Instructional Materials Services
ims Online

Applied Agricultural Science and Technology
Animal Growth and Development
Class Notes Key

INTRODUCTION

Growth and development have important implications for domestic animal production because they significantly influence the value of the animal being produced. A substantial proportion of agricultural research focuses on how to make animal growth and development processes more efficient. This research involves several disciplines because animal growth and development are controlled by genes and hormones. Because growth and development are continuous and dynamic processes requiring integration of numerous physiological functions, they are influenced by:

- nutrition
- efficiency of metabolism and respiration
- hormonal regulation
- immune responses
- physiological status of the animal
- diseases and parasites
- maintenance of homeostasis

Animal growth and development can be separated into processes occurring before birth or hatching (pre-natal) and those occurring after birth or hatching (post-natal). An animal originates from a single cell (ovum or egg), which is fertilized by the male spermatozoon (sperm). The resulting zygote then develops in an enclosed environment (either the uterus or an egg) for a certain time period known as the gestation or incubation period. In cattle, gestation is approximately 283 days; in sheep, approximately 150 days; and in swine, about 112 days. The length of incubation of a chicken egg is 21 days.

After they are born or hatched, young animals experience a period of rapid growth and development until they reach maturity. After an animal matures, some processes (for example, bone elongation) stop while others slow down (for example, muscle deposition). The maximum size of an animal is determined by its genetics, but nutrition and disease influence whether the animal reaches its genetic potential for size.

PRE-NATAL GROWTH AND DEVELOPMENT

Pre-natal growth and development are broken down into two stages, embryogenesis and organogenesis.

Embryogenesis extends from the union of female and male gametes to the emergence of the embryonic axis and development of organ systems at the neurula stage. During embryogenesis, the zygote develops into the morula, which becomes the blastula and then the gastrula.

The zygote is a single cell that is repeatedly cleaved to form a multi-celled ball known as the morula. Cleavage is a process that involves mitotic division of the original cell into two cells, which then divide into four cells and then into eight cells. Although the number of cells double at each stage of cleavage, individual cells do not grow or enlarge in size. So, the morula is the same size as the original zygote, even though it is made up of numerous cells, called blastomeres. Cleavage continues until the cells of the developing embryo are reduced to the size of cells in the adult animal. The cells of the morula are rearranged to form a hollow sphere filled with fluid. At this stage, the embryo is referred to as a blastula and the fluid-filled space inside the sphere is called the blastocoel.

The blastula undergoes a process known as gastrulation and becomes a gastrula. Up until this stage, cell division has occurred but the blastomeres (cells) have not increased in size. The embryo is in the gastrula stage when cell growth occurs at the same time as cell division. The process of gastrulation involves extensive rearrangement of the blastomeres. The cells on one side of the blastula move inward and form a two-layered embryo. The two layers formed are the ectoderm (outer layer) and the endoderm (inner layer). A third cell layer known as the mesoderm is formed between the ectoderm and the endoderm. The cavity that forms within the gastrula is known as the primitive gut; it later develops into the animal's digestive system. All tissues and organs form from one of the three layers of cells in the gastrula. After the germ layers are established, the cells rearrange and develop into tissues and organs. During this phase, known as organogenesis, cells grow and differentiate.

The process of organogenesis extends from the neurela stage to birth or hatching. The neurela stage is distinguished by differentiation, which is when unspecialized embryonic cells change into specialized cells destined to form specific tissues or organs (refer to Table 1).

Table 1. Organs and tissues that form from the three germ layers.

Ectoderm	Mesoderm	Endoderm
Nervous system including the brain, spinal cord, and nerves	Bones and muscle Reproductive and excretory systems	Lining of the digestive tract Liver and pancreas
Lining of the mouth, nostrils, and anus	Blood and blood vessels	Lining of the trachea, bronchi, and lungs
Epidermis of the skin, sweat glands, hair, and nails	Inner layer (dermis) of the skin	Thyroid, parathyroid, thymus, and bladder

Differentiation starts at the upper surface of the gastrula. Cells of the ectoderm divide and form the neural plate. Two raised edges or neural folds appear and gradually come together to form the neural tube. A mass of cells called the neural crest is pinched off the top of the neural tube and then migrates to other parts of the embryo to give rise to neural and other structures. Eventually, the front part of the neural tube thickens and forms the brain; the remainder of the tube becomes the spinal cord.

In the first few weeks after conception, cells differentiate into organs and body structures. The embryo is then referred to as a fetus and the body structures continue to grow and develop until birth. In horses, the embryo is referred to as a fetus at about 40 days following conception, while in humans it takes approximately 56 days to develop the fetus.

Body tissues and organs are formed in a specific sequence; the head is formed before the tail and the spinal cord is formed before other organs. Some highly differentiated cells, such as brain and nerve cells, cannot be replaced if they are destroyed after the original number is fixed during the fetal stage. Thus, nerve cells that are seriously damaged thereafter are not replaced and usually remain permanently damaged. Muscle cell numbers are also fixed during the fetal stage and can only increase in size, not in number. Bone, and therefore skeletal size, can be increased to a degree by environmental conditions, but not beyond the genetic potential of the animal.

POST-NATAL GROWTH

The period of post-natal growth extends from birth or hatching until death, and the length of this period depends greatly on species. The average life span of a mouse is about 2 years, while humans and elephants live to be well over 60 years of age. Sheep and cattle tend to live to be around 15 and 30 years of age, respectively.

Muscle, bone, and fat are the three main types of tissues that develop as an animal grows. The rate of deposition depends on the age of the animal and the type of tissue being deposited.

Muscle fibers are formed from multiple cells called myoblasts. While the animal is still in the prenatal stage, myoblasts fuse together to form a myotube, which develops into a muscle fiber. As a result, one muscle fiber has multiple nuclei. Because no new fibers are formed after birth, postnatal growth of muscle is characterized by increases in length and diameter. Muscle fibers are predominantly protein, and therefore fiber size is determined by the rate of protein synthesis minus the rate of degradation. The deoxyribonucleic acid (DNA) content of muscle cells also increases as the animal develops.

Bone tissue grows both before and after birth. A bone grows in length through the ossification or hardening of the cartilage at each end. After the cartilage on the ends of a bone has completely hardened, the bone stops growing. However, bones also have the capability of increasing in width and can repair themselves if broken. Although individual bones reach a mature length and stop elongating, bone tissue is constantly being deposited and resorbed.

Fat tissue is comprised of fat cells and connective tissue. Fat cells increase or decrease in size depending on the nutritional status of the animal. Two types of fat tissue include white fat, which stores energy, and brown fat, which maintains a constant body temperature. Fat is deposited in four different areas throughout the body or carcass. Fat that is deposited in the abdominal cavity around the kidneys and pelvic area is called intra-abdominal fat; it is usually the first fat deposited. Fat deposited just under the skin is referred to as subcutaneous fat, or backfat, and is usually the largest amount of fat deposited. Fat deposited between the muscles of animals is called intermuscular fat, while fat deposited within the muscle is called intramuscular fat. The level of intramuscular fat deposited is referred to as the degree of marbling and affects the quality and taste of meat. In the United States, an important factor effecting the value of a beef carcass is its quality grade, which is determined by the degree of marbling in the carcass. Therefore, manipulation of this process is very important in meat production systems. Intramuscular fat is the last type of fat to be deposited, so animals with high degrees of marbling also have large amounts of fat deposited in other areas of the carcass.

Muscle, bone, and fat are deposited differently throughout the animal's life. Bone elongation stops after the animal reaches a mature body size but bone tissue deposition and resorption continue until the animal dies. The majority of muscle tissue develops between birth and maturity. Muscle growth then slows down, but it is not physiologically halted as is bone growth. Fat deposition occurs mainly after the bulk of the muscle has been deposited. It is a common misconception that fat is only deposited in middle aged or mature animals; a significant amount of fat is deposited in the young. It is only because protein deposition declines markedly with age that fattening is more apparent in mature animals. The rate of deposition and the amount of fat deposited depend on the diet of the animal. Young animals receiving an overabundance of milk or nutrients become fat.

During early stages of an animal's life, growth occurs very quickly. After puberty, bone elongation stops so skeletal size does not increase much after that point, although live weight continues to increase. In cattle, puberty occurs at about 10 months of age while in sheep and pigs it occurs around 6 and 5 months, respectively.

HORMONAL CONTROL

Deposition of different tissues and partitioning of energy for various processes involved in growth and development are regulated by hormones. Some of the more important hormones involved in growth and development are insulin, growth hormone, Insulin-like Growth Factor 1 (IGF-1), thyroid hormones, glucocorticoids, and the sex steroids.

Insulin is a very important hormone involved in muscle growth and development. It stimulates the transport of certain amino acids into muscle tissue and is active in reducing the rate of protein degradation. It is also a key hormone in the regulation of food intake, nutrient storage, and nutrient partitioning.

Growth hormone stimulates protein anabolism in many tissues. This effect reflects increased amino acid uptake, increased protein synthesis, and decreased oxidation of proteins. Growth hormone also enhances the utilization of fat by stimulating triglyceride breakdown and oxidation in adipocytes. In addition, it seems to have a direct effect on bone growth by stimulating the differentiation of chondrocytes. Growth hormone is one of many hormones that serve to maintain blood glucose within a normal range. For example, it is said to have anti-insulin activity because it suppresses the ability of insulin to stimulate uptake of glucose in peripheral tissues, and it enhances glucose synthesis in the liver. Somewhat paradoxically, the administration of growth hormone stimulates insulin secretion, leading to hyperinsulinemia. The major role of growth hormone in stimulating body growth is to stimulate the liver and other tissues to secrete IGF-1.

IGF-1 stimulates proliferation of chondrocytes (cartilage cells), thus resulting in bone growth. It is also important in protein, fat, and carbohydrate metabolism. Further, IGF-1 stimulates the differentiation and proliferation of myoblasts and the amino acid uptake and protein synthesis in muscle and other tissues.

Animals require thyroid hormones for normal growth. Deficiencies of T_4 or thyroxine and T_3 (Triiodothyronine) cause reduced growth as a result of decreased muscle synthesis and increased proteolysis. Alterations in thyroid status require several days to take effect, and they are associated with changes in the ribonucleic acid (RNA)/protein ratio in skeletal muscle. In addition, thyroid hormones have an important influence on the prenatal development of muscle.

Glucocorticoids restrict growth and induce muscle wasting; they have different effects on different types of muscle. Some evidence indicates that glucocorticoids also effect metabolic rate and energy balance. Androgens (male sex hormones) have an obvious effect on muscle development and growth in general because male animals grow faster and develop more muscle than do females. However, estrogens (female sex hormones) also have significant roles in maximizing growth and are commonly used in artificial growth promotants for both male and female cattle. Estrogen is thought to act indirectly through its effects on the secretion of other hormones. However, it is believed that androgens have a more direct effect because of androgen receptors located on muscle cells.

HOMEOSTASIS

Homeostasis is a concept that is closely integrated with the growth and development of an animal. Normal growth patterns are affected if homeostasis is not maintained at all times. The concept refers to the maintenance of an internal equilibrium. Many processes and functions, both voluntary and involuntary, contribute to maintaining this state of internal balance, which is controlled by the nervous system (nervous regulation) and the endocrine system (chemical regulation).

Homeostasis is maintained at all levels, from individual cells to the whole animal. For example, cells must maintain suitable salt and water levels while tissues and organs require specific blood glucose levels. Therefore, maintaining a state of homeostasis requires a high level of interaction between hormonal and nervous activities.

An example of homeostasis is the maintenance of a constant internal temperature. Temperature is something that must be kept within a certain range for an animal to remain alive and grow and function normally. If an animal is becoming increasingly hot, it may move from an open area to a shaded area to help reduce body heat. This is a voluntary action performed by the animal. At the same time, the animal may involuntarily start to sweat. This is a mechanism that many animals use to dissipate heat, but it is not something controlled by the animal. Rather, it occurs automatically in response to internal stimuli.

GENETIC CONTROL

Most processes involved in growth and development are occurring at a cellular level. Because this is such a finite level, it can be difficult to control or manipulate these processes outside of a scientific laboratory. However, managers of livestock systems must manipulate growth and development to optimize production. Consequently, the knowledge of what is happening at a cellular level must be applied at a whole animal level so that growth and development can be managed. Manipulation of genetics is an important factor in the management of livestock operations because the genetic composition of an animal determines its potential for growth and development.

All animals have a set genotype that determines their potential for growth. However, their phenotype is affected by environmental factors, including nutrition, disease, parasites and injuries. Traits are heritable, which means that they are passed on to an individual from its parents, but some traits are more heritable than others. That is, the genotype of an individual is expressed more strongly, and environment is less influential, for particular traits. Specific genes code for different traits and some traits are influenced by multiple genes. For example, rate of growth is a trait influenced by many genes controlling things such as appetite, tissue deposition, skeletal development, energy expenditure, and body composition. The genes for all of these traits add together to produce the growth rate we can measure. Heritability of some growth-related traits and how they differ between species are listed in Table 2.

Table 2. Heritability of Various Traits in Sheep, Swine and Cattle

	Sheep	Swine	Cattle
Weaning weight	15% – 25%	15% – 20%	15% – 27%
Post weaning gain efficiency	20% – 30%	20% – 30%	40%– 50%
Post weaning rate of gain	50% – 60%	25% – 30%	50% – 55%
Feed efficiency	50%	12%	44%
Loin eye area	53%	53%	56%

Genetic potential for prenatal growth can be inhibited by environmental factors. For example, prenatal growth in chickens is limited by egg size because of the amount of nutrients available to the developing chick. In litter-bearing animals such as swine and rabbits, birth weight of individuals may be affected by the size of the litter and, consequently, the available uterine space and supply of nutrients. Embryos from small breed parents have been transplanted into larger breeds within the same species resulting in birth weights that are greater than their non-transplanted contemporaries. However, birth weights were not as large as offspring of larger breeds with the genetic potential for heavier birth weights.

Growth from birth to weaning is affected significantly by the amount of milk produced by the dam. Many studies of swine indicate that up to 20% of growth during this period is controlled by heritability while 35% to 50% of the weaning weight is affected by the milking ability of the dam, litter size, and other environmental factors. In cattle and sheep, growth during this period is more strongly related to genetic ability, with heritability estimates ranging from 20% to 30%.

During this period, the individual's genetic potential for growth can be more easily evaluated, provided the nutritional levels are adequate and disease and parasites are controlled. Selecting for mature size differences over time has developed large and small strains of chickens, rabbits, swine, cattle, and sheep. The mature size of animals is directly related to their rate of gain and feed efficiency.

Large and late maturing animals are still growing when they reach conventional market weights and are carrying less fat and waste. These larger framed animals are more suitable for markets requiring lean meat. Thus, the grower who produces animals with high-yielding carcasses is rewarded financially. On the other hand, small and early maturing animals have just about finished growing when they reach desirable market weights and are frequently carrying much higher proportions of fat. So, in markets where marbling is a desired feature, this is a good characteristic.

The objectives of individual livestock production operations need to be considered when planning breeding programs. Genetic manipulation through breeding is a long-term commitment; producers need to carefully consider their long-term market objectives and opportunities.

Most animals are produced for a specific market; throughout Texas and the United States, cattle production is focused on feedlot systems that produce meat almost entirely for domestic consumption. Cattle that produce high-yielding carcasses possessing sufficient marbling also have high feed efficiencies; they are considered most valuable. All levels of production, including cow-calf operations, stocker operations, and feedlots focus on producing beef of acceptable quality as efficiently as possible.

In Australia, cattle are grass-fed until they are two to three years old, resulting in leaner, larger carcasses that are ultimately destined for export to Asian countries such as Japan or the Philippines. Greater emphasis is placed on growth rates in male animals and calving percentages in females. Survival is also a major factor to be considered because of harsh environmental conditions. For example, tick resistance and heat tolerance are very important traits.

Selecting for increased growth rates ultimately result in a line of larger framed animals. The negative results of this can be decreased marbling and feed efficiency, increased feed costs, higher birth weights, and higher rates of dystocia. This has led some producers to consider feed efficiency a more suitable selection trait; however, the heritability of feed efficiency is low and genetic improvement is slow. For these reasons, selection based on indirect traits may be more effective.

THE INFLUENCE OF EXTERNAL FACTORS

An animal never reaches its genetic potential for growth, fattening, milk production, egg laying and other developmental processes if diet and environmental conditions are not optimal or at least favorable. Nutrition is the variable that managers of livestock production systems have the most control over in the short-term. An animal requires a certain level of nutrition for the normal development and functioning of its body systems. This is commonly referred to as the maintenance requirements of an animal. Additional nutrients are then required if the optimal growth of muscle and fat is to occur.

Poor nutrition can have multiple consequences such as stunted growth, malformed organs, disease, brittle skeletons, increased susceptibility to parasites, and poor reproductive performance. All of these consequences lead to reduced income for the owner of the animals. Consequently, livestock operations spend a lot of time and money trying to provide optimal nutrition for their animals. For more intensive livestock systems such as swine and cattle feeding operations and broiler grow-out farms, feed costs can contribute to more than 80% of the total costs involved in producing an animal.

Nutrition affects all stages of growth and development. The nutritional status of the dam throughout the gestation period and while she is lactating has significant effects on the offspring's development. Poor nutrition in reproducing females leads to low birth weights and heavy death losses in newborn progeny. Species differ in how they adapt to poor nutrition. For example, sheep and cattle partition as many nutrients as possible into the fetus and even use their own reserves to meet nutrient deficiencies. Iron deficiencies cause problems because the dam utilizes her own reserves to supply the iron requirements of the growing fetus.   In comparison, some species abort the fetus if their nutritional status falls below a certain level.

The effects of poor nutrition after birth on postnatal growth and ultimate mature size depend on three factors: (1) the age at which poor nutrition occurs, (2) the length of time during which the animal was subjected to poor nutrition, and (3) the kind of poor nutrition to which the animal was subjected (for example, a specific imbalance of one or more essential amino acids). Poor nutrition at any stage in an animal's development has long-term effects. For example, cattle that experience a period of poor nutrition as young calves never meet their genetic potential to marble. However, structural development continues as normal if the period of poor nutrition is relatively short in duration. Poor nutrition even provides a benefit in the form of compensatory growth. Compensatory growth is a phenomenon that has been identified in animals that go through a short period of malnutrition but then return to an adequate or high plane of nutrition. Animals lose weight or their development is temporarily slowed but then as the animal's nutritional status improves, they start utilizing nutrients more efficiently. Thus, the resulting weight gain occurs more quickly and more efficiently.

Nutrition is used to manipulate the growth patterns of animals. For example, in feedlots, high-energy diets are commonly fed in the finishing phase to encourage deposition of fat (marbling). The nutritional strategies used depend on the desired end-product, the age at turn-off and the available feed sources.

Any form of disease negatively impacts the growth and development of an animal. Sickness usually requires nutrients to be repartitioned and commonly causes reductions in intake. Some diseases also create long-term consequences that impair the animal's ability to harvest, digest, or absorb nutrients causing long-term impairment of growth and development.

The effect of parasites varies from mild to severe and can be as drastic as death. Both internal and external parasites decrease appetite and therefore the intake of food, depress wool production, inhibit normal digestive functions, cause permanent internal tissue damage, and make the animal physically sick (for example, blood poisoning caused by ticks). Many treatments are available to prevent and combat parasitic infections.

THE AGING PROCESS IN ANIMALS

Aging involves a series of changes in animals that lead to physical deterioration and eventually to death. An age is reached at which each species reaches the peak of its productive life. For example, maximum egg laying is highest during a hen's first year of production, and maximum litter size in swine occurs at 3 to 4 years of age. It has been said that as an animal is born, it begins to die. In a physiological sense, this is true, because shortly after formation of the embryo, cells of certain tissues stop dividing.

Subsequently, cell division stops in other tissues until only those tissues essential to the maintenance of life (that is, skin and blood) continue to divide.

An animal's longevity is roughly proportional to the length of time required for the animal to reach maturity. For example, rabbits, which reach maturity in about 6 months, have a life expectancy of about 4 years. Cattle require 2 to 3 years to mature and have a life expectancy of 20 to 25 years.

Most physiological functions of animals deteriorate with age. The reproductive organs secrete lower levels of hormones, muscular strength and speed of motion decline, and reaction time is increased. Also, the time required for recovery from body substance imbalances becomes longer with age. Collagen or proteins in the skin and blood vessels become less elastic with age, and thus wrinkles form and vessels collapse or burst. An increased breakdown of neural and glandular control involved in the aging process also occurs. Reproductive and lactating abilities of females decrease with age, lowering their productivity. Sows become inefficient producers even earlier because they reach excessive sizes creating higher body maintenance requirements and resulting in more injuries to baby pigs. So, they are frequently culled by 3 years of age. Cows are usually culled from the breeding herd at 10 to 11 years and ewes at 7 to 8 years.

Many factors, both genetic and environmental, affect the life span of animals. Longevity of animals is a heritable trait, so it is estimated by knowing the life span of an individual's parents and siblings. Moreover, life span is decreased if an animal is required to produce at higher than normal levels for a substantial period of time. This is commonly seen in high-producing dairy cows. Inadequate or excessive nutrition also hastens the aging process. Higher environmental temperatures seem to shorten life expectancy, and sex appears to be involved in longevity because females usually outlive males.