

# Cardio-respiratory, bone and muscle development from Hatchery



**Edgar O. Oviedo-Rondón**

*Prestage Department of Poultry Science, North Carolina  
State University*

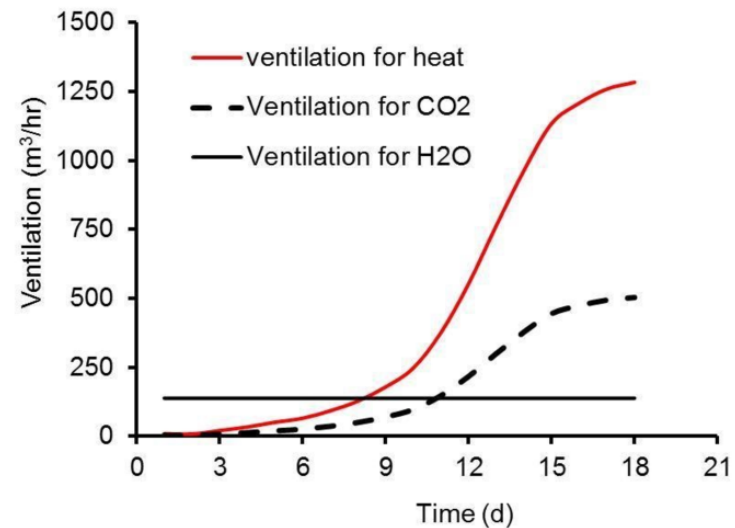
# Learning objectives

- ④ This module will inform you of **the importance of incubation factors on hatchlings' general health and hatchling quality**. The purpose is to understand precisely the effects of incubation on cardiorespiratory, bone, and muscle development.



# Egg and embryo respiration, blood vessel and heart development

Eggs lose water and carbon dioxide (CO<sub>2</sub>) during incubation while they uptake oxygen. Ventilation is typically done to maintain water loss and CO<sub>2</sub> removal, but after 11 days of incubation, it becomes more important to lose heat.



Hatchability.com



During the first five to seven days of incubation, high levels (3,000 to 7,000 ppm) of CO<sub>2</sub> provide and stimulus for development of blood vessels and heart, and the development of the chorioallantoic membrane (CAM), a vital extraembryonic membrane necessary for respiratory exchange.

Embryos depend on CAM respiration up to day 18.5 of incubation. Around day 17 of embryo development, the eggshell reaches the plateau of oxygen uptake or maximum capacity to obtain oxygen.

Then, there is a **transition period when the lungs start to work**. During this transition, chicks break into the egg air cell by internal pipping. **This is a critical period that may be affected by the incubation temperature.**

The eggshell conductance properties can also affect embryo development because this capacity to transfer gases may limit the amount of oxygen embryos can receive from CAM. **Hypoxia is a standard stimulus that promotes internal and external pipping and hatching but can also become developmental stress with harmful effects for life post-hatch.** The sounds of this process can be captured and are used frequently to synchronize the hatch.

# Hypoxia and hypercapnia affecting heart development

**Hypoxia and hypercapnia induce phenotypic modifications, morphological and physiological maturity, and self-repair capabilities during avian incubation.** Hypoxic conditions commonly affect heart ventricular development.


In commercial incubators, some eggs may endure conditions of higher temperatures, lower ventilation, and higher CO<sub>2</sub> concentrations in microenvironments.

**These microenvironments are more common in multistage machines than in single-stage incubators.**



- ▶ High temperatures increase the glucose requirements of the embryo because metabolism is accelerated by heat, but also because generally higher CO<sub>2</sub> and lower O<sub>2</sub> decrease yolk utilization.
- ▶ High eggshell temperatures can reduce heart development by almost 30%. A chicken of the same size will have a smaller heart to pump the same blood volume. This reduction in heart development can generally cause right heart hypertrophy, which is the common origin or etiology of ascites.
- ▶ Acute or chronic temperature stress during incubation with temperatures above 37.5 °C can induce right ventricle hypertrophy, higher hemoglobin and red blood cell concentrations, ascites and chicken mortality.

# Leg bone development

 Bone development can also be affected by incubation conditions.

**Leg and bone problems are one of the most important, prevalent, and noticeable welfare issues.** The costs are high due to the loss of output and resources wasted on culled birds, treatment, and prevention.

It is also a processing problem since it causes carcass defects and condemnations. Birds affected have poor feed conversion, weight gain, and decreased carcass and boneless yield. The economic losses due to leg problems can become significant.





**Temperature during the first and last three days of incubation is critical for bone development** and affects broilers, turkeys, and ducks.

We studied the effects of keeping the eggshell temperature constant at 37.8 °C (100.0°F) or having low (98.4 °F = 36.9 °C) eggshell temperature during the first three days of incubation or elevated eggshell temperature (102.0 °F – 38.9 °C) during the last three days.

- ▶ The low temperatures can be observed for poor pre-warming before incubation or low machine temperatures (99.3 °F = 37.5°C).
- ▶ The high temperatures are observed on days 17-18 when the machine temperature is not reduced from 37 °C (98.6 °F). This is a typical condition in multistage machines, but it can be observed in single-stage machines when temperatures are not reduced.



**The higher eggshell temperatures are a result of embryo metabolic heat production.**

Even when machine temperatures are reduced below 36.5 °C (97.7 °F), the eggshells will be above 100.0 °F. The low-elevated profile reduces bone development and affects ossification.

# Asymmetry of leg bones

A developmental defect known as the relative asymmetry between the collateral bones in the legs is also observed.

Suboptimal conditions increase the relative asymmetry. The higher the relative asymmetry, the more gait problems or lameness, tibia dyschondroplasia, valgus, or other bone developmental problems and leg defects will be observed.

**The asymmetry caused by stress during incubation can cause splayed or twisted legs at hatching or days after at the farm.**

The incidence can be higher depending on the degree of thermal stress or ventilation conditions in the incubator, the hatcher, or during transportation to the farm.



# Egg storage and breeder age

We evaluated the effects of egg storage in young and old breeder flocks. We compared fresh eggs stored for only three days and eggs stored for 14 days together with a fast egg prewarming for two hours or slow for 18 hours at 34 °C.

- ▶ The stored eggs had more relative asymmetry of femur weights at hatch than from fresh eggs. Broilers raised from this experiment showed an interactive effect of egg storage with the prewarming rate in the incidence of valgus, a common leg problem.

**Egg storage effects**, experiment: 1,080 fertile eggs Cobb 500

Storage (days)	Hen age (wk)	
	Young	Old
14 (stored)	33	57
3 (fresh)	35	59

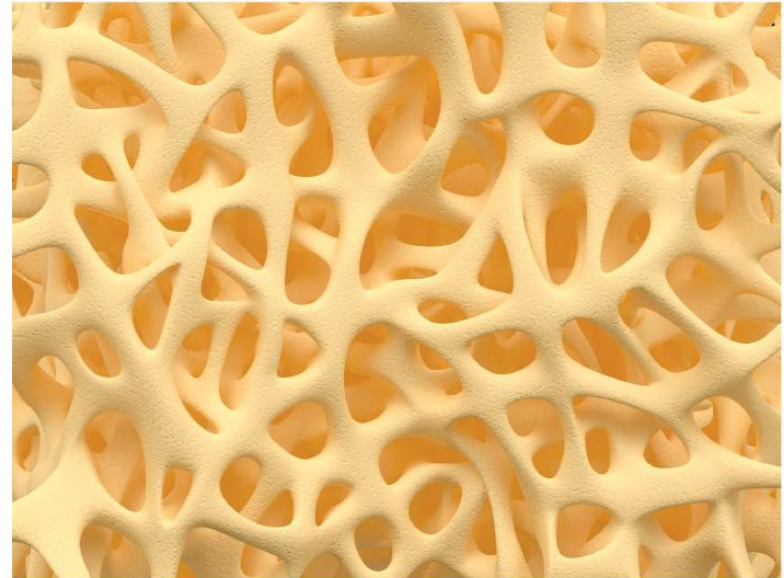
Before incubation eggs *pre-warmed at 34 °C* in 2 incubations at 2 hours (*fast*) or 18 hours (*slow*).

- ▶ Eggs stored or fresh from the old breeder flock had a higher incidence of valgus than from young flocks, especially when stored eggs were prewarmed slow or fresh eggs were prewarmed fast.
- ▶ Eggs from young flocks had higher valgus incidence only when stored eggs for 14 days were prewarmed fast, but fresh eggs had the lowest valgus incidence and were not affected by the prewarming rate.

# Incubation systems and bone issues

In experiments comparing multistage and single-stage incubation, **we observed more crooked toes in males from the multistage machines.**

The incidence of valgus in 56-day-old heavy broilers was also higher in those coming from multistage machines than single-stage machines. Gait issues were also more evident in multistage machines.



# Incubation and back and tendon issues

**Incubation conditions may increase the spondylolisthesis and spondylitis enterococcic.**

We observed that suboptimal incubation conditions that increase the relative asymmetry could increase the incidence of cartilage damage called *osteocondrosis dissecans* (OCD).

There is a correlation of 0.65 between OCD and spondylitis enterococcic. This indicates that proper incubation is involved in preventing this disease.



The gastrocnemius tendon is very important for avian locomotion, and non-infectious defects are observed at the farms.




Looking at incubation effects on tendon development, we have observed changes in the orientation of the collagen fibers and the concentration of collagen in these fibers. Suboptimal incubation reduces the development of tendons, which can partially explain some of the leg problems observed in the field.



# Myopathies and incubation

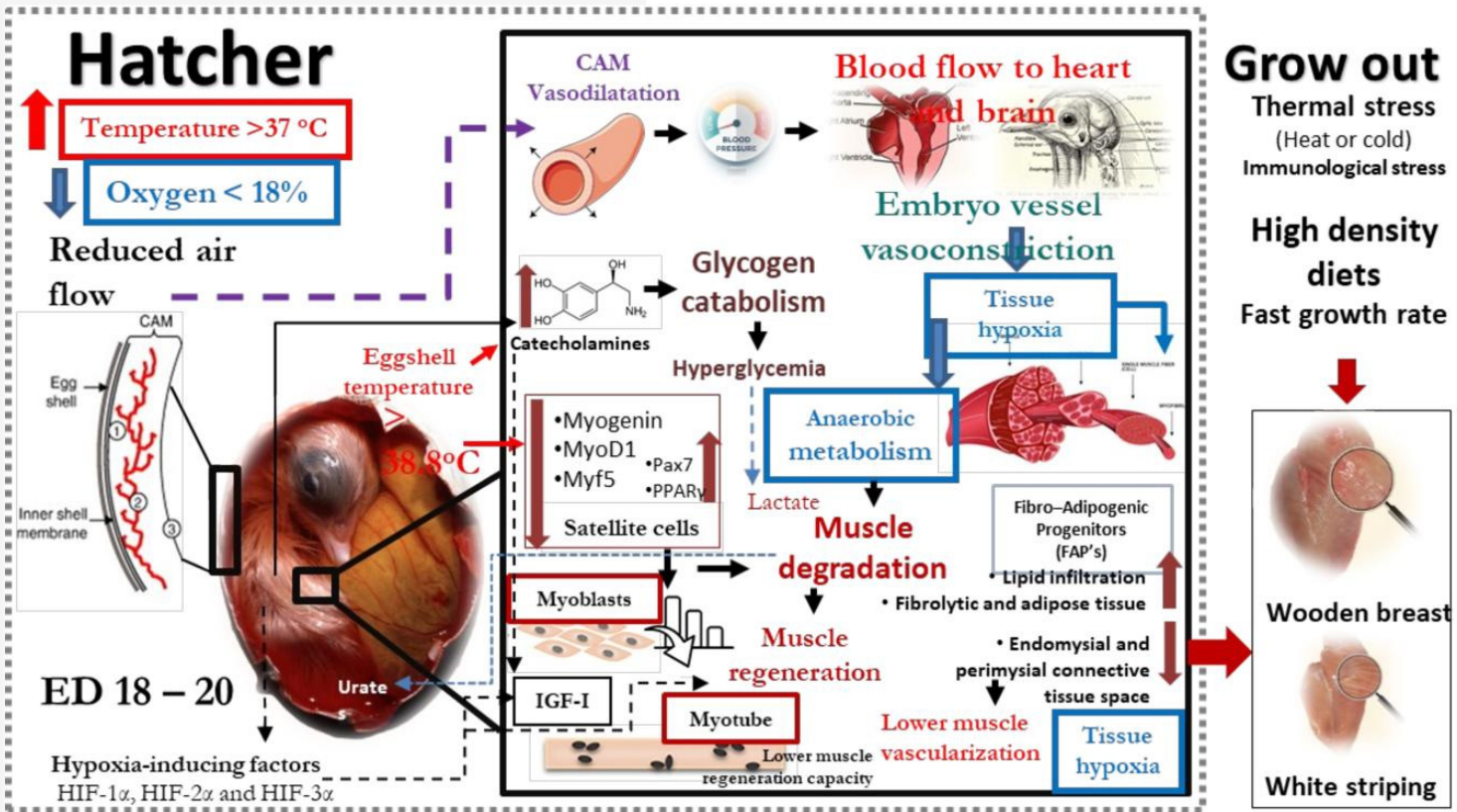
Myopathies commonly observed now at processing plants, like white stripping, wooden breasts, and spaghetti muscle, could be influenced by embryo stress during incubation.

 **The elevated temperatures (> 37 °C) and the hypoxia (< 18 O<sub>2</sub>) that are natural at hatching time could cause stress during embryo development.**

When the eggshell temperature is above 38.8°C, the chorioallantoic membrane is vasodilated to expel more heat and obtain more oxygen. **The elevated temperature increases embryo oxygen demand.**

Vasodilation in the CAM and body reduces blood flow to the embryo's heart and brain. The stress stimulates fast muscular glycogen catabolism and causes hyperglycemia.

**Due to reduced oxygen levels or tissue hypoxia, an anaerobic metabolism prevails,** with the production of lactate and muscle myoblast degradation. The hypoxia-inducing factors and stress hormones cause modifications in satellite cell gene expression.



**Muscles have regenerative capacity after a period of hypoxia and high lactate levels.**  
Myotubes are normally regenerated.



However, **in chicks that suffer more significant stress for several hours, regeneration capacity can be affected,** apoptotic cells degenerate myofibers, and conjunctive and adipose tissue replace the myofibers.

The fibro-adipogenic progenitors increase, there is lipid infiltration, and the endomysial and perimysial connective tissue space increases. There is lower muscle vascularization. During grow-out post-hatch, diets with high nutrient density, fast growth, environmental stress, either cold or high temperatures, and immunological stress during brooding can increase the incidence of myopathies at processing.

All these characteristics can be observed at the hatch in chicks exposed to higher temperatures (102 °F eggshell temperature) and low oxygen levels (17% O<sub>2</sub>). **We have confirmed that suboptimal incubations can increase the probability of observing wooden breast score 2.**

In Cobb broilers, the magnitude of effects is larger due to their lower eggshell conductance, and they can increase the myopathies more than in Ross birds. However, **myopathies are prevalent in all modern genetic lines with fast growth.**

We have also observed similar effects of muscle damage in ducks at 35 days of age, depending on incubation conditions. Ducks coming from eggs that suffered hypoxia due to wax applied to 1/3 of the egg had more conjunctive tissue in their muscles.

The high hatcher temperature from day 24 to 28 of incubation also caused similar muscular damage. However, **the combination of high temperature and hypoxia caused the worst issues. The effects were observed in male and female ducks, but they were more evident in the females.**



**High incubation temperature (39.5 °C) for 3 or 12 hours between days 14 to 18 increased myopathy in broilers. Chick hatched late (last 55%) had more score 1 myopathy, while chicks hatched early (first 25%) had more score 2 myopathy.**



## Conclusions:

- ▶ **Egg storage, elevated eggshell temperatures, low oxygen, and excessive CO<sub>2</sub> during the last phases of incubation have a detrimental effect on the cardiorespiratory, bone, and muscle development of avian embryos**
- ▶ **The last phase of incubation is the most critical for development and health post hatch**
- ▶ **Temperatures should be controlled to improve livability, locomotion, reduce leg problems, and muscle myopathies.**





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# Thank you!

## **Grupo de Comunicación Agrinews S.L.**

*Avinguda de Jaume Recoder, 17, 08301 Mataró,  
Barcelona (España)*

*[info@grupoagrnews.com](mailto:info@grupoagrnews.com)*

*Tel: +34 93 115 44 15*