or mycotoxins.
    11. Parasites, such as mites.
    12. Inadequate floor space.
    13. Decreased mating frequency, or no mating, is commonly seen in many of the conditions listed above; this may often be the direct cause of infertility.
    14. Inadequate lighting (intensity or day length).
    15. Improper artificial insemination procedures (if artificial insemination is used).

2. ***Sign:*** **Eggs candle clear; broken out eggs show enlarged germinal disc; no blood. Fertile. Some are termed "blastoderm without embryo."** ***Causes:***

    1. Eggs stored too long. They should be stored <7 days.
    2. Eggs held under poor conditions, temperature too high or too low. Fluctuating temperatures. Temperature should be 60° to 65°F (15.6° to 18.3°C).
    3. Fumigation improper -- too severe or done between 12 and 96 h of incubation. Incorrectly spraying or foaming eggs with disinfectant.
    4. Eggs damaged during handling and transport by jarring, temperature shock (temperature increased or decreased too rapidly), etc.
    5. Eggshell sealed -- respiration inhibited.
    6. High temperature in early incubation.
    7. Very young or very old breeders.
    8. Heredity, inbreeding, chromosome abnormalities, or parthenogenesis.
    9. Breeder flock diseases.
    10. Failure of a basic organ system to develop normally.
    11. Egg wash temperature too high.
    12. Egg-borne infections (e.g., salmonella).
    13. Drugs, toxins, pesticides, etc.
    14. Infrequent or incomplete egg collection.

3. ***Sign:*** **Eggs candle clear; broken out eggs show blood ring or small embryo that died before 3 days of incubation; no dark eye visible.** ***Causes:***

    1. Eggs stored too long or under improper temperature.
    2. Fumigation improper -- too severe or done between 12 and 96 h of incubation.
    3. High temperature in early incubation.
    4. Low temperature in early incubation.
    5. Eggs damaged during transport by jarring, etc.
    6. Breeder flock diseases.
    7. Old breeders.
    8. Embryological development accidents.
    9. Inbreeding, chromosome abnormalities.
    10. Severe nutritional deficiencies, e.g., biotin, vitamin A, copper, vitamin E, boron, or pantothenic acid.
    11. Frequently associated with a high incidence of infertility.
    12. Drugs, toxins, or pesticides.
    13. Contamination.
    14. Embryos less developed at oviposition, i.e., pre-endoderm or very early endoderm formation.

4. ***Sign:*** **Dead embryos; 3 to 6 days of incubation; yolk sac circulatory system present, embryo on left side, no egg tooth.** ***Causes:***

    1. See causes 3.1-14
    2. Lack of ventilation, or sealed shells, carbon dioxide >1%.
    3. Improper turning -- <1/h or >6/h; improper turning angle.
    4. Vitamin deficiencies -- vitamin E, riboflavin, biotin, pantothenic acid, or linoleic acid.

5. ***Sign:*** **Dead embryos; 7 to 17 days of incubation; each embryo has egg tooth, toenails, feather follicles (8 days), feathers (11 days).** ***Causes:***

    1. Improper incubator temperature, humidity, turning, ventilation. Low humidity increases abnormalities of aortic arches (13 days).
    2. Contamination.
    3. Nutritional deficiencies -- riboflavin, vitamin B_{12}, biotin, niacin, pyridoxine, pantothenic acid, phosphorus, boron, or linoleic acid.
    4. Lethal genes (>30 have been described).

6. ***Sign:*** **Dead embryos; >18 days of incubation.** ***Causes:***

    1. Improper incubator temperature, humidity, turning, ventilation.
    2. Improper hatcher temperature, humidity, ventilation.
    3. Contamination, especially from molds (aspergillis, etc.).
    4. Fumigation too severe or too prolonged.
    5. Eggs chilled in transfer, or transferred too late.
    6. Broken shell -- pre-set, during incubation, or at transfer.
    7. Nutritional deficiencies -- vitamin D, vitamin A, folic acid, or pantothenic acid, riboflavin, vitamin E, selenium, vitamin K, biotin, thiamin, vitamin B_{12}, calcium, phosphorus, manganese, or linoleic acid.
    8. Embryonic malposition; embryo fails to move into proper hatching position (see #21).
    9. Embryological development accident. Failure to change to lung respiration and all intra-embryonic circulation, and/or to retract the intestinal loops and yolk sac. These and other changes are critical at this time.

10. Heredity -- lethal genes, chromosome abnormalities.
11. Twinning.
12. Hatcher opened too much during pipping and hatching.
13. Poor shell quality.
14. Breeder diseases.

Troubleshooting: Specific Problems

1. ***Sign:*** **Not pipped. Full-term embryo, large yolk sac; yolk sac may not be fully enclosed by abdominal wall, may have residual albumen.** ***Causes:***
    1. Inadequate turning, resulting in decreased embryonic membrane development and nutrient absorption.
    2. Humidity too high during incubation or after transfer.
    3. Incubator temperature too low.
    4. Hatcher temperature too high.
    5. Eggs chilled (e.g., at transfer).
    6. Nutritional deficiencies.
    7. Heredity.
    8. Embryological development accident.
    9. Breeder diseases.
    10. Inadequate ventilation.
    11. Prolonged egg storage.
2. ***Sign:*** **Pipped. Full-term embryo, dead in shell.** ***Causes:***
    1. Low humidity or temperature for a prolonged period.
    2. Low humidity during hatching.
    3. High temperature during hatching.
    4. Nutritional deficiencies.
    5. Breeder diseases.
    6. Poor ventilation.
    7. Inadequate turning during first 12 days.
    8. Injury during transfer.
    9. Prolonged egg storage.
3. ***Sign:*** **Shell partially pipped, embryo alive or dead.** ***Causes:***
    1. See 8.a-i.
    2. Excessive fumigation during hatching.
    3. Eggs set small end up.
4. ***Sign:*** **Chicks hatch early; tendency to be thin and noisy.** ***Causes:***
    1. Small eggs.
    2. Differences among breeds.
    3. Incubator temperature too high.
    4. Incubator humidity too low.
5. ***Sign:*** **Chicks hatch late.** ***Causes:***
    1. Large eggs.
    2. Old breeders.
    3. Eggs stored too long (40 min. increase in incubation time/day of storage, .5% to 1.2% decrease in number hatched/day of storage).
    4. Incubator temperature too low.
    5. Weak embryos.
    6. Inbreeding.
    7. Incubator humidity too high.
6. ***Sign:*** **Slow, protracted (drawn-out) hatch.** ***Causes:***
    1. Mix in the incubator of eggs stored for long and short periods (1.2% loss of hatch/day of storage when all eggs set at the same time;

only .5% loss/day when eggs stored for long periods are set earlier to allow a longer incubation period).

2. Mix of eggs from young and old breeders.
3. Mix of large and small eggs.
4. Improper egg handling.
5. Hot or cold spots in incubator or hatcher.
6. Incubator or hatcher temperature too high or too low.
7. Room ventilation system improper; high positive pressure or low negative pressure. Such pressures may alter incubator or hatcher ventilation.

7. ***Sign:*** **Trays not uniform in hatch or chick quality.** ***Causes:***
   1. Mix of large and small eggs.
   2. Mix of eggs from young and old breeders.
   3. Mix of eggs from different strains or breeds.
   4. Some eggs stored much longer.
   5. Lack of uniform ventilation in setter or hatcher.
   6. Disease or other stress in one or more breeder flocks.
   7. Variation in egg storage procedures among flocks.

8. ***Sign:*** **Sticky chicks; chicks smeared with albumen.** ***Causes:***
   1. Low incubation temperature.
   2. High incubation humidity.
   3. Improper turning. This results in reduced embryonic membrane growth and reduced nutrient absorption.
   4. Old eggs.
   5. Very large eggs.

9. ***Sign:*** **Chicks stuck in shell, dry; chicks with shell fragments stuck to down feathers.** ***Causes:***
   1. Humidity too low during egg storage, incubation, and/or hatching.
   2. Improper egg turning.
   3. Cracked eggs or poor shell quality.

10. ***Sign:*** **Premature hatching; bloody navels.** ***Causes:***
    1. Incubator and/or hatcher temperature too high.

11. ***Sign:*** **Small chicks.** ***Causes:***
    1. Small eggs.
    2. Low humidity during egg storage and/or incubation.
    3. High incubation temperature.
    4. High altitude. Hatcheries at high altitudes (>1,500 m or 4,920 ft) may need to adjust for low humidity, carbon dioxide, and oxygen. Atmospheric pressure <600 mmHg (~1,830 m or 6,004 ft) reduces growth and metabolic rate, increases loss of water from the egg.
    5. Thin, porous shells.

12. ***Sign:*** **Unhealed navel; dry, rough down feathers.** ***Causes:***
    1. High incubator temperature or wide fluctuations in temperature.
    2. Low temperature in hatcher.
    3. Humidity too high in hatcher or not lowered when hatching complete.
    4. Inadequate breeder nutrition.

13. ***Sign:*** **Unhealed navel, wet, odorous; mushy, large, soft-bodied, and lethargic chick.** ***Causes:***

1. Omphalitis (navel infection). Contamination from dirty trays, unsanitary machines or hatchery, dirty eggs, inadequate egg sanitation or fumigation.
2. Low incubator temperature.
3. High incubator or hatcher humidity.
4. Inadequate ventilation.

14. ***Sign:*** **Weak chicks.** ***Causes:***
    1. High hatcher temperature.
    2. Poor hatcher ventilation.
    3. Excessive fumigation.
    4. Contamination.

15. ***Sign:*** **Chicks malpositioned. Normal position after 19 days of incubation: embryo's long axis same as long axis of egg; head in large end of egg; head to the right and under right wing; beak toward air cell; feet toward head.** ***Causes:***
    1. Eggs set small end up or in horizontal position.
    2. Inadequate or improper turning.
    3. High or low incubator temperature.
    4. High humidity.
    5. Old breeders.
    6. Round-shaped eggs or very large eggs.
    7. Nutritional deficiencies, especially vitamin A and vitamin B_{12}.
    8. Eggs handled or stored improperly.
    9. Retarded development.
    10. Embryos <18 days old may be in a position different from that for hatching but one normal for their age (for example, the head-between-thighs position). The feet-over-head position is hard to distinguish and may be normal. The beak-over-wing position is probably a normal variant. Some malpositions are lethal; others are not.

16. ***Sign:*** **Malformations.** ***Causes:***
    1. Improper egg storage.
    2. Jarring of eggs or transporting large end down.
    3. Heredity.
    4. Nutritional deficiencies, e.g., biotin, riboflavin, zinc, or manganese.
    5. Inadequate turning.
    6. Improper egg orientation, e.g., small end up.
    7. High or low incubator temperature.
    8. Breeder diseases.
    9. Inadequate ventilation or shells with low porosity or permeability.

17. ***Sign:*** **Crooked toes, spraddled legs.** ***Causes:***
    1. High or low incubator temperature.
    2. Inadequate nutrition.
    3. Smooth bottom hatching trays.

18. ***Sign:*** **Short down, wiry down.** ***Causes:***
    1. Nutritional deficiencies, especially riboflavin.
    2. Mycotoxins and other toxic or inhibitory substances, resulting in nutritional deficiencies.
    3. High incubation temperature during days 1 to 14.

19. ***Sign:*** **Eyes closed, down stuck to eyes.** ***Causes:***
    1. Temperature too high in hatcher.
    2. Humidity too low in hatcher.
    3. Down collectors inadequate.

4. Chicks remain in hatcher too long after hatching

5. Excessive air movement in hatcher.

20. ***Sign:*** **Exploders.** ***Causes:***

1. Dirty eggs from nest. Dirty nests.

2. Floor eggs.

3. Eggs improperly washed; eggs wiped or cleaned with contaminated cloth or buffer.

4. Dust from breeder house, cooler, transport, etc.

5. Water condensation on eggs (sweating).

6. Water sprayed, fogged, or splashed on eggs; eggs dipped in contaminated solutions.

7. Contamination from earlier exploders, leakers, or broken eggs.

8. Contamination from handling eggs with dirty hands or equipment.

9. Contaminated setter flats, air filters, water (humidity) system.

21. ***Sign:*** **Dwarf embryos: runts in growing chicks.** ***Causes:***

1. Egg contamination.

2. Hatchery contamination, especially during hatching.

3. Breeder diseases.

4. Heredity.

5. Nutritional deficiencies.

6. Thyroid abnormalities.

22. ***Sign:*** **Crossed beak, twisted beak.** ***Causes:***

1. Heredity.

23. ***Sign:*** **Missing eye(s), other eye abnormalities.** ***Causes:***

1. High incubator temperature during days 1 to 6.

2. Low oxygen during days 1 to 6.30.

24. ***Sign:*** **Exposed brain.** ***Causes:***

1. High incubator temperature during days 1 to 3.

2. Low oxygen during days 1 to 3.

25. ***Sign:*** **Red hocks in hatched chicks or unhatched pips.** ***Causes:***

1. Prolonged pushing on shell during pipping and hatching.

2. Vitamin deficiencies.

3. Thick shells, as in pullet flocks.

4. High incubator humidity and/or low incubator temperature.

26. ***Sign:*** **Small air cell, broad pip area, membrane incompletely cut, red hocks, edematous chick, unabsorbed albumen, yolk incompletely retracted, egg weight loss <10%.** ***Causes:***

1. High incubator humidity.

2. Very thick shells, as in pullet flocks.

3. Low incubator temperature.

27. ***Sign:*** **Micromelia (shortened long bones, parrot beak, bent bones); chondrodystrophy (similar to micromelia).** ***Causes:***

1. Heredity, lethal genes.

2. Nutritional deficiencies (biotin or manganese).

28. ***Sign:*** **Short beak, missing beak, face abnormalities.** ***Causes:***

1. Incubator temperature too high during days 1 to 5.

2. Heredity, lethal genes.

3. Developmental accidents.

4. Nutritional deficiencies (niacin).

29. ***Sign:*** **Ectopic (exposed) viscera.** ***Causes:***

    1. Incubator temperature too high.

    2. Heredity, lethal genes.

30. ***Sign:*** **Hemorrhage.** ***Causes:***

    1. Red skin -- incubator or hatcher temperature too high.

    2. Bleeding in chorioallantois -- rough handling at transfer.

    3. Nutritional deficiencies (vitamin K or vitamin E).

    4. Embryos that died at days 11 to 15 and appear small and dark red -- usually caused by molds or other contamination.

31. ***Sign:*** **Swollen head and back of neck (exudative diathesis - increased capillary permeability).** ***Causes:***

    1. Nutritional deficiencies -- vitamin E or selenium.

Nutritional Deficiencies and Toxicities; Almost Always a Breeder Flock Problem

1. ***Vitamin A:*** Circulatory system development abnormal; skeletal abnormalities, especially in the skull and spinal column; degenerative changes in the brain, spinal cord, and nerves; embryonic mortality is early (during days 2 to 3). Chicks hatching may have watery discharge from eyes or have eyelids stuck together. A great excess of vitamin A also will cause skeletal abnormalities.

2. ***Vitamin D_3:*** Late embryonic mortality (>17 days); stunting; poor skeletal growth; rickets.

3. ***Vitamin E:*** Circulatory system problems, exudative diathesis, hemorrhages, stunting, encephalomalacia, eye abnormalities (e.g., cloudy lens or hemorrhages), edema of neck and feet; embryonic mortality peaks during days 2 to 5. Muscular weakness after hatching.

4. ***Vitamin K:*** Hemorrhages in embryo and membranes, especially at or near time of hatching.

5. ***Thiamin:*** Polyneuritis; early mortality peak and late peak >=19 days; many dead chicks in hatching trays.

6. ***Riboflavin:*** Stunting, short legs, disorganization of the circulatory system, edema, clubbed down, curled toes, micromelia, anemia, brown or dark green liver; mortality peaks during days 3 to 5, 10 to 15, and 21 to 22. Mortality peaks change from late to early as breeder depletion of riboflavin proceeds.

7. ***Niacin:*** Hypoplasia (decreased growth and development) of skeletal muscles, edema, short upper beak, nervous and vascular system abnormalities. Mortality peaks during days 8 to 14.

8. ***Vitamin B_6 (pyridoxine):*** Inhibition of early embryonic growth; mortality peaks during days 8 to 14.

9. ***Pantothenic acid:*** Subcutaneous hemorrhages, edema, hydrocephalus, poor feathering, twisted legs, fatty livers, opacities of the eye, pale, dilated hearts; embryonic mortality peaks during days 2 to 4 and 11 to 15.

10. ***Biotin:*** Chondrodystrophy and micromelia (deformed skeleton, shortened long bones, parrot beak), syndactylism (webbing between toes); hemorrhages in the embryo and chorioallantois; peak embryonic mortality during days 3 to 4 and >=17. The early mortality peak is greatest with severe deficiency, while the late peak is greatest with mild deficiency.

11. ***Folic acid:*** Bent tibia, syndactylism (toe webbing), flattened head, small eyes, exposed viscera, parrot beak, other beak defects, stunting; peak embryonic mortality days >17.

12. ***Vitamin B_{12}:*** Edema (especially around eyes), hemorrhages, curled toes, short beak, poor leg muscle development, dwarfing, fatty liver, enlarged thyroid, dilated, irregularly shaped heart, head-between-thighs malposition; peak embryonic mortality during days 8 to 14 (small peak) and 16 to 18.

13. ***Manganese:*** Chondrodystrophy, deformed skeleton, shortened long bones, parrot beak, micromelia, edema, abnormal down feathers; peak embryonic mortality days >18. Chicks uncoordinated.

14. ***Zinc:*** Skeletal defects, especially in posterior vertebral column (most common defect is rumplessness), small eyes, exposed viscera, beak and head abnormalities, edema. Chicks are weak; will not stand, eat, or drink. Embryonic mortality can be very high.

15. ***Calcium:*** Effects more indirect through poor shell quality, increased egg weight loss, and increased contamination. Stunted growth, decreased bone development, and increased mortality tend to occur in later stages. A great excess of calcium also will cause embryonic abnormalities.

16. ***Magnesium:*** Nervous tremor, gasping, and convulsions at hatching.

17. ***Phosphorus:*** Abnormal bone formation, stunting; mortality peaks during days 14 to 16.

18. ***Copper:*** Blood and circulatory system defects. Mortality peaks during days <3.

19. ***Iodine:*** Affects thyroid activity. Deficiency or excess causes increased incubation time, decreased growth, and increased mortality. Thyroid may be enlarged.

20. ***Selenium:*** Exudative diathesis; selenium will spare vitamin E. Very high levels of selenium are toxic: edema of head and neck, twisted legs, necrosis in brain and spinal cord, short upper beak, missing eyes, protruding eyes, an increase in malpositions.

21. ***Molybdenum:*** >17 ppm in the egg results in 100% mortality by day 12.

22. ***Lithium:*** Excess causes high embryonic mortality associated with inhibited development, eye defects, enlarged aorta, abnormal neural tube.

23. ***Boron:*** Excess boron in egg (44 ppm) causes embryonic mortality in early development and at day 13. Abnormalities similar to those of riboflavin deficiency. Face, beak, and appendicular skeleton abnormalities.

24. ***Protein, amino acids:*** Deficiency, excess, or imbalance of some amino acids can cause embryonic abnormalities and mortality. Abnormalities include small or abnormal upper and/or lower beak, disorganized protrusions in the brain, exposed viscera, twisted and shortened limbs, twisted spine, short body, degeneration of the eye.

25. ***Fat, fatty acids:*** Linoleic acid deficiency: slow development, 75% of embryos in the head-over-right-wing malposition; mortality peaks during days 1 to 4, 8 to 14, and >21. Lipid transfer from the yolk to the embryo is reduced in the first few eggs produced by young pullets; this appears to result in increased embryonic mortality.

26. ***Miscellaneous substances:***

    1. *Tetracyclines:* Inhibition of skeletal mineralization, erosion of long-bone cartilage, skeleton malformation.

    2. *Sulfanilamides:*Retarded growth, shortened long bones, extreme micromelia, parrot beak, rumplessness.

    3. *Penicillin:*Edema and hemorrhage in wings, legs, and head.

    4. *Aflatoxin B_1*:Stunting (beginning at day 12), small liver, high mortality.

    5. *Ammonia (in incubators):* No closure of neural tube, mortality.

27. ***Microorganisms:***

    1. *Infectious bronchitis:* Stunting, retarded lung development, small heart, enlarged spleen. Small chick resulting from thin, porous shell and excessive water loss.
    2. *Newcastle disease:* Reduced growth, small amnion, abnormalities in neural and sensory tissues in early embryo.
    3. *Botulism:* Muscle atrophy, fat accumulation, joint problems, short upper beak.
    4. *Staphylococcus:* Extensive hemorrhages and tissue damage.
    5. *Streptococcus:* Destruction of the synovial lining of the joints.
    6. *E. coli:* Rots.
    7. *Aspergillus:* Black or dark green rots. Embryo red or dark, dwarfed.
    8. *S. pullorum, S. gallinarum, and S. typhimurium:* Egg transmitted. Embryonic septicemia, high embryonic mortality, high chick mortality.

Landmarks of Embryonic Development

Before Oviposition:

Ovulation -- First meiotic division of oogenesis.

30 min. post-ovulation -- Second meiotic division and fertilization.

4 h post-ovulation -- First embryonic division.

4.3 h post-ovulation -- Second embryonic division.

5.5 h post-ovulation -- Third division.

6.3 h post-ovulation -- Fourth division.

6.4 to about 25.5 h post-ovulation (oviposition) -- Continued division and growth; cells segregate into groups for special functions. Several hundred cells at oviposition.

Between oviposition and incubation -- No growth; embryo is inactive (if embryo is held below 76°F or 25.5°C, which is physiological zero); normal storage temperature is 55° to 65°F or 13° to 18°C.

During Incubation:

Day 1:

6 to 10 h - First kidney-like cells (pronephros) begin to form.

8 h -Appearance of primitive streak.

10 h -Yolk sac (embryonic membrane) begins. Functions include: a) blood formation; b) yolk digestion; c) yolk absorption; d) food provision after hatching. Mesoderm appears; embryo oriented at 90° angle to egg's long axis; mesonephros begins.

18 h -Primitive gut begins; primordial germ cells appear in germinal crescent.

20 h -Vertebral column begins.

21 h -Appearance of neural groove, nervous system.

22 h -Appearance of first pair of somites (block-like segments) and head.

23 to 24 h -Blood islands, vitelline (yolk sac) circulation, blood, heart,blood vessels begin (2 to 4 somites).

Day 2:

25 h -Appearance of eye; vertebral column visible; embryo begins to turn on left side (6 somites).

28 h -Ear begins (7 somites).

30 h -Amnion (embryonic membrane around embryo) begins. Primary function is to protect embryo against shock and sticking; also responsible for some albumen absorption.

Chorion (embryonic membrane that fuses with allantois) begins; heartbeat begins (10 somites).

38 h -Cranial flexure and torsion evident; heartbeat moves blood (16 to 17 somites).

42 h -Thyroid begins.

48 h -Anterior pituitary and pineal glands begin to develop.

Day 3:

50 h -Embryo turns on left side; allantois (embryonic membrane that fuses with chorion) begins. Functions of chorioallantois are: a) respiration; b) albumen absorption; c) absorption of calcium from shell; d) storage of kidney excretions.

60 h -Nasal pits, pharynx, lungs, anterior limb buds begin.

62 h -Posterior limb buds begin.

72 h -Middle and outer ear, trachea begin; amnion completes growth around embryo.

Day 4: Tongue and esophagus begin; embryo separates from yolk sac; allantois grows through amnion; contractions occur in amnion wall; adrenal development begins; pronephros (nonfunctional kidney) disappears; metanephros (definitive or final kidney) begins; proventriculus, gizzard, ceca, large intestine begin. Pigment visible in eye (dark eye).

Day 5: Reproductive system and differentiation of sex appear; thymus, bursa of Fabricius, duodenal loop begin; chorion and allantois begin to fuse; mesonephros begins to function; first cartilage present.

Day 6: Beak appears; voluntary movement begins; chorioallantois (chorion fused with allantois) lies against shell near large end of egg.

Day 7: Digits appear; comb growth begins; egg tooth begins; melanin produced; absorption of mineral from shell begins. Chorioallantois is attached to inner shell membrane and growth around the inner surface is progressing.

Day 8: Father tracts appear; parathyroid begins; bone calcification begins.

Day 9: Growth of chorioallantois about 80% complete (still open at small end); mouth opening appears.

Day 10: Beak begins to harden; digits completely separated.

Day 11: Abdominal walls established; loops of intestine begin to protrude into the yolk sac; down feathers visible; comb and wattles visible; claws and scales appear on toes; mesonephros reaches maximum level of function, then begins to degenerate; metanephros begins to function.

Day 12: Chorioallantois completes enclosure of egg contents; embryo water content begins to decrease.

Day 13: Cartilaginous skeleton is relatively complete; embryo heat production and oxygen consumption begin to increase rapidly.

Day 14: Embryo begins to turn head toward large end of egg; long bone ossification becomes rapid. Turning of egg no longer essential.

Day 15: Intestinal loops easily seen in yolk sac; contraction of amnion ceases.

Day 16: Beak, claws, and scales relatively cornified; albumen is practically gone and yolk increasingly important as food source; down feathers cover body; intestinal loops begin to retract into body.

Day 17: Amniotic fluid decreases; embryo positioning head toward large end, toward right wing with beak toward air cell; definitive feathers begin.

Day 18: Blood volume decreases, total blood hemoglobin decreases. Embryo should be in proper position to hatch: embryo's long axis the same as long axis of egg; head in large end of egg; head to right and under right wing; beak pointed toward air cell; feet toward head.

Day 19: Intestinal loop retraction complete; yolk sac begins to enter body cavity; amniotic fluid (swallowed by embryo) disappears; beak may pierce air cell and lungs begin to function (pulmonary respiration).

Day 20: Yolk sac completely drawn into body; air cell pierced, followed by functioning of pulmonary respiration; embryo makes sounds; chorioallantoic circulation, respiration, and absorption decrease; embryo may pip shell.

Day 21: Hatching process: chorioallantoic circulation ceases; embryo breaks shell over air cell with egg tooth; embryo slowly rotates in egg counterclockwise, chipping and breaking shell as it does; embryo kicks and attempts to straighten neck, pushes shell open; kicks free of shell, rests, straightens, dries.

>Day 21: Some embryos are unable to hatch but survive beyond the normal hatching time.

Developmental stages of other avian species can be estimated by comparing with those of the chicken on the basis of *percentage of incubation time.*

Hatching Egg Breakout

A breakout analysis of hatching eggs must be done to evaluate the breeder flock's progress with respect to fertility and hatchability. It is an absolutely essential diagnostic tool for identifying the cause(s) of problems in hatchability. Three types of breakout are advantageous in evaluation and problem analysis. These are: (1) breakout of fresh, nonincubated hatching eggs; (2) candling of eggs incubated for 5 to 12 days, breakout of nonviable eggs, and recording of eggs set small end up; and (3) breakout of eggs that did not hatch (hatch residue).

Breakout of fresh eggs is used to provide an immediate evaluation of flock fertility and to confirm fertility estimated from hatch residue breakout and candling between 5 and 12 days of incubation. The breakout following candling will include eggs determined to be infertile, eggs containing early dead, and cracked eggs. The hatch residue breakout includes all eggs that did not hatch. Candle breakout and residue breakout should be done weekly or at least every 3 weeks. Regular, consistent analysis of these breakouts will result in flock histories that can be used to diagnose hatchability problems, minimize losses, and compare strains, flocks, farms, hatcheries, and many other variables.

Sample selection and size are important for obtaining valid results from the breakouts. Samples should be selected to include eggs from representative locations in setters and hatchers for each flock at each sampling time. Suggested minimums for sample size include: (1) 10 unhatched eggs from 5 hatcher trays; (2) all unhatched eggs from 4 hatcher trays per setter or hatcher; (3) all unhatched eggs from 1,000 set eggs; as well as many others.

Records should include, but not be limited to, the following variables: flock, strain, farm, date set, machine(s) used, location of eggs in machine, number of eggs set, number of fertile eggs, number of early dead (0 to 7 days), number of middle dead (8 to 14 days), number of late dead (embryos 15 days or older), age of each embryo, malpositions (in embryos 19 days or older), number pipping, malformations, number of eggs contaminated (rots), number of cracked eggs (transfer cracks and others), unusual egg traits (size, shape, shell quality, cleanliness), number of dead and culled chicks, and number of live chicks. Clear, accurate records are essential for useful egg breakout analysis.

Eggs should be removed from the hatcher tray, placed on egg flats, and identified as to flock, location, etc. The exterior of the egg is examined first for egg traits, pipping, and location of the air cell. The shell is cracked at the large end, over the air cell, and a hole opened in the shell and membranes to observe the interior of the egg. If the egg appears to be infertile or contains a very early dead embryo, the germinal disc must be located to make a definitive identification of fertility. If the embryo is relatively small, the egg can be broken into a dish for further examination. Eggs with late-stage embryos should be observed for pipping into the air cell, then opened with tweezers or scissors from large end to small end without disturbing the position of the embryo. The embryo's position (see earlier discussion on positions), the embryo's age (see section on development stages), malformations, contamination,

and other factors should be observed and recorded. Comparisons with live embryos of various ages can be used to train those developing experience in the breakout technique.

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