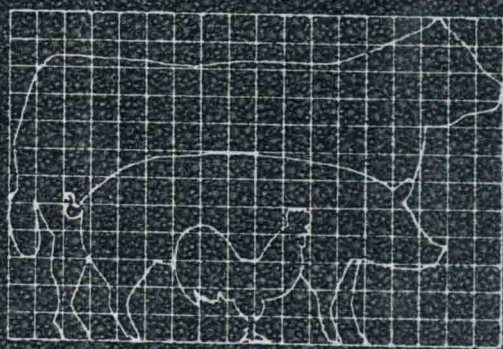


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# *Structure and Development of Meat Animals and Poultry*



H. J. SWATLAND

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LANCASTER • BASEL

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*For J. R. B., 1918–1993.*

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This book is a revised and updated version of *Structure and Development of Meat Animals*, published in 1984. Much of the material in the book concerns poultry, and this is now indicated in the title. In recent years there has been dramatic progress in this field, and I am most grateful to Dr. Joseph Eckenrode of Technomic Publishing for his support and encouragement for this expansion of the original book. Thanks also to Susan Farmer and Doug Bishop for friendly and efficient help in editing and production.

There are many excellent books that deal with animal growth and meat science from biochemical and endocrinological viewpoints, but I think it is important for us to maintain and expand our knowledge of the subject from a structural or anatomical viewpoint as well. This approach to the subject was pioneered by Sir John Hammond at Cambridge fifty years ago and I first encountered some of his studies as a teenager when, as an apprentice butcher, they made immediate sense to me—looking at the growth of farm animals in a way that explained where the weight of valuable meat cuts originated. Hammond integrated studies on quantitative gross anatomy with muscle histology, and explored their interrelationships with physiology and biochemistry, always aiming at explaining both the yield and quality of the final product. This wide sweep of subjects poses a formidable challenge, since I make no claim to be an expert in all the various topics that surface in this volume. I fear I have made many mistakes in specialized areas where my knowledge is weak, but hope that the value of Hammond's generalist approach to the subject will survive.

The whole work has been generally revised and many new references (since 1983) have been added, but also there are specific changes and improvements. Chapter 1 presents the basic information required to understand animal structure and slaughtering, and experience in presenting this



to undergraduate classes has suggested an improved order of presentation. This chapter, like the rest of the book, is studded with low-level information—just the things that beginners may not know, and that we older ones with fewer brain cells may have forgotten.

Chapter 2 explains how the connective tissue of the carcass—bones, gristle and fat—shape the skeleton yet threaten meat quality with toughness or wastefulness. Modern meat now has a lot less fat than before, and it is important to see how this has been achieved, as well as examining the consequences. Our basic problem is that consumers prefer to buy meat with a very lean appearance, but when judging cooked meat, they generally prefer the samples that had a higher fat content.

Chapter 3 gives a synopsis of US and Canadian carcass grading and meat cutting. The information on grading has been updated but, within a few years of publication, readers will have to check their own libraries for newer material. This should not be too difficult, using the bibliography to find the source documents cited, then looking for any recent acquisitions at the same call number. The section on meat cutting has been expanded to include more detail for the United Kingdom (following broad hints from British readers) and new information for Japan (to where everyone wishes to export their meat). Electronic grading, a topic that seemed almost far-fetched when the phrase was coined in the first edition, is now a standard practice in many countries. The section has been updated to show the trends that have emerged, and how grading for meat yield and quality may evolve in the future. The first applications of robotics to meat grading make their debut in this second edition.

Chapter 4, a hands-on dissection guide for identifying the muscles of the carcass, remains the same; no major problems have been reported by those who have used it. Chapter 5, which shows how the commercial properties of meat are determined by the basic structure and biochemistry of striated muscle, has gone through a major review, going into greater depth on the basic side. Topics such as the cytoskeleton, which were new in 1983, now have matured into an integral part of understanding meat texture. Some of the minor proteins named in this second edition may, in the future, emerge to be major causes of cooked meat toughness.

For Chapters 6 and 7, which describe the cellular basis of pre- and postnatal muscle growth and development, many recent discoveries have been surveyed. Judging from the interest generated at recent conferences, histochemical fiber typing now is being used on a large scale for research into meat quality, thus justifying the work of pioneers in the field such as Bob Cassens. Chapter 6 gives an extensive introduction to this topic, as well as others that have not yet reached application. Chapter 7 deals in detail with the postnatal cellular growth and development of meat. To make for

easier reading, I have removed the tedious system of footnotes used in the first edition, although we should not forget the warnings they conveyed—that inattention to detail easily may invalidate the general conclusions drawn from a study.

Animal growth and development in Chapter 8 follows the same general pattern as before. In all honesty, we still do not have any idea how the overall growth of animals is controlled. Perhaps there is no central control, and the numerous mechanisms surveyed in Chapter 8 are simply added, compounded and integrated to determine the overall growth curve.

Finally, the greatest changes are to be found in Chapter 9, which attempts to unite the information presented in earlier chapters to explain the origins of meat quality. Now that the molecular basis of the porcine stress syndrome is known, thanks to Jim Mickelson, Peter O'Brien and other major players whom I do not know personally, it is possible to reduce the confusion and separate causes from effects in this important area, the dollar values of which never cease to amaze me.

I extend my apologies to foreign authors whose names I may have printed without proper accents, due to the limitations of an earlier word-processor. Likewise, I hope readers will forgive my own shaky free-hand diagrams and home-made plotting software. Photographic illustrations to supplement the line drawings have been placed at the back of the book (pages 583–599), where I thought readers might like to browse through them to obtain their own perspective of the various levels of tissue structure involved in understanding the structural properties of meat. Thus, they are not in any particular order, although their subject matter is included in the index. Except where indicated otherwise, they are from my own research and I hope readers will overlook my lack of professional skill in darkroom technique. Specks of detritus that are invisible to me under the red lights of the darkroom have an uncanny knack of clustering right in the main line of vision when the final print is viewed in full daylight. To all readers of the first edition and its Spanish translation who sent me kind comments and constructive criticism—I send my thanks and hope that this edition will prove equally useful.

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# Body Structure and Abattoir Technology

## INTRODUCTION

Apart from the present chapter, the remainder of this book is concerned with the structure and development of muscle, fat and bone in the commercial carcasses of meat animals. But the animal by-product industry is a vital part of the overall economic system of animal agriculture and must be included in any consideration of animal growth or meat science. In many countries, the by-products of animal production and slaughtering are an important source of fuel and fertilizers, and a source of materials for clothing, bedding, and building (McDowell, 1977). Abattoir technology includes all the methods used to produce a dressed carcass from a live animal and is an important subject with regard to animal welfare. From a scientific viewpoint as well, it is not possible to ignore all other body systems except those that contribute directly to the commercial carcass. This chapter briefly reviews the structure, function and economic importance of the systems that keep the animal alive, but which are removed in the abattoir.

## Some Descriptive Terms

A number of anatomical terms are needed to describe the relative positions of structures within the body.

anterior: towards the head

posterior: towards the tail

dorsal: towards the upper part or back of the standing animal

ventral: towards the lower part or belly of the standing animal

medial: towards the midline plane that separates right and left sides of the body

lateral: towards the sides of a standing animal

proximal: towards the body in a limb of the animal

distal: away from the body in a limb of the animal

The names for different types of farm animals also may be unfamiliar to some readers. The adjectives that relate to cattle, sheep and pigs are bovine, ovine and porcine, respectively. The first of these may be used elliptically so that bovine may stand for bovine animal. For cattle, sheep, pigs and poultry, the sire or father is called a bull, a ram, a boar or a cock (tom in turkeys), respectively, while the dam or mother is called a cow, a ewe, a sow or a hen, respectively. A heifer is an immature female bovine, and a gilt is an immature female pig. A hogget is a yearling sheep. The neonates or newborn of cattle, sheep and pigs are called calves, lambs or piglets, respectively. For pigs, the process of birth or parturition is called farrowing. Newly hatched chickens, turkeys, ducks and geese are called chicks, poults, ducklings or goslings, respectively. For cattle, sheep, pigs and poultry, a castrated male is called a steer, a wether, a barrow or a capon, respectively.

## DIGESTIVE SYSTEM

The alimentary tract of the digestive system is composed of the mouth, pharynx, esophagus, stomach, small and large intestines, rectum and anus. Associated with the alimentary tract are the following accessory organs; teeth, tongue, salivary glands, liver and pancreas.

### Mouth, Pharynx and Esophagus

The jaw and tongue muscles are an important source of low grade meat from cattle, pigs and lambs. The mouth is lined by a slippery mucous membrane which, in cattle and sheep (ruminants), has posteriorly directed tags of tissue known as papillae. Bovine papillae are stiffened by a core of keratin in their axis (Steflik et al., 1983). Lips, cheeks and teeth are, of course, absent in poultry. Whereas mammals have a secondary palate that separates the mouth from the nasal cavity, the nostrils of poultry open directly into the roof of the mouth. Thus, when drinking, a bird must use its long neck to keep its head in a horizontal position.

After the mouth, the alimentary tract leads to the pharynx. The pharynx is a complicated junction because the posterior nares from the nasal cavity open into it, as well as the eustachian tubes balancing the air pressure behind the ear drums, the larynx which tops the windpipe from the lungs and, finally, the esophagus which continues the alimentary canal. When a bolus

of food is swallowed, the pharyngeal muscles contract to force it down the esophagus.

The esophagus is a long muscular tube that runs to the stomach. It is located dorsally to the trachea so that it appears behind the trachea when the throat is opened ventrally in the abattoir. At this point in the slaughter of ruminants it is desirable to tie off the esophagus to minimize the spread of ruminal contents onto the carcass. In the meat trade, the esophagus is known as the gullet or weasand. Weasands from beef and lamb carcasses may be used as sausage casings after they have been cleaned and scraped.

In poultry, just before the esophagus enters the thoracic cavity, there is a large sack-like expansion on the right side known as the crop. The crop is a temporary storage area for feed. The muscular wall of the mammalian esophagus starts with two oblique or spiral layers that then develop into inner circular, and outer longitudinal layers farther down. In ruminants, all the muscle tissue of the esophagus is striated. Smooth muscle replaces striated muscle at the level of the diaphragm in pigs. Smooth muscle occurs along the remainder of the alimentary tract and in other organs such as the uterus. Microscopically, smooth muscle is formed from thick layers of elongated cells, each with a single nucleus. The contractile elements of smooth muscle cells do not form microscopically striated fibrils as they do in heart and skeletal muscles.

## **Stomach**

The stomach differs in structure between pigs, ruminants, and poultry. Pigs have a relatively simple, single-chambered stomach (monogastric). Cattle and sheep have three additional chambers before the true stomach. Poultry have a second chamber after the true stomach.

In pigs, the entrance of the esophagus into the stomach is controlled by a sphincter. This region is called the cardia (not to be confused with the cardiac gland region farther into the stomach). The esophageal region of the stomach (Figure 1.1) receives incoming food and is lined by stratified squamous epithelium. An epithelium is a sheet of cells; squamous cells are flattened in shape; stratified tissues have more than one layer of cells. In the adjacent cardiac gland region, the epithelium is supplemented by simple and by compound tubular glands which produce mucus to keep the food sliding through. Tubular glands are formed from a layer of cells rolled into a tube. Each cell secretes its products into the lumen of the tube which then opens into the stomach. Compound tubular glands are formed by branching tubes. In the fundic gland region of the porcine stomach, simple (unbranched) tubular glands open into pits in the stomach wall (Figure 1.2). Cells in the necks of these glands produce mucus. Parietal cells in the body



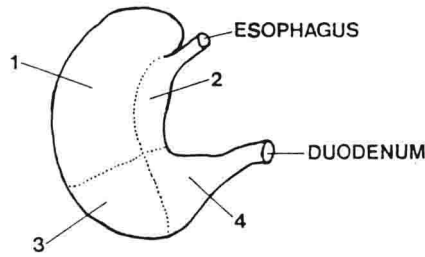


FIGURE 1.1. Regions of the pig stomach: (1) cardiac gland region, (2) esophageal gland region, (3) fundic gland region, (4) pyloric gland region.

of the gland produce hydrochloric acid. Other cells called chief or zymogen cells produce pepsinogen which is split by hydrochloric acid to release the digestive enzyme pepsin. The zymogen cells of milk-fed young animals produce rennin which initiates the digestion of milk. The pyloric glands are deeper and more branched, and they produce a small amount of protease and a lot of mucus.

In cattle and sheep, instead of opening directly into a glandular stomach where digestion begins, the esophagus leads to a series of three extra compartments, the rumen, the reticulum and the omasum. These compartments are lined with stratified squamous epithelium. In young lambs and calves that are still drinking milk, the rumen and reticulum may be by-passed. The presence of the milk is detected by sensory nerve endings in the mouth and pharynx. Reflex activity brings heavy muscular folds in the walls of the

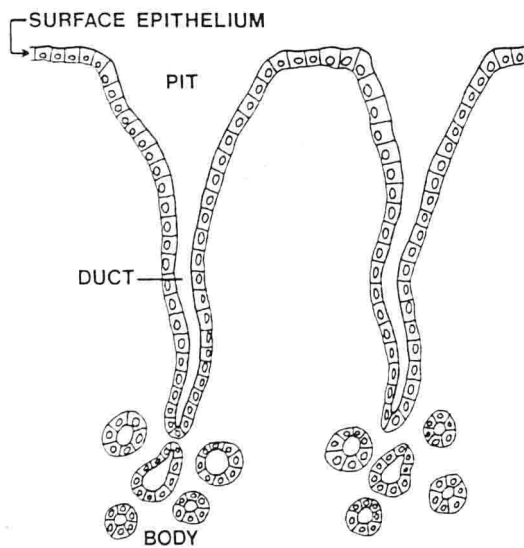


FIGURE 1.2. General microstructure of a stomach gland.

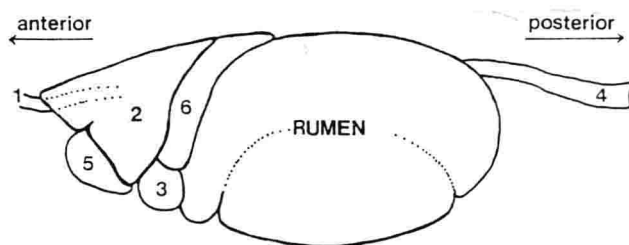


FIGURE 1.3. Relative positions of the viscera in beef as seen from the left side: (1) esophagus, (2) lungs, (3) reticulum, (4) rectum, (5) heart, (6) spleen.

rumen and reticulum together forming an esophageal groove that leads directly from the cardia to the omasum. The rumen or paunch is a very large muscular bag on the left side of the body, extending from the diaphragm back to the pelvis. The smooth muscle of the rumen wall consists of two layers: a superficial layer from anterior to posterior, and an inner layer running transversely to form muscular pillars. The reticulum is lined by thin, wall-like ridges arranged in a honeycomb pattern. The reticulum is posterior to the heart and diaphragm (Figure 1.3). The rumen and reticulum contain countless microorganisms whose metabolic activity greatly enhances the nutritive value of typical ruminant feed.

The omasum is almost spherical in shape and is filled with muscular plates hanging from the dorsal roof. These plates or laminae are studded with short, blunt papillae whose function is to grind roughage. The trade name of the omasum is the manyplies or book-bag. The true glandular stomach or abomasum is located ventrally to the omasum (Figure 1.4). The

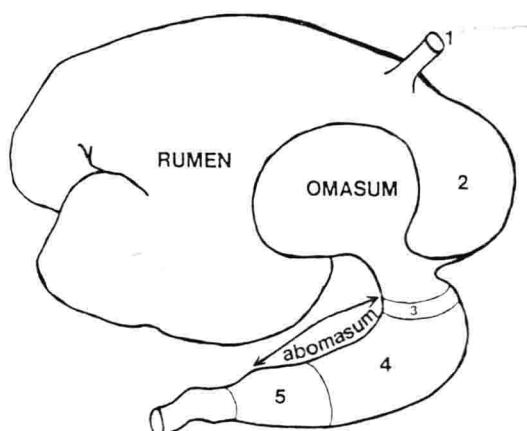


FIGURE 1.4. Beef stomach seen from the right side: (1) esophagus, (2) reticulum, (3) cardiac gland region, (4) fundic gland region, (5) pyloric gland region.