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Anatomy and Physiology of the Bowel and Urinary Systems

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INTRODUCTION

The aim of this chapter is to increase the reader's understanding of the small and large bowel and urinary system as this will enhance their knowledge base and allow them to apply this knowledge when caring for patients who are to undergo stoma formation.

LEARNING OBJECTIVES

By the end of this chapter the reader will have:

❑ an understanding of the anatomy and physiology of the small and large bowel;
❑ an understanding of the anatomy and physiology of the urinary system.

GASTROINTESTINAL TRACT

The gastrointestinal (GI) tract (Fig. 1.1) consists of the mouth, pharynx, oesophagus, stomach, duodenum, jejunum, small and large intestines, rectum and anal canal. It is a muscular tube, approximately 9 m in length, and it is controlled by the autonomic nervous system. However, while giving a brief outline of the whole system and its makeup, this chapter will focus on the anatomy and physiology of the small and large bowel and the urinary system.

The GI tract is responsible for the breakdown, digestion and absorption of food, and the removal of solid waste in the form of faeces from the body. As food is eaten, it passes through each section of the GI tract and is subjected to the action of various

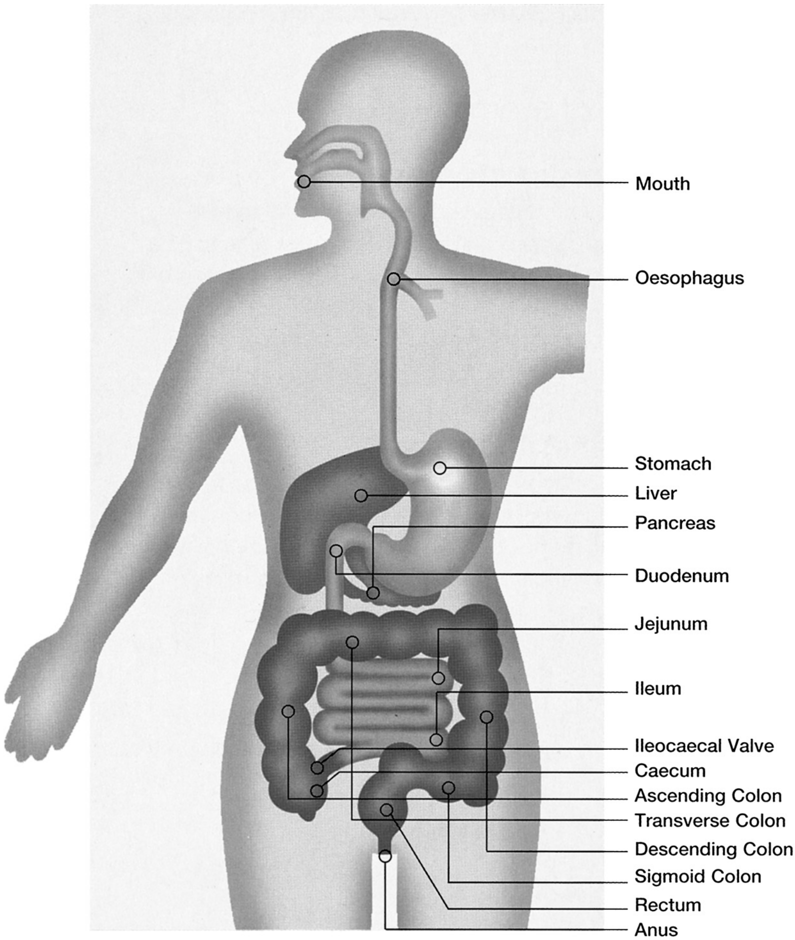

Fig. 1.1 The digestive system. Reproduced with kind permission of Coloplast Ltd from *An Introduction to Stoma Care* 2000

digestive fluids and enzymes (Lehne 1998). The salivary glands switch into action as soon as food enters the mouth, and as the food continues on its journey, enzymes found in the stomach, small intestine, the pancreas and the liver continue the process. It is this secretion of fluids that helps maintain the function of the tract (Tortora & Grabowski 2001).

Lining of the GI tract

Throughout the GI tract, the walls are made up of mucous membrane, constructed in such a way that the various parts can act independently of each other. The walls of the GI tract consist of four layers. These are the:

- adventitia;
- muscularis;
- submucosa;
- mucosa.

Adventitia

The adventitia or outer layer consists of a serous membrane composed of connective tissue and epithelium. In the abdomen it is called the visceral peritoneum. It forms a part of the peritoneum, which is the largest serous membrane of the body (Thibodeau & Patton 2002).

Peritoneum

The peritoneum is the serous membrane that lines the abdominal and pelvic cavities, and covers most abdominal viscera. It is a large closed sac of thin membrane which has two layers:

- the parietal peritoneum, which lines the abdominal and pelvic cavities;
- the visceral peritoneum which covers the external surfaces of most abdominal organs, including the intestinal tract.

The serous membrane is made up of simple squamous epithelium and a supporting layer of connective tissue. The potential space between the visceral and parietal layers is known as the peritoneal cavity and contains serous fluid. In some diseases, such as liver disease, the peritoneal cavity can fill up with serous fluid called ascites. Some organs protrude into the abdominal cavity but are not encased in the visceral peritoneum. The kidneys lie in this type of position and are said to be 'retroperitoneal'.

The folds of the peritoneum bind the organs to the cavity walls and to each other. The folds include the mesentery, the lesser omentum, the greater omentum and the faciform ligament. These folds contain the nerve, blood and lymph supply to the abdominal organs. The mesentery is attached to the posterior abdominal wall and this binds the small intestine to the abdominal wall. The lesser omentum arises from the lesser curvature of the stomach and extends to the liver. The greater omentum is given off from the greater curvature of the stomach, forms a large sheet that lies over the intestines, and then converges into parietal peritoneum. The falciform ligament attaches the liver to the anterior abdominal wall and to the diaphragm (Ross *et al*. 2001).

Muscularis

The muscularis mostly consists of two layers of smooth muscle, which contract in a wave-like motion. The exceptions can be found in the mouth, pharynx and the upper oesophagus, which are made of skeletal muscle that aids swallowing. The two smooth muscle layers consist of longitudinal fibres in the outer layer and circular fibres in the inner layer. The contraction of these two layers of muscle assists in breaking down the food, mixing it with the digestive secretions and propelling it forward. This action is referred to as peristalsis. Peristaltic action looks like an ocean wave moving through the muscle. The muscle constricts and then propels the narrowed portion slowly down the length of the organ forcing anything in front of the narrowing to move forward.

Between the two muscle layers the blood vessels, lymph vessels and the major nerve supply to the GI tract can be found. The nerve supply is called the mesenteric or Auerbach's plexus, and it consists of both sympathetic and parasympathetic nerves. It is mostly responsible for GI motility, which is the ability of the GI tract to move spontaneously (Tucker 2002; Martini 2004).

Submucosa

The submucous layer is highly vascular as it houses plexuses of blood vessels, nerves and lymph vessels, and tissue. It consists of connective tissue and elastic fibres. It also contains the submucosal or Meissner's plexus, which is important in controlling the secretions in the GI tract (Martini 2004).

Mucosa

The mucosa is a layer of mucous membrane that forms the inner lining of the GI tract. It is made up of three layers:

- a lining layer of epithelium, which acts as a protective layer in the mouth and oesophagus, and has secretory and absorptive functions throughout the rest of the tract;
- the lamina propria, which supports the epithelium by binding it to the muscularis mucosae and is made up of loose connective tissue that contains blood and lymph vessels;
- the muscularis mucosae layer, which contains smooth muscle fibres (Siegfried 2002).

SMALL INTESTINE

The small intestine begins at the pyloric sphinter and coils its way through the central and lower aspects of the abdominal cavity and joins the large intestine (colon) at the ileocaecal valve. The small intestine is divided into three separate segments: the duodenum, jejunum and ileum. The nerve supply for the small bowel is both sympathetic and parasympathetic.

It is approximately 6.5 m long and has a diameter of approximately 2.5 cm. The walls of the small intestine consist of the same four layers as the rest of the GI tract, however, both the mucosal and submucosal layers are modified. The mucosal layer consists of many glands called intestinal glands. These glands are lined with glandular epithelium, and they secrete intestinal juice. The submucosa in the duodenum contains glands that secrete mucus which is alkaline, this is designed to protect the small intestine walls from the acid in chyme and prevent the enzymes from acting on the walls. The small intestine is further modified in that throughout its length the epithelium covering the lining and the mucosa is made up of simple columnar epithelium. This contains both absorptive and goblet cells. If you were to examine the small intestine using a powerful microscope you would note that the absorptive cells actually contain projections described as 'finger-like'. The projections are known as microvilli and allow the small intestine to deal with larger amounts of digested nutrients, having simply increased the surface area for digestion (Thibodeau & Patton 2002; Ellis 2004).

The mucosa has a velvety appearance because its surface is made up by a series of villi. There are approximately 20–40 villi per square millimetre and these also increase the absorptive and digestive surface of the small intestine. They are about 0.5–1 mm long and their walls are made up of columnar epithelial cells with tiny microvilli. The cells enclose a network of blood and lymphatic capillaries. The lymphatic vessels are known as lacteals. Nutrients pass via the blood capillaries and lacteals into the cardiovascular and lymphatic systems (Tortora & Grabowski 2002).

The surface area of the small intestine is further increased by the presence of circular folds about 10 mm high. These are unlike the rugae in the stomach that flatten out, in that they remain in place. They cause the chyme to twist around as it moves through the small intestine. This assists the digestive and absorptive processes. Throughout the mucous membrane in the small intestine numerous lymph nodes occur at irregular intervals. The nodes are known as either solitary or aggregated lymphatic follicles (Peyer's patches) that occur in groups, and they are found mostly in the ileum (Watson 2000; Ross *et al*. 2001).

Thus, the main function of the small intestine is digestion and absorption and its makeup is designed to help this process. The chyme is broken into small molecules that can be transported across the epithelium and into the blood stream. This occurs in the presence of pancreatic enzymes and bile, which are important in the digestive process. The small intestine absorbs most of the water, electrolytes (sodium, chloride, potassium) and glucose (amino acids and fatty acid) from the chyme. The small intestine not only provides nutrients to the body but also plays a critical role in water and acid–base balance (Tortora & Grabowski 2002; Martini 2004).

The chyme from the stomach moves along the small intestine at approximately 1 cm/min. As the small intestine is about 6.4 m in length, chyme can remain in the small intestine for up to eight hours. The chyme is moved along by peristaltic movements, which are controlled by the autonomic nervous system. Digestion is completed in the small intestine with the aid of juices from the liver and pancreas. Waste is then transported to the large intestine for disposal.

The superior mesenteric artery supplies the whole of the small intestine and venous blood is drained by the superior mesenteric vein that links with other veins to form the hepatic portal vein (Watson 2000; Ross *et al*. 2001).

Duodenum

This is approximately 25 cm in length and it curves around the head of the pancreas. In the mid-section of the duodenum there is an opening from both the pancreas and the common bile duct. This opening is controlled by the sphincter of Oddi.

Jejunum

This is approximately 2.5 m in length and extends to the ileum.

Ileum

This is the terminal part of the small intestine that ends at the ileocaecal valve. It measures about 3.5 m in length. The ileum will usually empty approximately 1.5 litres of fluid into the colon each day.

Pancreas

The pancreas is attached to the duodenum and lies posterior to the greater curvature of the stomach. When chyme enters the duodenum the hormone secretin is released and this stimulates the pancreas to secrete its juices. The pancreatic juices pass through the pancreatic ducts into the duodenum to aid digestion by neutralising the acid to continue the digestive process (Ross *et al*. 2001).

Liver and gall bladder

The liver is situated in the right hypochondrium and extends into the epigastric region. Bile, which is produced in the liver, passes from the hepatic ducts into the cystic duct prior to entering the gall bladder for storage. When fatty foods are detected in the duodenum the hormone cholecystokinin is secreted. This causes the gall bladder to contract thus pushing the bile into the duodenum to emulsify the fatty food (Kumar & Clark 1998; Page 2001).

LARGE INTESTINE

The large intestine is so called because of its ability to distend. It forms a three-sided frame around the small intestine leaving its inferior area open to the pelvis. It is designed to absorb water from the contents of the small intestine that pass into it. Although the small intestine absorbs some water this process is intensified in the large intestine until the familiar semisolid consistency of faeces is achieved. The large intestine is approximately 1.5 m in length and extends from the ileum to the anus. Its size decreases gradually from the caecum, where it is approximately 7 cm in diameter, to the sigmoid, where it is approximately 2.5 cm in diameter (Keshav 2003). The large intestine has four segments: the caecum, colon, rectum and anal canal. The colon is divided into four sections: the ascending colon, transverse colon, descending colon and sigmoid colon.

The large intestine also houses a variety of bacteria. These bacteria, known as commensals, live happily in the bowel and generally do not cause any problems. In fact, they play an important part in digestion – they ferment carbohydrates and release hydrogen, carbon dioxide and methane gas. The bacteria also synthesise a number of vitamins such as vitamin K and some B vitamins. They are also responsible for breaking down the bilirubin into urobilinogen, which gives the faeces its characteristic brown colour. However, outside the bowel the bacteria can cause illness and even death.

The blood supply to the large intestine is mainly by the superior and inferior mesenteric arteries. The internal iliac arteries supply the rectum and anus. Venous drainage is mainly by the superior and inferior mesenteric veins, and the rectum and anus are drained by the internal iliac veins. The nerves supplying the large intestine are via the sympathetic and parasympathetic nerves. The external anal sphincter is under voluntary control and is supplied by motor nerves from the spinal cord (Siegfried 2002; Ellis 2004).

Caecum

The small intestine terminates at the posteromedial aspect of the caecum. The caecum is fixed to the right side near the iliac crest. At the opening to the caecum there is a fold of mucous membrane known as the ileocaecal valve, which allows the passage of materials from the small intestine into the large intestine and prevents the reflux of contents from the colon back into the ileum. The contents of the colon are heavily colonised by bacteria whereas the small intestine is relatively free of microbes. The caecum is a dilated portion and has been described as a blind pouch approximately 6 cm in width and 8 cm in length. It is continuous with the ascending colon superiorly and has a blind end inferiorly. Attached to the caecum is a coiled tube closed at one end called the vermiform appendix. It is usually 8–13 cm in length although this can vary from 2.5 cm to 23 cm and has the same structure as the walls of the colon; however, it contains more lymphatic tissue (Moore & Dalley 1999).

Colon

Ascending colon

The ascending colon is approximately 15 cm long and joins the caecum at the ileocaecal junction. The ascending colon is covered with peritoneum anteriorly and on both sides, however, its posterior surface is devoid of peritoneum. It ascends on the right side of the abdomen to the level of the liver where it bends acutely to the left. At this point it forms the right colic or hepatic flexure and then continues as the transverse colon (Thibodeau & Patton 2002).

Transverse colon

This is a loop of colon approximately 45 cm long that continues from the left hepatic flexure across to the left side of the abdomen to the left colic flexure. It passes in front of the stomach and duodenum and then curves beneath the lower part of the spleen on the left side as the left colic or splenic flexure and then passes acutely downward as the descending colon (Watson 2000).

Descending colon

This section of the colon passes downwards on the left side of the abdomen to the level of the iliac crest. It is approximately

25 cm in length. The descending colon is narrower and more dorsally situated than the ascending colon.

Sigmoid colon

The sigmoid colon begins near the iliac crest and is approximately 36 cm long. It ends at the centre of the mid-sacrum, where it becomes the rectum at about the level of the third sacral vertebra. It is mobile and is completely covered by peritoneum and attached to the pelvic walls in an inverted V shape.

Rectum

The rectum is approximately 13 cm in length and begins where the colon loses its mesentery. It lies in the posterior aspect of the pelvis and ends 2–3 cm anteroinferiorly to the tip of the coccyx, where it bends downwards to form the anal canal (Tortora & Grabowski 2002).

Anal canal

This is the terminal segment of the large intestine and is approximately 4 cm in length opening to the exterior as the anus. The mucous membrane of the anal canal is arranged in longitudinal folds that contain a network of arteries and veins. The anus remains closed at rest. The anal canal corresponds anteriorly to the bulb of the penis in males and to the lower vagina in females and posteriorly it is related to the coccyx. The internal anal sphincter is composed of smooth muscle and is the lower of the two sphincters. It is about 2.5 cm long and can be palpated during rectal examination. It controls the upper two-thirds of the anal canal. The external sphincter is made up of skeletal muscle and is normally closed except during elimination of faeces. The nerve supply is from the perineal branch of the fourth sacral nerve and the inferior rectal nerves (Martini 2004).

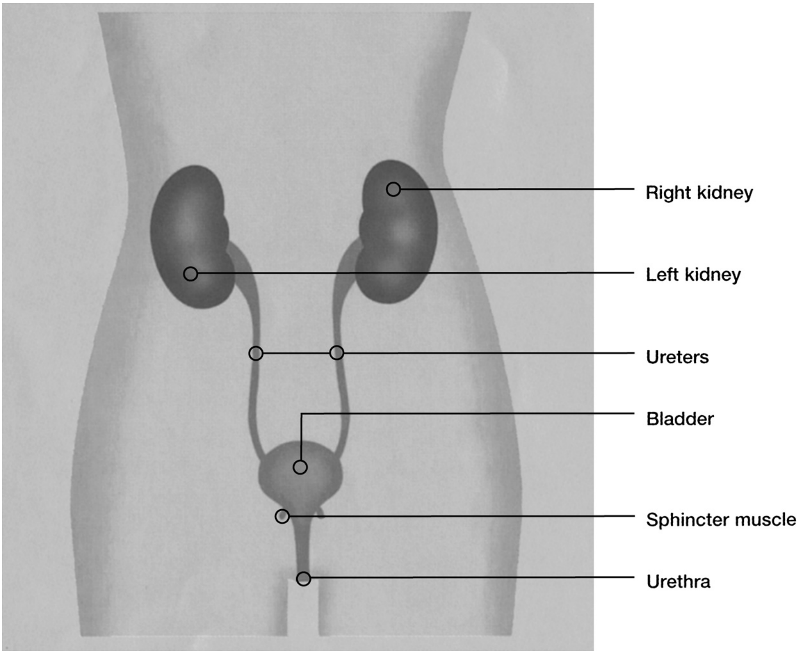

Fig. 1.2 The urinary system. Reproduced with kind permission of Coloplast Ltd from *An Introduction to Stoma Care* 2000

URINARY SYSTEM

The urinary system consists of the kidneys, ureters, bladder and urethra (Fig. 1.2). It has three major functions:

- excretion;
- elimination;
- homoeostatic regulation of the solute concentration of the blood plasma.

Kidneys

The kidneys are situated on either side of the vertebral column and they lie retroperitoneally between the 12th thoracic and

3rd lumbar vertebrae. The left kidney lies slightly superior to the right kidney and it is also slightly longer.

The kidneys are bean-shaped, and approximately 10–12 cm in length, 5–7 cm wide and 2–5 cm thick. The blood supply, nerves and lymphatic vessels enter and exit at the hilum.

The superior surface of the kidney is capped by the adrenal gland. Each kidney is surrounded by three layers.

(1) *Renal capsule:* this is a layer of collagen fibres that covers the outer surface of the entire organ.
(2) *Fat:* this keeps the kidney in place and surrounds the renal capsule.
(3) *Renal fascia:* this is a dense fibrous outer layer that also secures the kidney to the posterior abdominal wall and to the surrounding structures (Ross *et al*. 2001).

The kidney itself is made up of two layers, the cortex and the medulla. The cortex is the outer layer and the medulla is the inner layer. Within the medulla there are 8–18 distinct conical or triangular structures called the renal pyramids. The base of each pyramid is turned towards the cortex and the tip of the pyramid is directed towards the renal sinus. The tips of the pyramids are referred to as the renal papillae. The pyramids are separated from each other by bands of cortical tissue called the renal columns. The renal cortex and the pyramids together make up the parenchyma. The parenchyma consists of approximately 1.25 million nephrons, which are the functional units of the kidney as they form urine and help regulate the composition of the blood (Raferty 2000; Tucker 2002; Martini 2004)

Nephron

The nephron is the functional unit of the kidney. It is responsible for filtration of the blood and for the re-absorption of water and salts and the absorption of glucose. About 1.25 million nephrons can be found in the cortex. The nephron consists of a renal tubule and a renal corpuscle. The tubule is approximately 50 mm in length and consists of the convoluted tubule and the loop of Henle. The renal corpuscle is made up of the Bowman's capsule and the capillary network of the glomerulus (Tucker 2002).

Blood and nerve supply of the kidney

The right and left renal arteries transport about 20–25% of the total cardiac output and approximately 1200 ml will pass through the kidney each minute. As the renal artery enters the renal sinus, it divides into the five segmental arteries, which then subdivide into a series of interlobar arteries that radiate outwards and between the renal columns. At the base of the renal pyramids the arteries arch between the medulla and the cortex and are known as the arcuate arteries. These divide again to form the interlobular arteries. The interlobular arteries enter the renal cortex and become efferent arterioles which deliver blood to the capillaries known as peritubular capillaries.

Blood exits the kidney via the peritubular venules which then join the interlobular veins. These drain through the arcuate veins into the interlobar veins, which, in turn, join the segmental veins. The segmental veins join the renal vein which leaves the kidney at the hilum (Ellis 2004).

Nerve supply of the kidney

The nerve supply to the kidneys is from the renal nerves, which are derived from the renal plexus of the sympathetic division of the autonomic nervous system. The nerves enter the kidney at the hilum and run alongside the blood supply to reach the individual nephrons. The nerves regulate the circulation of blood in the kidneys by controlling the size of the arterioles (Martini 2004).

Ureters

The ureters are muscular tubes that link the kidneys to the bladder. They are approximately 30 cm in length and 3 mm in diameter. They consist of three layers: an inner layer of transitional epithelium, a middle layer made up of longitudinal and circular bands of smooth muscle and an outer layer of connective tissue which is continuous with the renal capsule. There are slight differences in the ureters in men and women as they have to accommodate the position of the reproductive organs.

The ureters transport urine from the kidneys to the bladder. Urine is forced along the ureter due to peristaltic action. The ureters enter the bladder on the posterior wall and pass into the bladder at an oblique angle. This prevents backflow when the bladder contracts (Ross *et al*. 2001).

Bladder

The bladder is a hollow, muscular organ that collects and stores urine. It is situated in the lower part of the abdomen and is lined with a membrane called the urothelium. The cells of this membrane are called transitional cells or urothelial cells. The bladder wall has three layers: mucosa, submucosa and muscularis. The muscularis is made up of layers of longitudinal smooth muscle with a circular layer sandwiched in between. This muscle layer is known as the detrusor muscle, and it is this mucle that contracts to expel urine from the bladder and into the urethra.

The bladder initally stores urine, however, afferent fibres in the pelvic nerves carry impulses to the spinal cord, which, in turn, sends messages to the thalamus and then along projection fibres to the cerebral cortex. At this point you become aware that your bladder requires emptying. The muscle of the bladder can then be contracted to force urine out of the body through a tube called the urethra (Ellis 2004).

Urethra

The urethra extends from the neck of the bladder to the exterior of the body. In women, the urethra is a very short tube, in front of the vagina, approximately 4 cm in length. In men, the tube is considerably longer, 18–20 cm long; it needs to be longer as it has to pass through the prostate gland and the length of the penis. It is made up of stratified epithelium (Ross *et al*. 2001; Thibodeau & Patton 2002; Martini 2004).

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