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**POULTRY BIOLOGY**  
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To better understand and manage your poultry flock, it is helpful to know a little about the biology of birds. This will help answer some of the questions as to why a certain management technique is called for.

Biologically, chickens and other poultry are similar to mammals and other animals; however there are some notable differences. For example, chickens have feathers instead of hair, wings instead of arms, no sweat glands, non-expandable lungs with air sacs and a body temperature between 105.6 and 107°F (40.9 - 41.6°C). Chickens have no teeth and use a muscular gland, the gizzard (ventriculus) to grind food. They have some characteristics in common with reptiles. For example: they lay eggs, and have scales (on their shanks).

Our main interest in the chicken is as a supplier of food, and as such we need to know as much about how it functions as possible, because in much of nature *form and function* are closely related. Most importantly we need to know how to make it grow and reproduce efficiently.

## **ORGAN SYSTEMS**

Poultry are complex animals with several organ systems, which, working together, make the animal function. These organ systems are:

1. Nervous System
2. Skeletal System
3. Integument
4. Digestive
5. Urinary
6. Reproductive
7. Endocrine
8. Exocrine
9. Muscular
10. Cardiovascular
11. Respiratory
12. Lymphatic
13. Immune

It is most difficult to talk about one system without involving the others since they all work together to make the animal function. So the rest of this paper will discuss some of the major organ systems and how they interact within a

healthy bird. However, before we can fully understand the function of the organs and the animal as a whole, we must learn about that of which it is made. *Cells* are what the organism is made of, and when we talk about feeding and caring for an animal, we are really talking about feeding and caring for all of its cells. If the individual cells that make up the organism are unhealthy or die, then it is difficult for the animal to survive.

## **Cell Biology**

The cell is the basic structure of all simple and complex living organisms. Up until about 1839 people knew nothing about cells. They thought that organisms just grew, sort of like crystals. Then Schleiden and Schwann proposed the cell theory and from there it just blossomed. The invention of more powerful microscopes led to the discovery of the inner working elements of the cell.

Two basic cell types have been identified. These are *eukaryotic cells* - those with a true nucleus and *prokaryotic cells* - those without a defined nucleus (Bacteria, blue-green algae)

Cells are composed of several sub-cellular systems or organelles. The major organelles and other cell parts we know of are:

- Nucleus
- Nucleolus
- Ribosomes
- Rough Endoplasmic Reticulum
- Smooth Endoplasmic Reticulum
- Golgi Apparatus
- Lysosomes
- Peroxisomes
- Mitochondria
- Cytoskeleton
- Cell Membrane

## **NUCLEUS**

The nucleus holds the DNA and is the largest organelle, occupying about 10% of the cell's volume. This is where the chromosomes and DNA are. The nucleus is the control center for many cell types. Some cells, like muscle cells, have more than one nucleus.

## **NUCLEOLUS**

The nucleolus is in the middle of the nucleus and is the site of manufacture of the precursors of the ribosomes.

## **RIBOSOMES**

The ribosomes read the genetic code from RNA and follow its instruction to make specific kinds of protein molecules. The protein molecules are the workhorse molecules of life that make up much of the structure of living organisms and, in the form of enzymes, carry out many of its chemical processes. A cell that makes a lot of protein may have millions of ribosomes. Most ribosomes are outside the nucleus stuck to the walls of a vast, irregularly shaped organelle called the Rough Endoplasmic Reticulum. Some are also stuck on cytoskeletal fibers and synthesize proteins that are incorporated into cytoskeletal fibers, like actin; or into the mitochondria, like cytochrome c; and into the peroxisomes, like

catalase.

## ENDOPLASMIC RETICULUM

The endoplasmic reticulum (ER) is a huge sac wrapped around the nucleus in an irregular pattern. There are many membranous channels between the folds of the sac. About half of the cell's volume is rough endoplasmic reticulum (RER). The function of the ER is to provide a chamber, separated from the rest of the cell's metabolic processes, for the chemical modification of some of the proteins made by ribosomes. Ribosomes make some proteins for immediate use in the open liquid of the cell (cytoplasm). But if the protein is one whose function inside the cell cannot be fulfilled without being modified, the ribosomes stick to the ER and inject the protein inside it. There, enzymes cause the chemical reactions that stick other molecules onto the proteins, enabling them to perform their function. Other proteins are partially modified, and then encapsulated into a vesicle. The many ribosomes dotting its surface give the endoplasmic reticulum the "rough" in its name.

Another type of ER is the Smooth Endoplasmic Reticulum - (SER) which contains enzymes to process proteins and fats and is the site of the synthesis and metabolism of fatty acids and phospholipids. The cells of the liver contain a lot of SER and RER.

## GOLGI APPARATUS

Some proteins need further processing prior to leaving the cell. This happens in the Golgi Apparatus, a medium sized organelle. The number of Golgi in a cell depends upon the volume of secretory products of the cell. There are two regions of the Golgi, Cis and Trans. Proteins in little vesicles travel from the ER and attach to the Cis region, pass through the Golgi and exit through the Trans region. Golgi are like the "traffic police" of the cell, sorting many of the cell's proteins, tagging and directing them to the proper destinations.

## LYSOSOMES

These small organelles are like the cell's stomach. They break down molecules of food that have been partially digested by the body's stomach. They contain about 50 digestive enzymes. These enzymes are so potent that if their membranes were to rupture, the cell would be digested away by *acid hydrolysis*. Nutrients (from food) reach the lysosomes in vesicles that form at the cell's outermost membrane - the cell wall. The nutrient molecules are sucked into a pit that forms in the membrane. As the pit deepens into the cell, the membrane closes over it, forming a vesicle that breaks loose and travels deeper into the cell until it fuses with the lysosome's membrane.

During starvation of the animal (or cell), the lysosomes start to digest other organelles in the cell to feed the rest of the cell. Severe oxygen deprivation, such as in suffocation or drowning, causes an even more extreme reaction-cellular suicide. The lack of oxygen turns cells more acidic and the lysosomal membranes break down and release enzymes that destroy the cell from the inside. Brain cells are the first to do this, within about 5 minutes after breathing stops.

## PEROXISOMES

The peroxisomes are small organelles that contain enzymes that degrade fatty acids and amino acids and in the processes produce hydrogen peroxide. The peroxisomes also

contain catalase, an enzyme that degrades the hydrogen peroxide to  $O_2$  and  $H_2O$ . A side product is heat, which helps maintain the proper temperature of the cell and the organism of which it is a part.

## MITOCHONDRIA

The mitochondria are the third largest organelle in animal cells, and occupy as much as 25% of the cell volume. They contain the enzymes that convert Glucose + ADP to ATP +  $CO_2$  +  $H_2O$ , a process called oxidative phosphorylation. They also contain several copies of a small DNA molecule, mitochondrial DNA. This DNA codes for 5 or 6 of the key inner membrane proteins of the mitochondria. The ATP molecules produced by the mitochondria are used to power the cell. Cells can have as many as 5,000 mitochondria.

## THE CYTOSKELETON

Lacing its way throughout the cell is a network of protein filaments of several types called the cytoskeleton (cyto=cell) or the skeleton of the cell. Some are straight lines and some are filigree. Some maintain the cell's shape or change to alter the cell's shape. Some change continually to make the cell crawl or move. Others act as the framework of hair-like projections from many cells, called cilia or flagella, and cause them to wave or beat.

The cytoskeleton filaments most visible to the naked eye are made of the protein keratin. Hair and the outer layer of skin are made of keratin-rich cells that have died and lost most of their components.

One of the newest known functions of the cytoskeleton involves filaments called microtubules. Biologists have recently discovered proteins that act as motors, hauling vesicles over microtubule tracks. They have discovered a protein called kinesin that could pick up vesicles and transport them along microtubules in one direction. Another protein called dynein moves them in the opposite direction. How these motor molecules work is still unknown. However, it is speculated that the proteins hinge, attaching to the vesicle on the one end and to the cell on the other end pulling each vesicle to the next set of hinges and so on, thus moving the vesicle along the cell until it reaches its final destination.

## CYTOPLASM

This is the jelly-like fluid within the cells that separates the organelles and allows substances to flow between organelles within the cell. This contains many of the proteins, molecules, and important substances that the cell needs, as well as keeping the organelles separate. It is similar to air for us; it has many essential ingredients for continued existence; it provides a medium in which the organelles can exist.

## VACUOLES

A vacuole is any membrane-bound organelle with little or no internal structure. It takes nothing from the cell, and produces nothing for the cell. It does, however, store things for the cell. In a sense it is a "vacuum". Though common in many cells, they are most prominent in plant cells, taking up most of the central space.

Although the contents of the vacuoles vary from organism to organism, as a rule, they contain:

atmospheric gases  
inorganic salts  
Organic acids  
Sugars  
Pigments

## THE CELL MEMBRANE

The cell wall and plasma membrane is thought to be a lipid bi-layer surrounding the cell. It has both lipophilic (fat attracting) and hydrophilic (water attracting) properties, thus allowing it to transport fats and proteins across and into the cell. It also communicates with other cells, by certain recognition sites. It also helps to contact other cells to form *tissues*.

The exact control of movement of materials into and out of the cells is still being studied, however many recent advances in cell biology have led to the discovery of beta blockers to treat heart conditions and the drug Lovastatin, to reduce blood cholesterol levels.

## EXTRACELLULAR MATRIX

The extra cellular matrix is what holds cells together to form organs. Much of this is called connective tissue of which there are two kinds. The first is called *Loose Connective Tissue*, and is found between cells, where blood vessels and other structures are found and its purpose is to hold cells together and feed them. The second type is known as *Strong Connective Tissue* and is found in bone, cartilage and tendons. Collagen is the major protein in the extra cellular spaces of connective tissue. It is the most abundant protein found in the animal kingdom. It forms insoluble fibers that have a very high tensile strength, which are secreted by *fibroblasts*.

There are many more structures and functions of cells, but this is not the forum for a lengthy discussion. If you are interested in learning more about cells and cell biology, it is suggested that you visit your local library and find a recent book on the subject. This is a rapidly growing field of study and new information is being gathered daily. Molecular biology is basically the study of the cells at the molecular level. Molecular and cell biologists have made the discoveries that have lead to cloning, and transgenics.

## Animal Growth

One of the important questions in animal biology is: How does body growth occur in animals? The answer to this question is multifaceted and will be developed below.

Basically there are two ways that growth occurs, one is called hyperplasia, which is an increase in the number of cells in the body, and the other is by hypertrophy, which is an increase in the size of the cells. Each organ system of the body is made up of millions of cells, working to perform a common function. Muscles, for example, are designed for producing movement by contraction. Since muscles are also the economically important tissue of broiler chickens and other meat birds, we will concentrate on how muscles grow and function first.

## MUSCLE GROWTH

There are three basic types of muscles in animals, skeletal, smooth and cardiac. Smooth muscles are found in blood vessels and intestines. The function of muscles is primarily for

the movement of the body and, in the process of movement, to generate heat. They also fill out the contour of the body and give each animal part of its characteristic shape. After puberty, most muscle growth is due to hypertrophy.

The pectoral muscles, or breast muscles (flight muscles), are the largest in the bird and are therefore the most economically important, providing more than half the edible meat of the chicken. The gastrocnemius muscle, another large muscle of the bird, on the back of the leg is attached to the toes by the gastrocnemius tendon which when relaxed causes the toes to grasp a limb, allowing a bird to sleep on a perch.

Two major types of skeletal muscle are of importance; light and dark muscle. (They are also known as white and red muscles.) Light muscle is such because of the low level of myoglobin, the oxygen holding molecules in muscles, and because white muscles have a very definite fibrillar appearance whereas red fibers have a more granular appearance and more myoglobin. Muscles that are used more tend to accumulate more myoglobin, such as leg muscles and flight muscles in wild birds. Since most domestic chickens and turkeys are genetically selected and raised for meat production and don't fly much, their breast muscles are light. Broiler-type chickens have muscle fibers that are larger in diameter and lighter in color than those of layers, mainly due to genetic selection.

Proper muscle development and growth depends upon the proper nutrients being supplied to the chicken. In the embryo, this means yolk, white and egg shell nutrients plus the proper temperature and humidity. In hatchlings and young birds this means a balanced ration and clean water. The proper balance of amino acids and minerals is the key to proper muscle growth. Muscles also need calcium, in addition to protein, to function properly. The point is: keep the birds fed properly and muscle growth will be normal. The energy source to keep muscles working comes mainly in the form of a carbohydrate called glycogen. Glycogen is stored in muscle tissue and the liver and utilized as needed, such as during exercise or when blood glucose levels fall. Storage of glycogen is dependent upon the pancreas and its release of insulin. There will be more on this later during the discussion on endocrinology.

#### OTHER CELL GROWTH

Other cells of the body, such as blood cells, feather follicle cells and skin cells always grow by cell multiplication, i.e. a progressive increase, such as 1, 2, 4, 8, 16, 32... . Growth potential is never fully reached, because of regulation of growth by hormonal or genetic control.

Nerve tissues and muscle (after hatching) grow by cell enlargement (hypertrophy). This same process occurs in fat cells once puberty is reached. Following feeding, lipids are mostly stored in existing adipocyte vacuoles, rather than in newly formed cells.

#### FAT

Body fat, to a large extent, acts as an energy reserve and is the most variable among the major body constituents. While it varies with species, sex, and age, it is also strongly affected, quantitatively as well as qualitatively by nutrition. Even following a prolonged starvation, body fat is never completely depleted and is not likely to drop below 4% of total body weight because of the need to protect the integrity of tissues and organs.

A laying hen fed a commercial laying diet will absorb little more than 3 g of fat per day. Since an average egg yolk contains approximately 6 g of fat, an appreciable part of the yolk lipid of a hen laying an egg almost every day must be synthesized from non-lipid constituents. Much of this comes from carbohydrates and to a lesser extent, from proteins. Thus absorption of fats from the intestinal tract and the synthesis of fats from non-lipid compounds become two distinct sources of depot (body fat), organ and egg lipids. About 2.5% of the fat in chickens is found in the abdomen. By the way, whole chickens purchased at the supermarket in which this fat has been removed can be labeled low fat chickens according to USDA rulings.

Recently, chemicals called partitioning agents have been tested which direct nutrients into the development of muscle and skin tissue. This may increase the protein content of the body by as much as 10% while decreasing fat by as much as 25%. None have been approved for general use poultry at this time.

## BONES

Bone growth is most rapid after hatching, followed by muscle growth, with fat accumulation the least rapid in growth. Bone growth is dependent upon the proper levels of calcium, phosphorous, other minerals, vitamin D, parathyroid hormone, calcitonin, growth hormone and steroids (estrogen in females and androgen in males). For example, the shanks of female chicks reach full growth in 16-18 weeks, whereas mature body size is not reached until 40-50 weeks after hatching. But the long bones of males, controlled by all of the above factors, including genetics, will be larger than those of the female. We must remember that without proper skeletal development, muscle development will not occur properly either. Tibial dyschondroplasia, or leg weakness, is a problem with some rapid growing birds. It occurs as a result of an overabundance of chondrocytes, cartilage cells, and not enough osteocytes, due to a possible surge in growth hormone. The new bone growth occurs without proper mineralization and vascularization occurring, so the bone is soft and unable to support the animals' weight.

Each bone has its special period of growth. The last bone to reach full maturity is the posterior part of the sternum (Keel). A bone grows in length because of cell division (increase in the number of cells). The dividing cells are called osteocytes and are found in the epiphysis, an area just below the end of the bone. On the other side of the epiphysis, toward the joint, new osteocytes are made. As they mature, they are surrounded by a matrix of connective type tissue which helps keep the cells in the proper arrangement. At the side of the epiphysis away from the joint the osteocytes change and begin to become calcified. As this process occurs the matrix is reabsorbed. During this process, the diameter and length both increase until puberty occurs.

Females have specialized bone called medullary bone, which is used as a storage area for calcium for egg formation. The medullary bone is influenced by parathyroid hormone, calcitonin, vitamin D and estrogen. This bone is formed about 10 days prior to the formation of the first egg and results in about a 10% increase in skeletal weight. This only occurs in laying hens, not males or immature females. Medullary bone is found in the tibia, femur, pubic bone, sternum, ribs, ulna, toes and the scapula. This type of bone fills the marrow cavity with fine interlacing spicules of bone to provide a ready supply of calcium.

The skeleton of birds is compact, lightweight and very strong. The vertebra of the neck are

very flexible but the thoracic and lumbar vertebra are fused to make a solid, strong support structure for flying birds. The sternum has the flight muscles attached to it and protects the vital organs.

Chickens have other specialized hollow bones, called pneumatic bones, which are connected to the respiratory system through the air sacs. These bones include the skull, humerus, clavicle, keel, and the lumbar and sacral vertebra. A chicken could actually breathe through a broken humerus.

## INTEGUMENT

The comb, wattles, feathers, preen gland and skin are all part of an organ called the integument. The comb, wattles and preen gland are considered specialized skin. The scales on the shanks are special epithelial (skin) cells. The chicken has no sweat glands in the skin. Thermoregulation occurs by other means to be discussed later. The comb and wattles are used in identification between birds and as an area for dissipation of excess body heat.

## FEATHERS

When the chick hatches it has almost no feathers. It is covered with down, except for the wings and tail. The down soon grows longer, develops a shaft and becomes the first set of feathers for the chick. By the time the bird is 4-5 weeks of age it is fully feathered. These first feathers soon molt and a new set is grown in by the time the bird is 8 weeks of age. The third set is completed just prior to sexual maturity.

Feathers comprise between 4 and 8% of the live weight of the bird. Older birds and males have the lowest percentage. Feathers cover the body in specific tracts. There are 10 feather tracts: head, neck, shoulder, breast, back, wing, rump, abdomen, thigh and leg. Feathers are used to protect the bird, aid in flight and insulate the bird as well as help distinguish between the sexes.

The order of feathering is as follows: Shoulder and thigh, 2-3 weeks; Rump and breast, 3-4 weeks; Neck, abdomen and leg, 4-5 weeks; Back, 5-6 weeks and wing coverts and head at 6-7 weeks.

The feather is made up of the quill, which is carried through the vane as the shaft or rachis. The barbs branch from the quill and the barbules branch from the barbs. The barbicells, which branch from the barbules, have small hooks on their end, called the hamulus, which are used to interconnect with other barbicells to make the feather more air tight. This attachment is similar to how Velcro works.

Slow feathering is a dominant trait and is sex linked. However, fast feathering is desirable on broilers and laying hens. In the rapid-feathering chick, the primaries and secondary feathers are longer than the coverts. In slow feathering chicks the primaries and coverts are about the same length at hatching. The cross between a fast feathering male and slow feathering female results in slow feathering males and fast feathering females.

Molting, the regression of the reproductive tract and loss of feathers is very important in layers and breeders, to extend the laying life of the bird. Feather loss during a molt is in a definite pattern starting with the head, neck, body, wings and tail. In a normal, natural molt,

the primary flights are lost at about one per week, with the first to be shed the one next to the axial feather. It takes about 6 weeks to grow out a new feather. The secondaries molt in the following order: 12, 13, 14, 10, 2, 3, 4, 5, 6, 7, 8, 9, 1.

## SKIN

The skin of the bird is very thin over much of the body, except for the comb, wattles, earlobes and preen gland. The preen gland stores fats and upon irradiation by ultraviolet light it forms vitamin D<sub>3</sub> which is worked into the skin by rubbing it with the beak. Yellow skin is the result of the hydroxyl-carotenoid pigment xanthophyll, from the feed. Corn, alfalfa and marigold petals are sources of xanthophyll. Yellow yolks are also a result of the pigment. The pigment is lost in parts of the skin as hens lay eggs. The numbers of eggs necessary to bleach various parts of the body are:

Vent - bleached by the time the first egg is laid.

Eye-ring and ear lobes - 9-12 eggs.

beak, starting from near the face to the tip as follows

inner 1/3 11 eggs

inner 2 18 eggs

inner 2/3 23 eggs

inner 4/5 29 eggs

whole beak 35 eggs

bottom of the feet - 66 eggs

front of the shanks - 95 eggs

back of shanks - 159 eggs

tops of toes - 175 eggs

hock joints - 185 eggs.

As the bird lays eggs all the pigment is diverted into the yolk so it leaves the body, but when the hen stops laying eggs, the pigment returns in the reverse order.

## Circulatory System

The function of the blood is primarily for the transport of oxygen to the tissues and to remove carbon dioxide from the tissues. It is secondarily for the transport of other nutrients to the tissues and to remove waste product from the tissues to be disposed of by the kidneys. Blood also transports the hormones from the endocrine glands to their target organs. With the aid of the kidney, the circulatory system helps to regulate body water. The antibodies are also transported in the blood. Blood constitutes about 5% of the body weight of the chick and about 9% of the adult chicken. Blood contains a fluid portion (plasma), salts and other chemical constituents, and certain formed elements, the corpuscles. The corpuscles include the erythrocytes (red blood cells) and leukocytes (white blood cells). The erythrocytes of birds are oval shaped and, unlike those of mammals, are nucleated and larger. In adult chickens there are about 3.0 (female) to 3.8 (male) million red blood cells per milliliter of blood. The leukocytes function in immunity and there are several different types of leukocytes. There are heterophils, eosinophils, basophils, lymphocytes and monocytes. Leukocyte counts are used in determining the level of immunity a bird has.

Heart rate varies from about 280 to 340 beats per minute in adult chickens, with a blood pressure of about 166/133 (systolic/diastolic). The heart is a muscle made up of

specialized tissue. The muscle fibers are unique to the heart and called cardiac muscle. The circulatory system works in conjunction with the respiratory system. The lymphatic system is a ductless system that eventually dumps lymph into the blood at the thoracic duct, which is then filtered by the kidneys and removed.

## **Respiratory System**

The respiratory system is comprised of the nasal cavities, pharynx, superior larynx, trachea, inferior larynx, bronchi, lungs, air sacs and also the pneumatic (hollow) bones. The air sacs are divided into 1 pair of abdominal air sacs, 1 pair of cervical, 2 pairs of thoracic and one single interclavicular air sac. Chickens do not have diaphragms. Breathing occurs when the abdominal muscles relax, the inspiratory muscles contract, and the body cavity expands, thereby creating a negative pressure in the air sacs, drawing air in through the lungs and over the parabronchi. Upon expiration, the expiratory muscles contract and force air back through the lungs and out the mouth and nostrils. The air sacs function similar to bellows, with their pressure and volume being modulated by the muscles of respiration. The avian lung is a rigid system of air and blood capillaries in intimate contact. The lung does not expand like the lungs of mammals and is actually a "flow-through system" with a small gas volume which does not expand to accept the tidal volume.

The air sacs and lungs also permit the evaporation of moisture and with it latent heat. This is one of the major ways in which chickens thermoregulate. Additionally, the air sacs perform the following for the bird: acts as a bellows moving air across the gas exchange surface of the lungs, as a balloon to lower the specific gravity, as ballast to obtain the proper center of gravity and as a friction reduction surface between muscles and other tissues and as a reservoir of air during violent muscle contractions.

The pneumatic bones are connected to the respiratory system through the air sacs. Air pressure within the hollow portion of the bone makes the pneumatic bones light and rigid.

## **Digestive System**

Chickens are omnivores and thus their digestive system has characteristics of both herbivores and carnivores. They have no lips, soft palate, cheeks or teeth, but do have an upper and lower horny mandible to enclose the mouth. The mandibles are referred to as the beak. The upper is attached to the skull while the lower is hinged. The hard palate (roof of the mouth) is divided by a long narrow slit in the center which allows air flow to the nasal passages. Because of this, the bird is unable to create a vacuum to draw water into the mouth. The bird drinks with the aid of gravity, which is why they raise their head every time they drink water. The tongue is pointed and has a rough brush-like surface at the back of it to help push food particles down the esophagus. Saliva, with the enzyme amylase, is secreted by the glands of the mouth to help lubricate food passing down the esophagus to the crop.

The crop is an enlargement of the esophagus, found just prior to where the esophagus enters the thoracic cavity, which acts as a storage place for food before it is sent down to the proventriculus, or true stomach.

In the proventriculus hydrochloric acid and enzymes, such as pepsin, are added to the food to aid in the digestion process. After the proventriculus the food passes into the ventriculus or gizzard where the food is mixed with the acid and enzymes from the proventriculus and ground into smaller particles. The addition of grit to the food will aid in this process, although it is not absolutely necessary. The time spent in the gizzard depends upon the coarseness of the food. The finer the particles, the less time spent.

Following the gizzard is the small intestine, the first part of which is the duodenum. Here, the food is mixed with secretions from the liver and the pancreas. The bile, stored in the gall bladder, is manufactured in the liver and contains enzymes and salts to aid in the digestion of fats. Cholesterol is also contained in the bile and is re-absorbed by the small intestines. Pancreatic enzymes actually help neutralize the acid from the proventriculus and aid in the digestion of starches, fats and proteins. The pancreas secretes five different enzymes into the duodenum including amylase, lipase and trypsin. Other enzymes are produced in the wall of the small intestine and further the digestion of protein and sugars.

Absorption of the nutrients from the intestine to the blood stream takes place in the duodenum and small intestine and is completed prior to entering the large intestine.

The ceca are located at the point where the small and large intestines meet. These are two blind sacs in which some bacterial digestion takes place, but relatively little of their function is known at this time.

The large intestine is only about 10 cm long and about twice the diameter of the small intestine. Water re-absorption takes place here to help maintain water balance in the bird.

The terminal portion of the large intestine is called the cloaca. It is a bulbous area at the end of the alimentary tract and means "common sewer". The digestive, urinary and reproductive tracts all empty here. The vent is the external opening of the cloaca.

The liver, in addition to functioning as a part of the digestive system, is also the site of blood detoxification and storage of glycogen and vitamins for use by the tissues as needed.

The liver also manufactures uric acid, which is filtered by the kidneys. Uric acid is the end product of protein metabolism, and the form in which excess nitrogen is excreted. Uric acid is mixed with the feces in the cloaca and is the white product seen in bird droppings.

## **Urinary System**

The uric acid produced by the liver is filtered by the kidneys and excreted into the cloaca via the ureters. Chickens have no urinary bladder and do not store urine. The kidney basically has three functions: filtration, excretion or secretion and absorption. It filters water and some substances normally used by the body from the blood, along with waste products of metabolism which are voided in the urine. It conserves needed body water, glucose, sodium and other substances by re-absorption. The kidney also produces the enzyme rennin which helps to regulate blood pressure, and synthesizes metabolites of vitamin D to aid in the absorption of calcium for shell and bone formation.

## **Reproductive System**

### **MALE**

The testes of the male bird are paired, but unlike those of most mammals, are located

within the body cavity, near the tip of the kidneys. Thus, sperm are produced at body temperature in birds, not a degree or two lower as in mammals. The weight of the testis in chickens constitutes about 1% of the total body weight at sexual maturity. This is quite large. They are almost kidney bean shaped, and a grayish-yellow color. In immature chickens they are much smaller and yellow.

Internally they are made up of a dense series of convoluted seminiferous tubules, connective tissue, blood capillaries and Leydig cells. In the seminiferous tubules, the sperm are formed from germinal tissue. The Leydig cells produce the male steroid hormone testosterone. Testosterone is responsible for maturation of the sperm cells and for secondary sexual characteristics of males, such as feather patterns, colors, and crowing in roosters.

The accessory sexual reproductive organs of the male include the vasa efferentia, epididymis, ductus deferens (the tube system from the testes to the Urodeum of the cloaca) and the ejaculatory groove and phallus. In the process of mating, intromission does not occur in the chicken or turkey. The semen is transferred to the cloacal area near the phallus, and the engorged phallus contacts the everted cloaca of the female and sperm is then transferred to the female, in what is called the *cloacal kiss*. The phallus of drake and other species of birds, however, is a vascularized, spiral-shaped sac with an ejaculatory groove that can protrude up to an inch or so. The average male chicken produces about 1 ml of containing up to 3.5 billion sperm.

Light is the major factor controlling sexual maturity and sperm production in the male. The hormones FSH and LH are released from the pituitary in response to increasing day length and in turn stimulate the testes to produce sperm and testosterone.

## FEMALE

The right ovary and oviduct are present in embryonic development in all birds, but only the left ovary and oviduct develop in Galliformes (fowl). Among falcons and brown kiwi, however, both the left and right ovaries and oviducts are commonly functional. In sparrows and pigeons, about 5% may have two ovaries.

In the chicken the left ovary of the immature bird consists of a mass of small ova, of which almost 2000 are visible. In a mature, functioning ovary, a hierarchy of developing follicles (yolks) are found, with between four and six large yolk filled follicles seen at any time. The largest one is the next to be ovulated to produce an egg. The follicle is covered by a membrane that is highly vascularized, except for one section, called the stigma. The follicular membrane ruptures along the stigma at ovulation. If the follicular membrane ruptures anywhere else, a small amount of blood will be released along with the follicle (yolk) and produce a blood spot in the egg.

After ovulation the egg is caught in the first section of the oviduct, called the infundibulum. In the infundibulum are sperm storage areas and this is where fertilization takes place. The first layer of albumen, called the chalaza, is also produced here. It takes about fifteen minutes for the egg to pass through the infundibulum.

The yolk passes next to the magnum, the longest part of the oviduct, where most of the albumen is formed and deposited around the yolk. It takes about 2-3 hours for the egg to

pass through the magnum.

Following the magnum is the isthmus. Here, the inner and outer shell membranes are formed around the egg and it takes about 1 1/4 to 1 1/2 hours to pass through.

The egg then enters the shell gland, or uterus. Here, the egg takes up salts and water in a process called *aplumping* and the hard shell is added. The egg spends about 18-21 hours in the uterus and this is where final calcification of the shell takes place. Following the uterus, the egg enters the vagina and the cuticle layer is added over the shell as it passes into the vagina. In the vagina the egg turns 180° so that now the large end comes out first.

The ovaries are responsible for production of estrogen and progesterone in the female. Estrogen stimulates secondary sexual characteristics and aids in calcium metabolism and the formation of medullary bone in the hen.

## ENDOCRINE GLANDS

The endocrine glands are ductless glands that secrete chemical substances (hormones) into the blood which act upon specific target organs. The glands are:

1. Pituitary-hypothalamus complex
2. Gonads
3. Pancreatic islets
4. Adrenal glands
5. Thyroid glands
6. Parathyroid gland
7. Ultimobranchial gland
8. Endocrine cells of the gut

In addition to these "classical" endocrine glands, hormone like substances are also produced by:

9. Pineal gland
10. Thymus
11. Liver
12. Kidney.

Each gland and its secretions and their effects on the target organs and how they affect the body will now be discussed.

The pituitary has been called by many the master gland of the body. The pituitary is also known as the hypophysis and in combination with the hypothalamus is known as the Hypothalamic- Hypophyseal Complex. The hypothalamus is largely responsible for releasing factors to stimulate the pituitary to release its hormones.

The pituitary gland is divided into the anterior and the posterior pituitary. The posterior pituitary gland consists of the neurosecretory terminals which release mesotocin or arginine vasotocin. Arginine vasotocin is released to cause the bearing down reflex or ovoposition (laying) of the egg. It is also the major antidiuretic hormone in birds.

The anterior pituitary secretes several different types of hormones: Gonadotropins, Thyrotropin, Somatotropin, Adrenocorticotrophic hormone and related peptides. The Gonadotropins we are most interested in are Luteinizing hormone (LH) and Follicle stimulating hormone (FSH). These are both glycoprotein hormones. In the male chickens, as in mammals, LH acts primarily to stimulate the Leydig cells of the testes to differentiate and to produce testosterone, while FSH promotes spermatogenesis.

Both LH and FSH are necessary for normal ovarian physiology; however their exact roles have not been fully established. Ovulation is induced by LH and both LH and FSH stimulate ovarian production of several steroid hormones. LH stimulates the largest follicles to produce estrogens, testosterone and progesterone, while FSH works on the granulosa cells of the smaller follicles. The secretion of LH and FSH are controlled by hypothalamic releasing factors.

As levels of estrogen increase in the female, it causes a negative feedback on the pituitary to stop the release of LH and FSH. Progesterone, on the other hand, exerts a positive feedback on the release of LH.

There is a pre-ovulatory surge of LH between 4 and 6 hours before ovulation. FSH was found to increase about 14 hours prior to ovulation.

#### THYROTROPIN

Thyrotropin, or thyroid stimulating hormone, (TSH) affects many aspects of thyroid function in the chicken, stimulating growth and the production and release of thyroid hormones. Thyroid stimulating hormone has a number of effects on thyroid cells that eventually lead to thyroxine ( $T_4$ ) and tri-iodothyronine ( $T_3$ ) secretion into the blood stream. There is also evidence that TSH is released in response to the secretion of thyrotropin-releasing hormone (TRH) from the hypothalamus.

#### PROLACTIN

In birds, prolactin is related to either reproduction or to osmoregulation and possibly in the regulation of metabolism and growth in some birds. Prolactin stimulates the production of crop milk in pigeons and doves. In other avian species, prolactin is related to incubation behavior (broodiness) and to inhibition of ovarian functioning. The exact relationship between prolactin and broodiness has yet to be elucidated.

#### GROWTH HORMONE

Growth hormone (GH or somatotropin) has been isolated from the pituitary of many species of birds, including chickens. The lack of GH due to removal of the pituitary gland (hypophysectomy) results in a dramatic decrease in the growth rate of chickens. GH exerts short term effects on metabolism in birds and has a lipolytic effect, meaning it will cause the utilization of fats and lipids as an energy source. This is very important in the broiler industry, with the search for fast growing, lean birds. GH also decreases lipogenesis, the increased manufacture and deposition of fat, and reduces glucose utilization. During periods of nutritional deprivation, GH levels are increased and result in the above mentioned actions.

The release of GH is controlled by several factors: (1) thyrotropin releasing hormone (TRH), (2) a GH-releasing factor (GRF) and, (3) somatostatin, which inhibits GH release.

Growth hormone release is inhibited by prostaglandins, and by insulin and glucagon in young chickens. Nutritional deprivation, such as 1 or 2 days of starvation or chronic feed restriction will also result in the release of GH.

Aberrantly low levels of thyroid hormones will cause an increase in GH release. All the functions and actions of GH in chickens have yet to be discovered.

#### ADRENOCORTICOTROPIC HORMONE

Adrenocorticotrophic hormone (ACTH) acts to stimulate corticosterone production by the cortical cells of the adrenal gland. ACTH is controlled by corticotropin-releasing factor (CRF).

#### ADRENALS

The avian adrenal glands are located at the tip of the kidney. The glands are divided into the outer cortical tissue and the inner medulla. Corticosterone, a glucocorticoid, is the principle steroid hormone of the adrenal cortex. Aldosterone, a mineralocorticoid, is the other major hormone released by the cortex. Corticosterone has been called the "stress hormone" because it is released in large concentrations when the bird receives stimuli it perceives as a threat to its survival or well being.

Corticosterone has many physiological effects in animals. Although corticosterone may cause an increase in food intake, it reduces growth in birds. The reduced body weight is accompanied by an increased deposition of body fat. This is caused by increased lipogenesis by the enlarged liver and by changes in lipolysis. Corticosterone acts to increase net muscle protein breakdown and plasma glucose and liver glycogen concentrations by stimulating the production of glucose from these stores of protein and carbohydrates in the body.

Birds that are under stress are more prone to sickness and disease. This is because corticosterone released in response to stressors is an immunosuppressant. The longer the period of stress, the greater the chance the bird will succumb.

Aldosterone secretion is controlled by the renin-angiotensin system. Renin is released from cells of the kidney in response to many stimuli, including low sodium concentrations, and low blood volume. This then helps the bird to return to normal levels of sodium and blood volume.

#### ADRENAL MEDULLARY SECRETIONS

The medullary secretions are Epinephrine and Nor-Epinephrine (adrenalin and noradrenalin) and are also called catecholamines. These are both mainly neurotransmitters of the adrenergic nervous system. They exert profound effects on the cardiovascular system and carbohydrate and lipid metabolism. Glycogenolysis is stimulated by adrenalin and lipogenesis is inhibited by adrenaline and noradrenalin. Lipolysis is stimulated in the chicken by adrenalin.

#### THYROIDS

The thyroid glands in birds are paired organs oval in shape and dark red in color. They are located on either side of the trachea on the ventral-lateral aspect of the neck just exterior to the thoracic cavity and can be found adhering to the common carotid artery just above the

junction of the common carotid with the subclavian artery. At day 7 of incubation the thyroid of the embryonic chick can concentrate radioactive iodine. It becomes functional and secretes  $T_4$  by 10-11 days of incubation.

The thyroid of birds is capable of concentrating iodine when the blood levels are extremely low and can trap iodine at about 2 to 4 times the rate of mammals. Both  $T_3$  and  $T_4$  have equal potencies for preventing goiter, stimulating body weight, comb growth and influencing oxygen consumption, and heart rate.

The function of the thyroid is governed, within certain limits, by the circulating levels of thyroid hormones and feedback on the hypothalamus to stimulate release of TSH from the pituitary. Some studies have shown that testosterone increases peripheral utilization of thyroid hormones.

## PARATHYROID AND ULTIMOBRANCHIAL GLANDS

### Parathyroids

Since birds, such as chickens, are able to produce an egg each day for extended periods, it represents a calcium demand of approximately 10% of the total body stores. Thus, chickens must possess an efficient and effective mechanism for maintaining calcium homeostasis. The parathyroids have been implicated in this phenomenon.

The four parathyroid glands are located slightly caudal (to the rear) to the thyroids, a pair of glands found on each side of the midline. Chicken parathyroid hormone (PTH) has a primary target of bone and kidney. Injection of PTH results in a rapid rise in blood calcium levels. PTH has been implicated in the renal synthesis of the hormonal form of vitamin  $D_3$ . It is also believed that PTH affects resorption of calcium from medullary bone.

### Ultimobranchial Glands

The Ultimobranchial glands of the chicken are located posterior to the parathyroid glands on either side. They secrete the hormone calcitonin (CT). Calcitonin levels increase in the plasma in relation to increased plasma calcium levels. They appear to maintain the balance between ionic (free or usable) and bound calcium in the blood. The full role of CT in chickens has yet to be elucidated.

## PANCREAS

The pancreas is located in the abdominal cavity, in the loop of the duodenum. Much of the organ is devoted to the synthesis of digestive enzymes: proteolytic, lipases and amylolytic enzymes. About 1-2% of the pancreas is dedicated to the synthesis of the endocrine products; insulin, (anabolic), glucagon (catabolic), pancreatic polypeptide and somatostatin.

Insulin and glucagon are primarily involved in the regulation of blood sugar levels. Briefly, insulin stimulates the production of glycogen from glucose and its storage in muscle and liver tissue. Glucagon works to increase gluconeogenesis, or production of glucose, from glycogen and other sources, along with corticosterone.

Somatostatin appears to help regulate the absorption and distribution of recently digested nutrients as well as in the paracrine regulation of glucagon and insulin.

## PINEAL GLAND

The pineal is located between the cerebral hemispheres and the cerebellum of the brain. Pinealocytes can actively take the amino acid tryptophan from the blood and transform it into 5-hydroxytryptamine (5-HT) and also produces the hormone melatonin. The peak of melatonin rhythm has been shown to occur in mid-scotophase (dark). Melatonin has been shown to affect sleep patterns, behavior and brain electrical activity. Some evidence shows that melatonin exerts significant influence over pituitary gonadotropins by affecting the hypothalamic releasing factors for LH and FSH. In chickens it was shown that melatonin has an inhibiting influence on LH release and inhibits ovulation and decreases the testes weight and ovaries of developing chickens. This may account for the fact that birds do not produce well on short days and long nights. The pineal also plays a role in the maintenance of body temperature, weight and adrenal size.

## OVARIAN HORMONES

Plasma concentrations of progesterone and estrogen have been shown to increase about 6-8 hours prior to ovulation in the largest and smallest preovulatory follicles, respectively. Production of progesterone by the ovarian granulosa cells is greatly enhanced by LH release. Both FSH and LH stimulate estrogen production by the thecal cells.

Progesterone may inhibit ovulation or induce molt when administered in large doses.

Ovulation is stimulated by an as yet unknown mechanism, although ovulation usually follows egg laying within 15-75 minutes. Blood LH peaks about 4-6 hours prior to ovulation. FSH peaks about 15 hours prior to ovulation.

Estrogens have also been implicated in the regulation of calcium metabolism in the hen, along with vitamin D<sub>3</sub> and calcium binding protein. It is believed that estrogen stimulates the production of calcium binding proteins.

The hen's reproductive cycle is greatly influenced by photoperiod, with decreasing day length being de-stimulatory and increasing day length being stimulatory. It has been found that less than 12 hours of light will not result in maximal production, whereas between 12-18 hours of light per day will result in normal egg production. It has been shown that the amount of darkness, and when it is applied will influence oviposition time. This has been demonstrated using intermittent lighting.

Ahemeral photoperiods (shorter or greater than 24 hours) have been shown to affect egg production also. A photoperiod of 27 hours reduces egg numbers but increases egg size.

## TESTES

The testis produce testosterone which has a negative feedback effect on gonadotropin secretion. Additionally, relatively large quantities of progesterone and smaller quantities of estrogen (estradiol 17-B) have been found in testicular tissues. The Leydig cells appear to be the major source of this hormonal activity.

Androgens affect secondary sexual differentiation such as size of comb, plumage and bill color and structure of feathers, vocalizations and behavior.

## TEMPERATURE REGULATION

Birds are "homeotherms" meaning they maintain a relatively constant body temperature. They are also "endotherms" implying that they can also help maintain their body temperature or increase it by generating heat within their tissues. Birds and mammals have many features of thermoregulation in common, however the differences are striking.

Feathers serve for flight and insulation in birds and the disposition of fat tends to be different in birds and mammals and is related to insulation. Birds do not have sweat glands but are very efficient at respiratory evaporative cooling.

Deep-body temperature may differ from skin or peripheral temperature. The cardiovascular system plays a major role in maintaining differential temperatures and aiding in the removal of excess heat from the core to be lost at the surface. The average deep body temperature is about 41.5°C (106.7°F). This temperature fluctuates with time of day and activity and follows a circadian rhythm.

The range of environmental temperatures at which birds exchange heat with the environment the least is known as the zone of least thermoregulatory effort or the zone of thermal comfort. This has traditionally been called the zone of thermo neutrality. This means heat is neither lost nor gained by the animal, but this rarely occurs. The typical range is between 22° and 26°C (71.6 - 78.8°F). Body temperature is determined by the balance between the amount of heat produced by the animal, gained from the environment and lost to the environment. The concept is illustrated by the heat-balance equation:

$$M = E + R + C + K + S$$

where M = metabolic heat production, E = evaporative heat loss (positive), S = heat storage, (positive if heat content of the body increases and body temp rises.) R = heat loss by radiation (positive if heat lost to environment), C= heat loss by convection (positive if heat lost to environment), and K= heat loss by conduction (positive if heat is lost to the environment.)

The comb, wattles and shanks and feet are exposed surfaces of the body where increased blood flow will result in increased heat loss to the environment. Birds standing on cool roosts (water pipes with cool water flowing in them) will maintain normal body temperature during periods of heat better than birds on standard roosts.

Much of the heat loss of birds is due to thermal panting and respiratory evaporative cooling, especially as the temperature increases past 29°C (84.2°F). Preventing heat loss to the environment is also accomplished by reducing blood flow to the surfaces and by countercurrent exchange between blood vessels in the limbs, especially the shanks.

Temperature regulation is under the influence of the hypothalamus and the spinal cord. This is why birds prefer a heat source from above their bodies rather than from the floor. Birds allowed free access to their environment also rely on behavioral thermoregulation. This means they will seek out the most energy efficient means of maintaining their body temperature such as feather ruffling, drinking water, moving into the shade or sun (or heat source), huddling and lying down.

## **NERVOUS SYSTEM**

The nervous system is divided into the central nervous system (CNS), which includes the brain and spinal cord and the peripheral nervous system (PNS), which includes the cranial and spinal nerves that emanate from the brain and spinal cord, respectively, and the many ganglia and plexi that are associated with visceral innervation. The nervous system is also divided by the type of control it provides, with the somatic being under normal conscious control, such as the voluntary muscles of the skeleton, and the autonomic being under reflexive or normally unconscious control, such as the viscera. Nerve cells, or neurons, are in contact with other neurons, through a synapse, to form a vast neural network constituting the nervous system. Neurons have a cell body and an axon which sends impulses away to another neuron, and dendrites that receive impulses from another neuron. Specialized neurons, called sensory neurons, act to sense the environment for animals. They help perceive heat, cold, light, sound, position, taste, smell, pressure and pain.

### **EYES**

The avian eye displays the basic pattern of organization found in all vertebrate eyes, with both rod and cone cells, and incorporates many adaptations that have greatly improved its visual abilities to the point where it is now considered to be the finest ocular organ in the animal kingdom. Most birds have the ability to focus within a range of 20 diopters, twice that of a 20 year-old man. Their color vision is good, peaking in the orange-red portion of the spectrum. They have both monocular and binocular vision and a field of view of about 300°.

### **HEARING**

Birds have a keen sense of hearing and a high degree of equilibration. For many species of birds, their excellent voice production and remarkable ability to imitate sounds has inferred an exceptional degree of sound analysis (pitch discrimination) within a wide range of auditory frequencies.

### **TASTE**

Chickens are indifferent to common sugars, but have a specific taste for sodium chloride. They will not eat food with salt concentrations exceeding 0.9%. This is about the limit their kidneys can safely handle. They have a range of acceptance for sour, either acid or alkaline. They have sensitivity for bitter taste and their feed intake can be controlled using di-methylantranilate. Another interesting fact is that chickens will not drink water that is about 10°F hotter than their body temperature, but will drink water down to freezing

## **IMMUNE SYSTEM**

The immune system of chickens is slightly different from that of mammals in that birds have a Bursa of Fabricius which produces B lymphocytes. Other organs involved with immunity are the thymus, Harderian gland, cecal tonsil and Peyer's patches, spleen, lymph nodes, and pineal gland. Immunity is subdivided into Humoral and Cell Mediated. Humoral immunity is provided through the T and B lymphocytes, which produce immunoglobulins, such as IgA and IgG and antibodies. Cell mediated immunity includes immunity not dependent upon the synthesis of antibodies. Examples of cell mediated

immunity are graft-verses-host (such as transplants of organs or skin tissue).

The main function of the immune system is to destroy foreign invaders in the body, such as bacteria, viruses, protozoa, etc. Some immunity is passed from the hen to her offspring through immunoglobulins and antibodies in the egg yolk and albumen. Vaccines provide immunity for many diseases of poultry. Vaccination schedules vary with the breed and species. Many vaccines can now be given *in-ovo*, into late stage embryos. Proper nutrition and environment can help maintain a healthy immune system.

## SUMMARY

This brief review of poultry biology should provide you with some insights into the rearing and managing of your poultry flocks. It is by no means meant to be comprehensive and complete. The interested reader should follow up with personal study of the many fine books on poultry biology, nutrition, physiology and health found in most major libraries.  
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