Veterinary Bioscience: Digestive System

LECTURE 17
PANCREATIC AND BILIARY CONTRIBUTIONS TO DIGESTION

LECTURER

PROFESSOR LIZ TUDOR
etudor@unimelb.edu.au

INTENDED LEARNING OUTCOMES

At the end of this lecture, you should be able to:

- Describe the histology of the pancreas and identify the exocrine and endocrine elements of the pancreas in tissue specimens prepared for light microscopy.
- Identify the exocrine glandular cells of the pancreas and explain how the structure and ultrastructure of the different cell types relates to their secretions.
- Describe the structure of the biliary tree, the secretory components of bile, and the path of bile from the hepatocyte to the intestinal lumen.
- Describe the cellular and biochemical mechanism of bicarbonate secretion from pancreatic ductal cells, and the mechanisms that control both binary and pancreatic secretions.

KEY WORDS

Acinar cell, Islet of Langerhans, ductal cell, hepatocyte, trypsinogen, chymotrypsinogen, procarboxypeptidase, pancreatic amylase, pancreatic lipase, bile salts, enterogastrone, vagus nerve, secretin, cholecystokinin, gastrin, bile salts, biliary tree, gall bladder, micelle, fat digestion, emulsification, bile salt dependent bile flow, enterohepatic circulation, bile canaliculus, auto-digestion, steatorrhea.

LECTURE OVERVIEW

Chyme that enters the duodenum is subjected to further chemical digestion due to the activity of secretions of the pancreas, the liver and intestinal mucosal cells.

The role of the pancreas in digestion

The pancreas functions both as an exocrine gland-secreting enzymes and electrolytes that enter the intestinal lumen through the pancreatic duct, and as an endocrine gland-releasing the hormones insulin and glucagon from islets of Langerhans into the blood stream. The exocrine secretions of the pancreas include

the proteolytic enzymes trypsinogen, chymotrypsinogen and pro-carboxypeptidase, as well as pancreatic amylase, lipase and bicarbonate.

Proteolytic enzymes are secreted in an inactive form and are auto-catalytically converted to their active form on entry to the small intestine- trypsinogen by activity of enterokinase secreted by cells of the intestinal mucosa, and the other cells by the activity of trypsin. These enzymes catalyse the breakdown of proteins to amino acids and small peptide chains. Complex intracellular mechanisms stabilize proteolytic enzymes within the pancreatic acinar cell to prevent auto-digestion of the pancreas.

The pancreas is the only site of production of lipase, the enzyme that can accomplish fat digestion, by hydrolysing dietary triglycerides to the absorbable units of monoglycerides and free fatty acids. As a consequence, excessive fat in the faeces (steatorrhea) may be result from insufficient pancreatic secretion.

Chyme entering the duodenum is highly acidic. Electrolytes (bicarbonate) secreted by ductal pancreatic cells, in a process that is catalysed by carbonic anhydrase, buffers this acidic chyme, to prevent damage to mucosal cells and to provide a pH optimal for the activity of pancreatic enzymes. Ductal secretion of an electrolyte rich solution contributes greatly to the volume of pancreatic fluid.

Control of pancreatic secretion

Pancreatic secretion is subject to a similar hierarchy of control mechanisms as exists for gastric secretion. Pancreatic secretion can be observed in all phases of digestion- cephalic, gastric and intestinal- and both neural and neuro-endocrine pathways are involved.

The cephalic phase- in response to the sight, smell or ingestion of food is mediated via vagal stimulation of acinar and ductal cells. The presence of food in the stomach, and particularly gastric distension and the presence of protein, increase pancreatic via two pathways- a vago-vagal reflex, and via release of gastrin that is a potent stimulus to pancreatic secretion. The intestinal phase of pancreatic secretion is the most significant, stimulated by the presence of chyme in the duodenum. An acidic (or fat laden) chyme stimulates release of the enterogastrone secretin from duodenal S cells, and subsequent secretion of bicarbonate rich aqueous fluid from ductal cells. A protein or fat rich chyme stimulates release of cholecystokinin (CCK) and subsequent release of enzyme containing zymogen granules from acinar cells with little change in fluid volume.

Bile secretion and the biliary tree

The liver is a complex metabolic organ with a multiplicity of functions. Amongst these is the synthesis and secretion of bile salts, that aid in the emulsification and subsequent digestion of fats by pancreatic lipase.

Bile salts are formed in hepatocytes by conjugation of cholesterol with amino acids. The steroid backbone of the bile acid is lipophilic; the amino acid conjugate is hydrophilic. Conjugated bile salts are thus able to function as detergents and serve to keep fats in solution in an aqueous environment and hence accessible to lipase. Bile salts aggregate spontaneously with fats to form micelles.

Bile salts are secreted across the lateral border of hepatocytes into the bile canaliculus, and then through a network of ductules and ducts to the bile duct and to storage in the gall bladder. The gall bladder stores and concentrates bile but has no secretory role.

Control mechanisms in secretion of bile

The vagus nerve plays a minor part in control of bile secretion. The enterogastrones secretin and CCK are significant regulators of bile secretion and release. As it does with pancreatic $NaHCO_3$ secretion, secretin stimulates an increased aqueous alkaline bile secretion by duct cells without a corresponding increase in bile salt secretion, i.e. secretin stimulated release of alkaline biliary secretion helps to neutralise gastric acid

entering duodenum. The presence of fat in duodenal chyme stimulates release of CCK, which as its name suggests, stimulates contraction of the gall bladder and delivery of bile to the duodenum.

Secretion of bile by hepatocytes is also regulated by chemical means, the so called 'bile salt dependent bile flow'. During a meal, bile is emptied from the gall bladder to duodenum, bile salts participate in fat digestion, then pass to the ileum where they are reabsorbed and returned by entero-hepatic circulation to the hepatocytes, where they serve to increase bile secretion. As bile is secreted and reabsorbed, its secretion is increased. Between meals, when bile salts are being stored in the gall bladder, secretion is low. Entero-hepatic circulation allows for a very high degree of conservation of bile salts (up to 98%), with the remainder synthesized de novo.

FURTHER READING

Sherwood, L. *Human Physiology from Cells to Systems* 8th Edition 2013 Ch 16

Cunningham's *Textbook of Veterinary Physiology* 6th Ed Elsevier 2020 Ch 27 & 28

Young B *Wheater's Functional Histology: A text and colour atlas* 4th Edn 2014 Churchill Livingstone (ebook)

Bacha WJ & Bacha LM *Color Atlas of Veterinary Histology* 2nd Edn 2012 Wiley-Blackwell