PHYSIOLOGY OF GROWTH AND REPRODUCTION IN LIVESTOCK

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Summary

This section provides an overview of the processes of growth and reproduction in animals and the physiological regulation of these processes. Growth and reproduction are important functions in all species which allow them to successfully occupy a particular ecological niche or niches in nature. In farm animals, these functions contribute in an important way to successful and economical production of food for humans by utilizing animals to harvest either natural plant resources or those from cropping systems. Growth of animal tissues results in formation of key food products such as meat which consists of muscle and connective tissues. In addition, reproduction is a key component determining efficiency of meat production. Important interrelationships and common physiological regulatory processes influence both growth and reproduction. The reproductive system itself consists of important products of whole animal growth. Both growth and reproduction are similarly responsive to nutritional and environmental factors, and both display substantial plasticity and

adaptability to changing conditions.

1. Growth

Growth is the process by which an animal becomes larger over time, and may be measured in different ways, such as physical height or length, but the most common measure is the body weight change. Growth can also be described in terms of the rate of deposition of the major specific chemical constituents of the tissues (e.g. protein, lipid, mineral, water). Carbon and nitrogen balance studies and energy balance measurements are often used to describe growth in animals. Growth occurs by processes of hyperplasia (increased cell numbers) and by hypertrophy (increased cell size). Organ systems are comprised of a mixture of tissue types that are arranged to give organs form and function. Growth is achieved by increase in the mass and /or number of cells comprising specific tissues and organs of the body in a dynamic way which involves not only new cell or material additions but also the degradation of older dying cells and removal of cell constituents. Cells consist of proteins, lipids, nucleic acids, carbohydrates, water and mineral components, all of which are in a dynamic state of turnover (synthesis, accumulation, degradation and elimination). In order for there to be an increase in size or mass the rate of synthesis or accumulation must exceed the rate of degradation. The fractional rate of growth is high in early life. When an animal reaches maturity, the rate of growth decreases although material turnover continues with synthesis rate more closely balancing the rate of degradation. Thus, growth is an on-going process of tissue remodeling.

1.1 Early Embryonic Growth

Organs of the body consist of associations of different tissue types which determine the function of the organ. The major basic tissue types include the following: epithelial, connective tissue, muscle and neural tissue. These tissues develop from basic embryonic germ layers formed during the early embryonic stages of growth. When the oocyte becomes fertilized it is a single, large diploid cell which immediately begins to undergo a series of cleavage divisions, first to 2, then 4, 8, 16-cells, etc. until the blastocyst stage (150 to 180 cells) has been formed inside the zona pellucida (membrane which surrounds the oocyte). Although the nuclear number (chromosomes) doubles at each division, the total volume of the cell mass does not increase much until it hatches from the zona pellucida. Prior to hatching there is migration of cells to form an inner cell mass which will become the embryo and a fluid-filled space surrounded by a single layer of cells which will form the trophoblast (future embryonic membranes). After hatching (9-11 days in cattle, 7-8 days in sheep and 6-7 days in pigs), the blastocyst undergoes rapid growth and reorganization, with the embryo giving rise to three germ layers, the ectoderm, the mesoderm and the endoderm.

1.2 Embryonic Origin of Various Organ Systems

The ectoderm gives rise to the following organ systems:

(a) Nervous tissue (the brain and spinal cord, sensory epithelia of the retina, internal ear, olfactory surface).

(b) Alimentary (mouth, teeth, tongue, salivary glands)
(c) Respiratory (nasal cavity, sinuses
(d) Urinary (urethra)
(e) Genital (Scrotum, penis)
(f) Integumentary (cutaneous glands, hooves, hair, nails lens, cornea, skin)

The mesoderm gives rise to the following organ systems:

(a) Alimentary (anal canal, stomach, intestines, salivary glands, liver, pancreas)
(b) Respiratory (trachea, lungs)
(c) Circulatory (heart, arteries, capillaries, veins, blood, lymphatic vessels, lymph)
(d) Urinary (kidney, ureter, urethra)
(e) Genital (Gonads, gonadal ducts, accessory glands, labia, clitoris)
(f) Musculoskeletal (Muscles, bones, cartilage, tendons, connective tissue)

The Endoderm gives rise to the following organ systems:

(a) Alimentary (pharynx, root of tongue, esophagus, liver, pancreas)
(b) Respiratory (pharynx, larynx)

1.3 Description of Tissue Types

1.3.1 Epithelial tissues

Epithelial tissues can be classified into two broad types; 1. Those that form covering or lining membranes (e.g. skin epidermis, lining of gut, respiratory tract, reproductive tract, etc.) or 2. Those that form glandular structures (e.g. liver, pancreas, endocrine glands, etc.). Some cells in the basal layers of epithelial tissues remain undifferentiated throughout life, and are capable of proliferating by mitotic division to generate new cells that can replace cells lost due to damage or sloughing.

1.3.2 Connective tissues

Connective tissues consist of cells (fibrocytes, chondrocytes, osteocytes) and intercellular materials (such as elastin fibres, collagen fibres, reticular fibres, and glycosaminoglycans) in various proportions. Connective tissues function to support and connect groups of other functional cells together. Thus all organs contain some connective tissue, as well as blood vessels, nerves and lymphatic vessels.

Different classes of connective tissues include:

1. Loose, ordinary connective tissues which forms a substrate to hold epithelial and glandular structures, nerves and blood and lymphatic vessels. Cells are fibrocytes which produce some intercellular elastin, and reticular fibres and small amounts of collagen.

2. Adipose tissue is a specialized form of loose connective tissue which, not only provides physical support, but also stores a large amount of lipid as an energy store

in the fat vacuoles of adipocytes (fat cells) and therefore has a major role in metabolism. White adipose tissue is the major type in adult animals and functions to store lipid which can be mobilized in times of need. Brown adipose tissue is often present in significant amounts in newborn animals, and plays a special role in thermogenesis. As animals grow older the proportion of brown adipose tissue declines as white adipose tissue growth predominates. Adults of many species continue to have small amounts of brown adipose tissue which may increase in mass and become activated during cold adaptation.

3. Hemopoietic (blood, and blood-forming) tissues consist mostly of cells which are released into a fluid vehicle such as blood plasma or lymph for transport. Blood-forming tissues include myeloid tissue of the bone marrow, and lymphatic tissues of the thymus gland, lymph nodes and spleen. Leukocytes (white blood cells) are produced in these sites, and are involved in immune responses to help maintain health and resistance to infection. Erythrocytes (red blood cells) play a critical role in transport of oxygen and carbon dioxide for respiratory exchange for all tissues. Blood also plays a critical role in cell nourishment by transport of metabolic substrates to tissues and removal of wastes to sites of elimination (kidneys, liver, lungs). Blood cells are produced in increased numbers under the influence of endocrine substances (e.g. erythropoietin stimulates an increase in mass of red blood cells in response to low partial pressure of oxygen in the atmosphere, and lymphokines and cytokines stimulate increases in numbers of lymphocytes in response to infection). Blood mass constitutes approximately 7 % of body weight.

4. Dense, regular or irregularly arranged connective tissue contains an abundance of intercellular materials. These tissues are strong and form supporting structures such as bone, cartilage, joints, tendons, ligaments and other skeletal structures. Most connective tissue cells are fibrocytes or other specialized cells which produce the intercellular matrix. In tendons, fibrocytes produce a preponderance of collagen fibers oriented in the linear direction of the tendon which gives a high amount of strength. On the other hand, in cartilage there is an abundance of a smooth plastic-like gel matrix (glycosaminoglycans) produced by the chondrocytes together with fewer collagen fibers which are oriented in various directions. The chondrocytes originate from chondroblasts in the outer layer (perichondrium) of cartilage where a good blood supply exists. However, once the chondrocytes become embedded in the accumulating intercellular gel material they lie in small spaces that become cut off from the blood supply as more matrix becomes deposited. Oxygen and nutrients must diffuse through thee gel-like matrix to reach the cells. This limits cartilage growth except from the perichondrium, which contains cells capable of proliferating and generating new chondrocytes. Hyaline cartilage (smooth and glass-like) provides a cushioning effect and smooth articulating surfaces at joints. In certain areas (larynx and pinna of the ear), elastic cartilage which grows on a membranous matrix provides semi-rigid structures which have some flexibility. Bone tissue has many similarities to cartilage (bone cells, the osteocytes, become embedded in an intercellular matrix). The intercellular matrix of bone contains organic material consisting of collagen, glycosaminoglycans, and glycoproteins. Bone growth begins on a cartilaginous matrix or model, as osteoblasts from the periosteum (surface covering or lining of bone) divide and grow in to replace the cartilage. As bone

becomes ossified, hydroxyapatite (containing calcium phosphate compounds) is deposited in the organic substrate of the matrix. Blood vessels accompany the development of osteocytes and thus, bone cells do not become cut-off from the circulation, as is the case with cartilage cells. In bone, the Haversian canal system in the bone matrix provides channels for blood vessels to reach the bone cells for nutrient exchange. Hence bone growth is not constrained in the same way as cartilage, and can achieve thicker masses of tissue.

The ossification of bone matrix provides rigidity and strength for skeletal support and formation of levers for locomotion. Bone material continues to be in a dynamic state of turnover throughout life. The normal process of growth involves both deposition of bone tissue by osteocytes and reabsorption from other sites in the bone by cells called osteoclasts. This process allows bone to remodel during growth and to increase thickness and strength in response to increases in body weight. Bone also forms a major reservoir of minerals in the body and contributes to calcium and phosphorus homoeostasis. During times of high demand, but insufficient intake of these minerals (e.g. onset of lactation), mobilization from bone can meet the metabolic demands, at least in the short term. Mature bone is approximately 75% mineral by weight. Of the organic material, about 88% is collagen.

Long bones of the limbs grow in length by proliferation of cells at the epiphyseal growth plate which lies at the junction between the shaft of the bone and the head of the bone. This is a layer of cartilage which retains the ability to proliferate until the long growth of the bone is complete. Cessation of growth of this plate is referred to as closure of the growth plate and is determined by species, genetics, sex of the animal and the hormone environment. Within an individual animal, closure occurs at different ages in different limb bones.

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Biographical Sketch

Dr R.J. Christopherson was born in Baldur, Manitoba, Canada. He holds a BSA (HON), Agriculture, and MSC, Animal Physiology/Nutrition from the University of Manitoba, Winnipeg. He received his PHD, Animal Physiology/Nutrition from the University of Alberta, Edmonton in 1971.

He has been employed in agriculture, including operation of the family Farm and as a Summer Research Assistant for Agriculture Canada, during his university years. After Graduation he worked as Agricultural Representative, Extension Branch, Manitoba Department of Agriculture. After completion of a PhD degree, he joined the Faculty at the University of Alberta as an Assistant Professor. He continued as a member of the Faculty of Agriculture and Forestry, advancing to Full Professor in 1982. He is currently Professor Emeritus at the University of Alberta, Edmonton, Alberta, Canada. He has published extensively and is a member of the Alberta Institute of Agrology, and an Honorary Life Member of the Canadian Society of Animal Science.

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