Nursing Children and Young People

CPD

The biological basis to the gastrointestinal system

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Abstract

This article continues in the CPD Anatomy and Physiology series of ‘The Biological Basis to…’ It will focus on describing the anatomy and physiology of the Gastro-Intestinal (GI) system, and its principle functions, in relation to. common childhood conditions. It will include Time Out reflective points to consider in relation to clinical practice. From this, the reader will be led to reflect on the nurse’s role in understanding their role in caring for children and young people with gastrointestinal disorders, from neonates to adolescence

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Keywords

Feeding, appendicitis, digestion, gastroenteritis, GI system, stomach

Aims and intended learning outcomes

The aim of this article is to enhance and build on your understanding and knowledge of the Gastro-intestinal (GI) system and relate it to common childhood conditions. By reading this article and completion of the timeout activities, you will be able to:

* Understand the basis of GI conditions of disease by exploring the embryological stages
* Describe the anatomy and physiology of the GI system, and how it relates to everyday clinical practice
* Reflect on the nurse’s role in caring for a child with minor and more complex GI disorders

Introduction

The GI system’s continuous functioning is crucial for life, and the understanding of these complexities is important to all nurses (Estai and Bunt [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\14)). The systems main role is to obtain and excrete nutrients to aid normal functioning of the body. Essentially, the GI system is made up of; the GI tract, which is a long muscular tube which starts at the mouth and ends at the anus (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)). With such a complex system, disorders and diseases are common, especially in childhood (Nesbitt [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\38)). This article will guide the reader through the GI system and consider various conditions children and young people may suffer from, separated into five categories: Embryological development and structural abnormalities, Ingestion and elimination: normal and associated conditions, obstructive disorders, malabsorption conditions , inflammatory diseases, and finally other considerations . Most of the anatomy and physiology of the GI system will be explored in conjunction with clinical conditions, apart from the Liver and the Gallbladder, which will be discussed in a future article of this series.

Time out 1

Review the diagram of the GI system (Figure 1). Briefly note where in your experience children’s GI tract problems typically arise and whether the conditions are acquired or congenital?

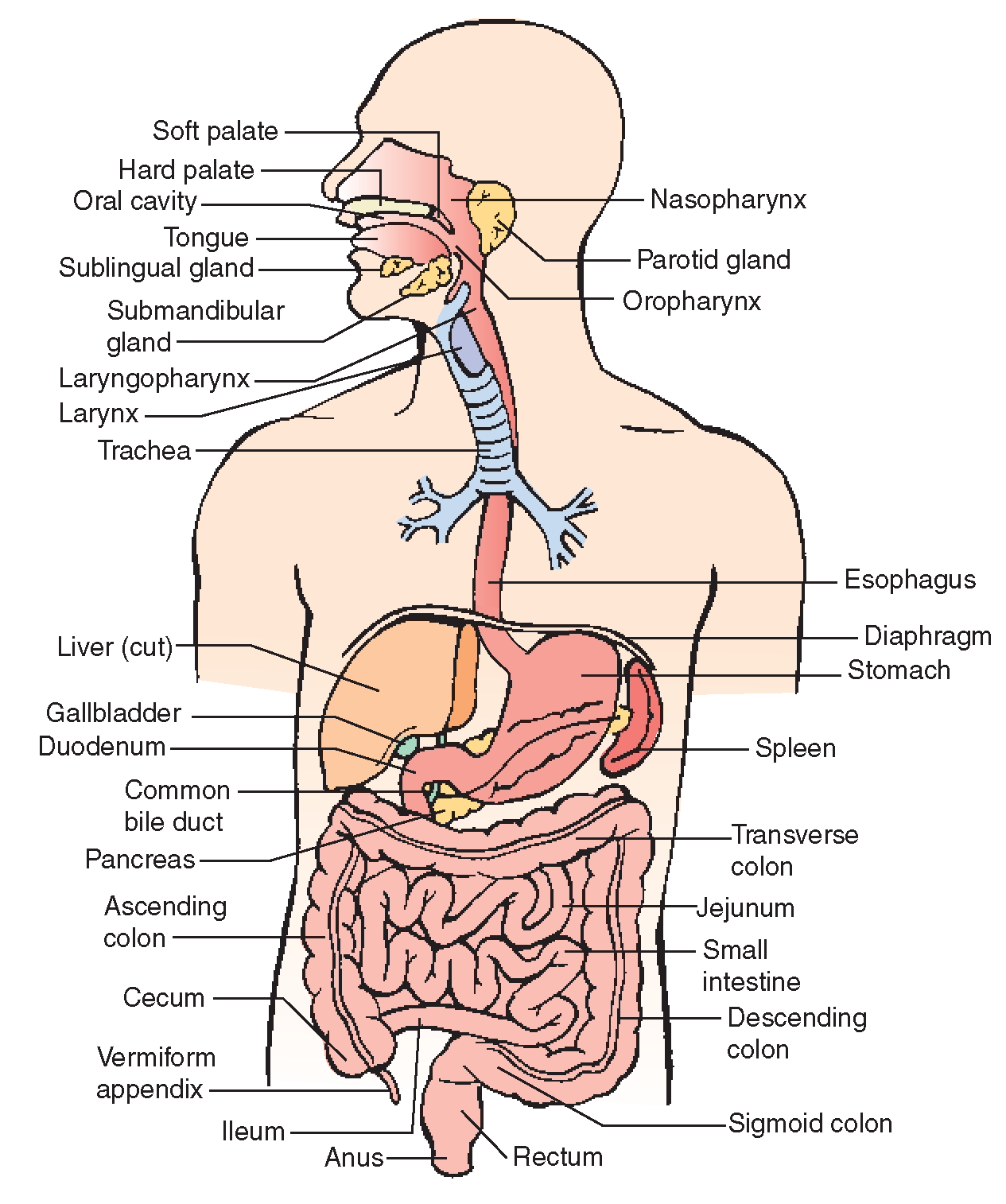


Figure 1: The gastrointestinal system

1 - Embryological development and structural defects

The primitive gut begins to form during the fourth week of gestation from the yolk sac (see Figure 2).

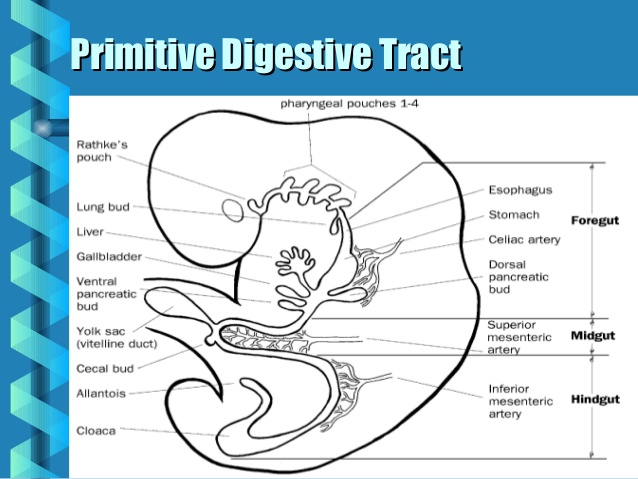


Figure 2: Primitive digestive tract

It starts as a hollow tube from the endoderm, which subsequently develops into the foregut, midgut and hindgut (Duderstadt [2014](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\12)). The foregut lends itself to the upper end of the GI tract, namely the developing pharynx, oesophagus, stomach, part of the duodenum, liver, biliary apparatus and the pancreas. Oral ectoderm and digestive endoderm become associated together during gastrulation (Chen, Jacox, Saldanha, & Sive, 2017), and the pharyngeal arches in the foetus start developing from 3 weeks gestation (Webster & de Wreede, 2016). Normally, the primary palate near the nose will fuse by week 9, but if this does not happen, a cleft lip will occur. The secondary palate should fuse at the same time, but again, if it does not, then a cleft palate will form (see Figure 3) (Chadha & Cobb, 2019).

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Figure 3: Main categories of cleft lip and / or palate (Jones & Volcano, 2018)

**Cleft lip / palate** is the most common structural abnormality of the head and neck, and around 1000 babies per year in the UK are affected (Bevan, 2019). Feeding is affected due to sucking and swallowing impairment, so involvement of the multidisciplinary team including speech and language therapists, with assistance in feeding, is mandatory. Surgery is the initial treatment for cleft lip /palate, with lip repair by three months of age, and up to year for palate repair (Duarte, Ramos, & Cardoso, 2016).

The coeliac artery supplies blood to the foregut from the descending aorta (Webster and de Wreede [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\55)). The oesophagus begins to elongate with the embryo and eventually separates from the trachea, by a developing trachea-oesophageal septum (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)).**Tracheo-oesophageal fistulae** (TOF) may sometimes occur from this stage of development, around 4 – 8 weeks gestation, which is when the oesophagus does not connect to the stomach and terminates in a ‘blind pouch’ (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)) (See Figure 4). TOF can sometimes be diagnosed antenatally, but otherwise at birth the baby may present with respiratory distress, and copious oral secretions (Forero Zapata and Pappagallo [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\15)), alongside choking on feeding, unmanageable pneumonia and frothy saliva and drooling (Ke, Wu, & Zeng, 2015). TOF and also oesophageal atresia can occur independently, but is commonly associated with the VACTERL syndrome: Vertebral, Anorectal, Cardiovascular, Renal and Limb defects, and the incidence is one in every 3,000 births (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)).

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Figure 4: Differing types of Tracheoesophageal Fistula / Oesophageal Atresia

The stomach develops, and as it enlarges, rotates by 90°, and the developing duodenum turns to the right. Further foregut development involves the liver growing from a ‘bud’, and extending into an area between the developing heart and the midgut, called the septum transversum (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)). As the liver grows, filling much of the abdominal cavity, the remaining foregut connection thins down, and develops into the bile duct.

The midgut develops into the distal part of the duodenum, and the rest of the small intestine, caecum, appendix, ascending colon, and most of the descending colon: its’ blood supply stems from the superior mesenteric artery (Duderstadt [2014](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\12)). The developing midgut becomes too big for the abdominal cavity, and herniates into the umbilical cord, but re-enters the cavity around week ten of gestation. More rotation occurs: the primitive colon rotates 180° into its’ final position. Sometimes, malrotation of the intestines can occur: if the return is not complete, the baby can be born with an **omphalocele** (see Figure 5), which is one of the most common anterior abdominal wall defects (Verla et al [2019](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\54)).

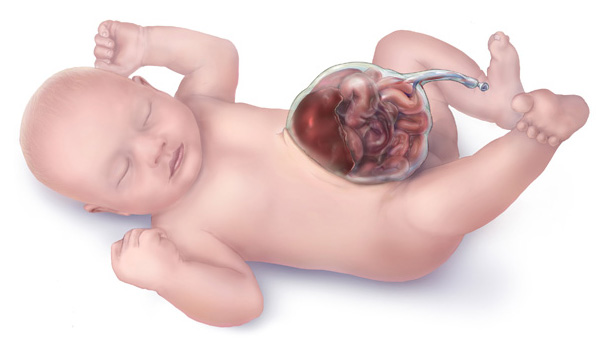


Figure 5: Omphalocele

An omphalocele is intestinal herniation into the umbilicus, and is often associated with Gastroschisis, where the intestines extend outside of the abdomen. An omphalocele differs in that the intestines, liver and sometimes other organs remain outside in a sac. It can occur from around the 8th–12th week of gestational development, when the herniated midgut does not return as it is intended (Khan et al [2019](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\28)). It is often associated with chromosomal abnormalities, such as trisomies 13, 18 and 21, and also Beckwith-Wiedemann syndrome, so the prognosis may be uncertain (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)).

Finally, the hindgut develops into the transverse colon, descending and sigmoid colon, rectum and upper anal canal, and is supplied by the inferior mesenteric artery (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)). The ‘end’ portion is named the cloaca, which divides at week 6, into an anterior urogenital system and a posterior anorectal system, by the urorectal septum. The urogenital sinus will develop into part of the bladder and the urogenital tract (Webster and de Wreede [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\55)). The cloacal membrane then ruptures in week 7, opening up the gut tube to the amniotic cavity: ‘normal’ development primarily depends on the normal formation of the cloacal membrane (Kluth et al [2011](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\29)). The tip of the urorectal septum develops into the perineal area. Subsequently, an ectodermal plug – the anal membrane – forms to create a part of the rectum. This membrane usually breaks down in-utero: however, failure to do so may result in an **imperforate anus**, where the anal opening is too tight, or absent, with a rectum ending up as a fistulae in a female vagina, or a male urethra (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)). Half of children both with an ano-rectal malformation will have associated abnormalities, including genitourinary, cardiovascular, spinal cord, gastrointestinal and VACTERL anomalies (Gangopadhyay and Pandey [2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\16)).

**2 – Normal ingestion and elimination and associated conditions**

From the mouth to the anus, the tract breaks down ingested food through both mechanical and chemical processes. Mechanical digestion is the mechanical breakdown of food. This is a series of coordinating movements throughout the tract to breakdown the food to smaller molecules (Griffiths [2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\20)). Starting with chewing and cutting in the mouth, the process is followed by smooth muscle contractions through the rest of the tract. (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)).

The mouth is the gateway for all food ingested (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)). The oral cavity is where food is broken down through chewing, cutting and the addition of saliva. This stage is also known as ‘mastication’, where food is prepared at this stage into a round bolus, which is then propelled down the oesophagus by the tongue (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)).

Good nutrition is essential in the developing child, and is the main influencing factor for childhood growth in infancy (Wei & Gregory, 2009). Infants will be either bottle fed or breastfed: sometimes, breastfeeding will not be possible, or may be delayed or contraindicated (Campbell & Dolby, 2018), or down to personal choice, although exclusive breastfeeding for the first 6 weeks of life is recommended (RCM, 2018). Breastfeeding is globally recognised as best for optimum growth and development, and children’s nurses are in the perfect position to encourage breastfeeding, but need to be mindful of difficulties or the mothers’ personal opinion.

However, feeding problems in infancy is common, and can be due to many factors, including structural abnormalities (like cleft lip / palate), developmental disorders, cardiorespiratory disorders, or gastrointestinal disorders. Infants usually have the root, suck, swallow and gag reflexes at birth, enabling feeding straight away (Borowitz & Borowitz, 2018). However, lactose intolerance is a common gastrointestinal condition, where there is an inability to digest and absorb lactose, which is the main carbohydrate in human milk (Heine et al., 2017). Causes can be due to genetic mutations, prematurity, or small bowel damage. Symptoms include bloating, flatulence, abdominal pain and sometimes watery diarrhoea (Szilagyi & Ishayek, 2018). Breastfeeding cannot be continued, and infants will have to be changed to a specific lactose free formula.

Ankyloglossia – **tongue tie** – is where the frenulum in the mouth is too short (see Figure 6)

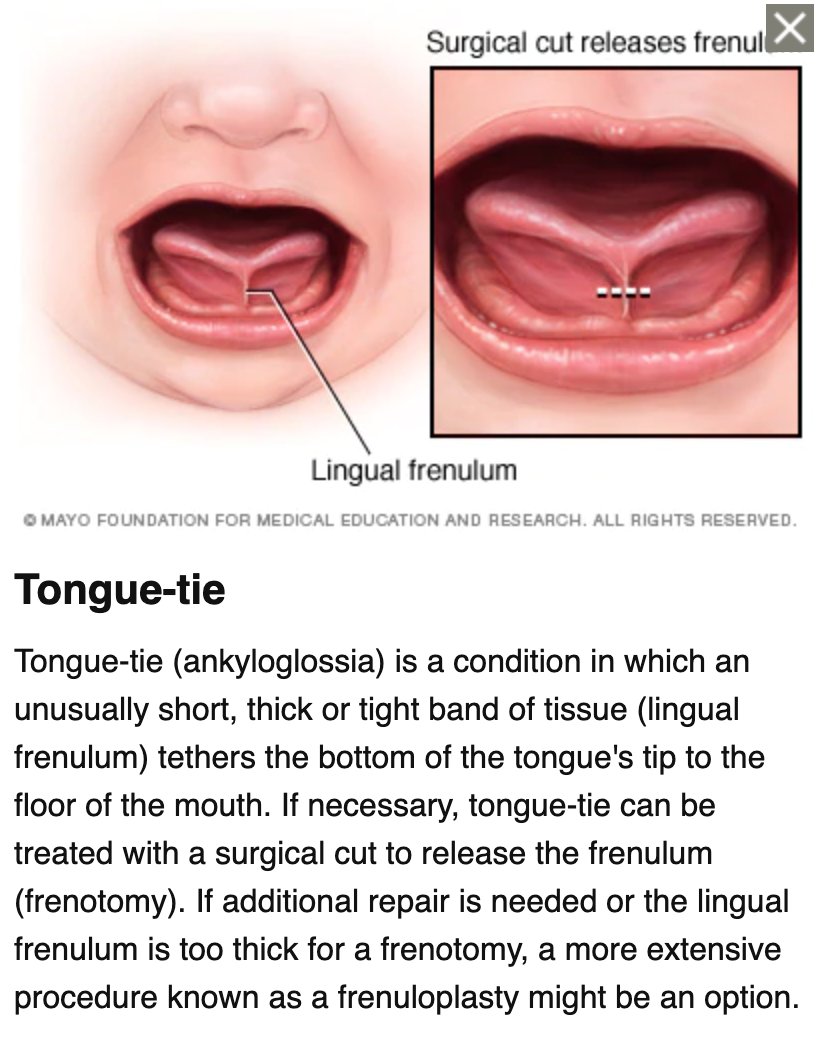


Figure 6: Tongue tie and frenotomy

It is too close to the tongue tip, and increase the difficulty in breastfeeding (Srinivasan et al., 2019). It is usually discovered at the newborn check, but can be difficult to see. Treatment may not be needed, but a frenotomy – a small cut in the skin – is effective (NHS, 2020)

The lips form the opening to the mouth, with the teeth as essential tools to making the food a bolus through cutting, tearing and chewing. From birth, infants have precursors within their jaw and in turn develop up to 20 ‘milk’ teeth between 6 months and 3 years; these teeth are then replaced with 32 permanent teeth by the age of 13 years (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)). The tongue plays a key role in the initiating of salivation through taste, with the thousands of taste buds or chemoreceptor’s distinguishing salty, sweet, bitter and sour tastes (McCance and Huether [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\34)).

There are three main pairs of salivary glands which are submandibular, sublingual and parotid glands, with the addition of smaller (unnamed) glands lining the mouth. These three main glands are responsible for the transport and excretion of saliva crucial for successful mastication. The saliva is made up water, salts, mucin, lysozyme and salivary amylase; the lysozyme aids to prevent bacteria reaching the lower digestive tract, while the salivary amylase start the chemical digestion of carboyhdrates (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)). Saliva also neutralises acid in the mouth with bicarbonate buffers, which can help prevent dental caries, as well as keeping the mouth and teeth generally clean (Johnstone et al [201](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\26)4) Certain anti-cholinergic drugs such as hysocine patches and glycopyrrolate are used to reduce saliva production in some children that may not have a safe swallow mechanism (Bavikatte et al [2012](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\5)), such as children with cerebral palsy or developmental delay (Reid et al [20](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\45)20).[Q?: The reference Reid et al (2019) has been changed to Reid et al (2020) as per the reference list. Please check.]

Behind the nose and mouth lies the air filled cavity the pharynx, which plays a key role in ensuring safe passing of food down to the oesophagus. When the coordinated action of swallowing begins, the soft palate closes nasal passages and the epiglottis moves over the glottis to close the larynx and trachea (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)). The pharynx also contains receptors that act in response to the pressure the food bolus makes, and send impulses to the swallowing centre in the brainstem, the medulla oblongata.

Once passed to the oesophagus, the food is passed down to the stomach by peristalsis. Peristalsis is coordinated waves of smooth muscle contractions behind the bolus of food and a wave of relaxation before it, which propels the bolus forward. This is now under involuntary action, which is a result of intrinsic neuromuscular reflexes (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)).

Time out 2

Consider what illnesses and conditions would affect the initial stage of digestion? Have you cared for any of these children within clinical practice? How did their condition affect their nutritional needs?

Chemical digestion is the chemical breakdown of food. Enzymes are responsible throughout the tract by chemically breaking down the food ingested. (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)).

The pancreas is the principle organ that produces amylase, protease and lipase. When a food bolus begins its journey down the GI tract, the enzymes are released to breakdown the different carbohydrates, proteins and fats into much smaller particles which can then be absorbed later in the chemical digestion process. Amylase has an important role in starch hydrolysis – that is, breaking down starches into simple sugars (Sundarram and Murthy [2014](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\50)). Protease breaks down proteins, and Lipases focus on the breakdown of more fatty acids, oils and triglycerides. The role and function of digestive enzymes in neonates, however, are different from more developed children: infants rely on milk for their food source, which is invariably made up of fats. Unabsorbed fats can be measured in stool samples, and has been found to depend on the infant’s gestational age, and the type of fat: breastmilk, or the type of formula. Specifically, human breast milk has been identified to be crucial for the developing gut’s micro-organisms. The quality and the quantity of the digestive enzymes are different in neonates and children, in comparison to adults, along with bile, pH values, gut permeabilty and diet, as well as the size of organs (Abrahamse et al [2012](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\1)).

The main functions of the stomach is to store, churn and digest food (see Figure 7). The stomach is a hollow muscular organ which sits in the upper part of the abdominal cavity. At the entrance lies the lower oesphageal sphincter; with three main functional areas fundus, body and antrum (McCance and Huether [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\34)). Once the food has been propelled down the oesophagus to the stomach the process of digestion continues, with the churning and digestive juices breaking down food to create a semi-liquid material called chyme (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)). First passing through the lower oesophageal sphincter (also known as the cardiac sphincter), that until physiological maturation occurs strengthening the sphincter in the first few months after birth, can cause a common condition called gastroesophageal reflux (Marseglia et al [2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\33)).

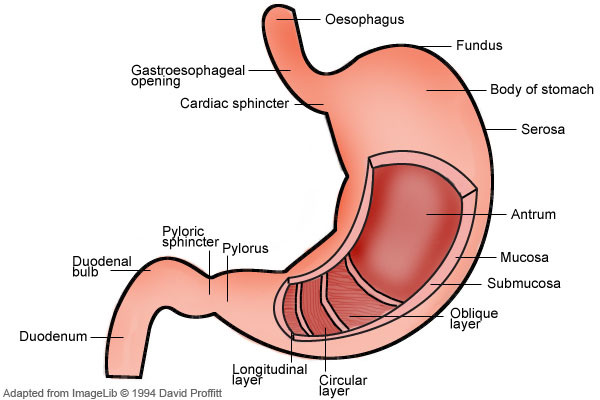


Figure 7: The stomach

**Gastro-oesophageal reflux disease** (GORD) is common, affecting 40% of infants (National Institute for Health and Clinical Excellence (NICE) [2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\40)), and predominately under the age of 1 year of due to immature development of the lower oesophageal sphincter and shorter oesophagus (Marseglia et al [2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\33)). GOR is the reflux of chyme from the stomach, up the oesophagus; many individuals experience this, and is very common in infants, which can be simple regurgitation (Rybak et al [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\46)). However, when the reflux causes further symptoms and discomfort it is classified as GORD (Johnstone et al 2014). Infants will often present with symptoms of regurgitation and vomiting, pain and discomfort, and sometimes pulmonary aspiration. NICE ([2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\40)) outline guidance for health professionals caring for infants with GOR, which identifies the need to reassurance and support parents.

Gastric pH

The specialised cells in the gastric glands, which lay under the surface of the mucous produce and secrete various gastric juices (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)). These specialised cells include goblet cells that produce mucous which helps protect the stomach from hydrochloric acid and pepsin, G cells that secrete the hormone gastrin and chief cells that produce pepsinogen, the inactive precursor of pepsin that breaks down protein (Johnstone et al 2014). In addition, the parietal cells produce hydrochloric acid, with a pH of 2 which kills bacteria that enters the stomach. Newborns have a neutral pH at the point of delivery. Measurements of pH can measure as high as 6 immediately post feeding, but can drop to a level of 2 after 3 hours, which is similar to that of an adult (Yu et al [2014](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\57)). Some infants and children require the placement of an oro or naso-gastric tube for the therapeutic purpose of administering fortified feeds or administering medications (Peter and Gill [2008](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\43)) (See Figure 8).

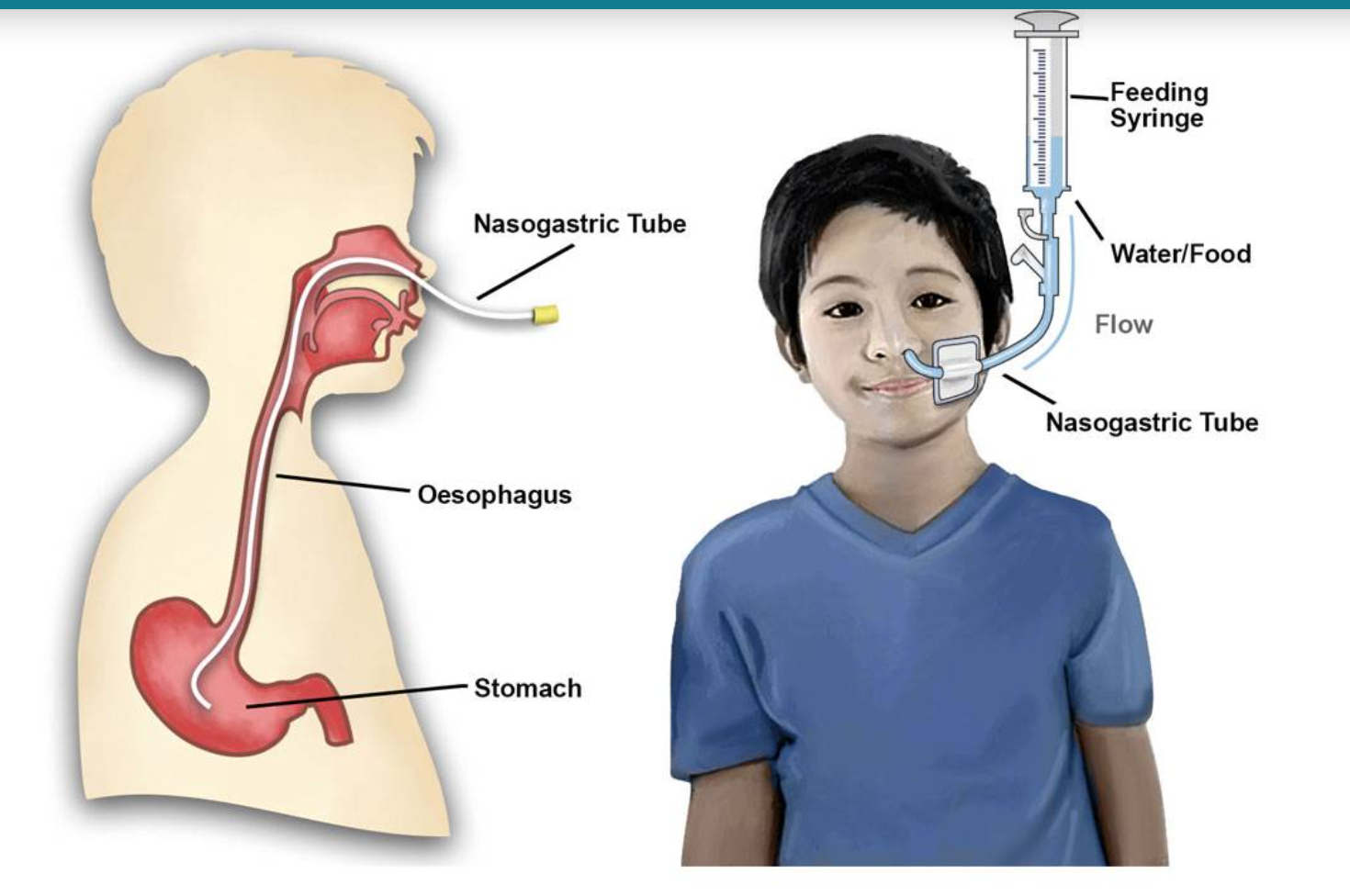


Figure 8: Nasogastric tube in a child

Naso-gastric tube placement relies on measuring the acidity of gastric contents, by aspirating back on the tube with a syringe. This can be an issue in children requiring continuous enteral feeds, or children who are prescribed proton pump inhibitors (PPI) such as Omeprazole, or histamine-2 receptor antagonists (H2RAs) such as Ranitidine (Irving et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\23)).

Time Out 3

Reflect now on the best means to Think about a colleague’s, or reflect on your own practice on how to test the correct placement for a naso-gastric tube. What would you do if you saw poor/outdated practice?

The stomach can hold approximately 6L of food in adult and varying volumes in infants and children (See Table 1). Delayed gastric emptying is sometimes found in neonates, because there is always residual milk present in their stomachs; however, gastric emptying time in fed conditions is similar between neonates and adults (Yu et al [2014](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\57)). This is an important factor to consider when caring for children requiring a general anaesthetic, as there is the potential for stomach contents to be regurgitated back into the oesophagus and potentially into the respiratory tract (Boore et al [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\7)), so ‘Nil by Mouth’ (NBM) regulations need to be strictly adhered to in practice.

Table 1. Stomach capacity in infants and children (Chamley et al [2005](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\10))

|  |  |
| --- | --- |
| Age | Stomach capacity (mL) |
| Newborn | 10-20 |
| 1 week | 30-90 |
| 2-3 week | 75-100 |
| 1 month | 90-150 |
| 3 month | 150-200 |
| 1 year | 210-360 |
| 2 years | 500 |
| 10 years | 750-900 |
| 16 years | 1,500 |

**Vomiting in children**

Vomiting differs from reflux, as it is forceful expulsion of gastric contents through the mouth or nose,(Shields & Lightdale, 2019) and there are many different causes, which can be age dependant, or there are four main pathways that will stimulate the emetic reflex: mechanical, blood borne toxins, motion, and emotional response. In children, it is usually self limiting, although intravenous fluids may be needed to correct dehydration if the vomiting continues for more than 24 hours (Bevan, 2019).

**Normal bowel motility and stool development**

The final and largest part of the GI tract is the large intestine or colon; extending from the ileocaecal valve to the anus. The large intestines measure approximately 2m in length and 6cm in diameter. They consist of the caecum with the appendix attached, the ascending, transverse, descending and sigmoid colons; and the rectum and anus (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)). The main functions are the absorption of vitamins, mineral and water; production of vitamins K and some B complexes; secretion of mucous and defecation (McCance and Huether 2016). Once the chyme enters the caecum it then takes on the form and consistency of faeces; and cannot pass back through the ileum due to the ileocaecal valve forcibly closing, preventing bacteria from the large intestine entering (Johnstone 2014).

The large intestine harbours 500 different species of bacteria, which are harmless unless transferred to other parts of the body. The colon is sterile at birth but with a few hours becomes colonised with E-coli, clostridium welchii and streptococcus (McCance and Huether 2016). Normal flora is established within 3 to 4 weeks after birth.

Faeces is made up of microbes, epithelial cells lost, cellulose fibre, fatty acids, water and mucous; and takes approximately 18-24 hours to pass through the whole colon (McCance and Huether 2016). The longer the faeces takes to pass through allows for excess water to be absorbed, which in turn causes constipation. In comparison if it moves too quickly less water can be absorbed which causes diarrhoea (Johnstone et al 2014). The walls of the large intestine primarily move through segmental movement; the circular muscles contract and relax. The defecation reflex is triggered by the presence of faeces in the rectum, which causes the internal sphincter to relax and the rectum and sigmoid colon to contract. The external sphincter that is under voluntary control must then relax for defecation to occur, although the rectum produces the urge to pass the faeces it can be prevented (McErlean [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\35)).

The very first stool a baby passes is called meconium, which has been present in the developing foetus: the passing of meconium indicates that the intestines are intact and present. Stools tend to be more yellow and soft/liquid during infancy, and turn brown after around 6 months of age (Steer et al [2009](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\49)), probably due to the introduction of more solid food. Breast fed (BF) babies tend to pass stools more frequently than formula fed (FF) babies, sometimes after every feed, whereas FF babies pass stools around once or twice a day. It is imperative for childrens nurses to be able to identify differences in stools, and the causes for the presentation, and The Bristol Stool Chart is a valuable aid (see Figure 9) (Lewis and Heaton [1997](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\31))., although the Amsterdam Stool Scale is more relevant for younger children still in nappies (Bekkali, Hamers, Reitsma, van Toledo, & Benninga, 2009). It is important for children’s nurses to be familiar for differing infant stools consistency, amount and colour, to inform them of clinical inconsistencies (See Figure 10).

A picture containing food

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Figure 9. The Bristol stool chart (Lewis and Heaton [1997](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\31))

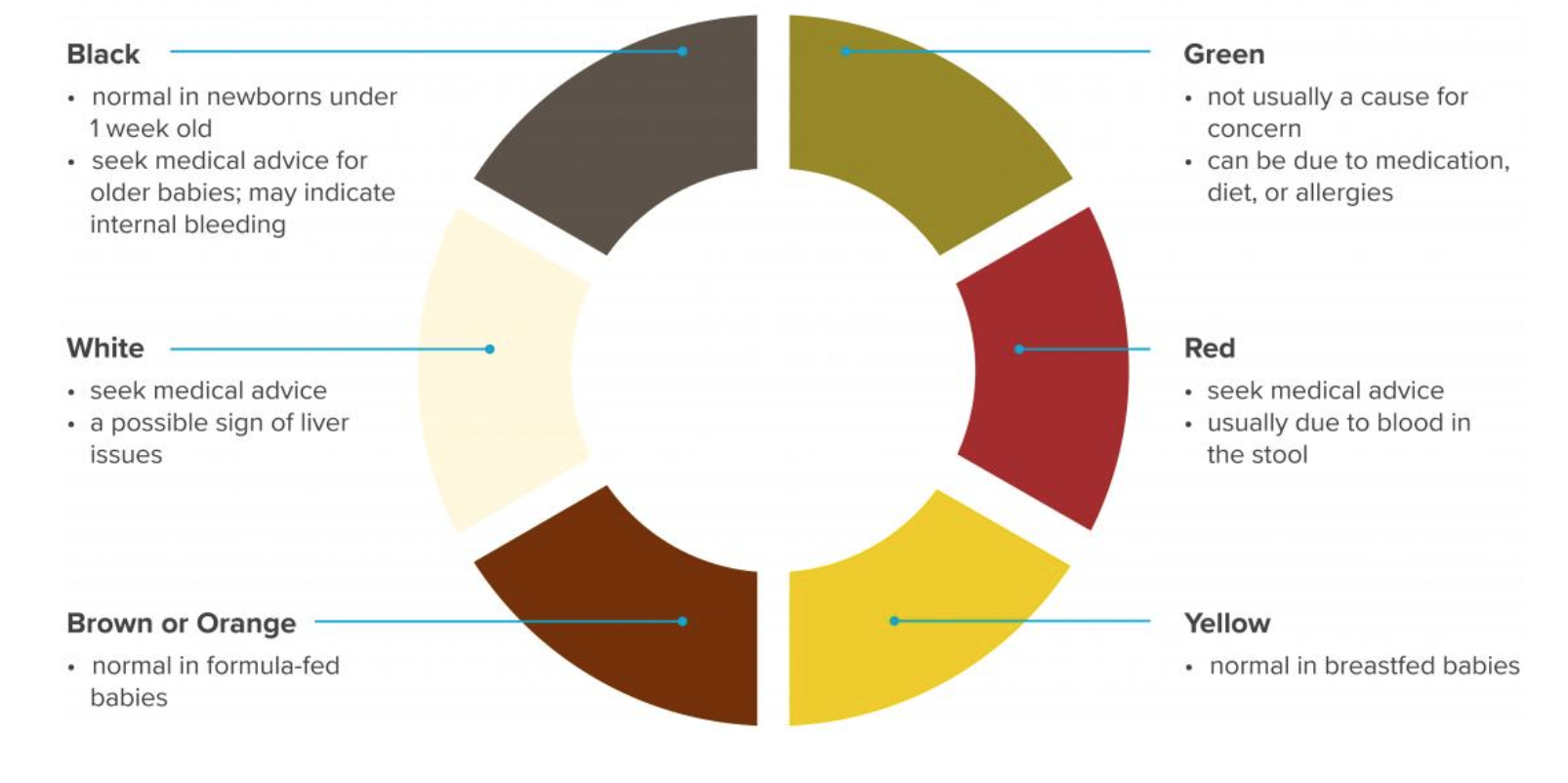


Figure 10: Infants stool colours (Stephens, 2019)

Useful factors to consider when considering bowel elimination include age, diet, fluid intake, activity, pain on passing, and medications. Characteristics to consider include stool shape, consistency, colour, smell, frequency, and presence of mucous or blood (Brewer and Seth [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\8)).

The young child needs to show that they are ready to start toilet training, but it is invariably around 2 years of age, although studies have shown that it could be later around two and a half years (Schum et al [2002](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\47)). ‘Readiness’ traits include showing an interest in training, understanding ‘potty’ or ‘toilet’ words, and verbalising during or after a bowel movement, and it seems that girls’ physical and language skills mature sooner than boys.

Gastroenteritis

Gastroenteritis in children is a major cause of morbidity and mortality worldwide and leads to large numbers of deaths (Churgay and Aftab [2012](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\11)). The rapid assessment of these children to prevent further deterioration is essential; firstly to assess the dehydration status for appropriate fluid management (NICE 2014). Children presenting with gastroenteritis will have numerous symptoms of diarrhoea, with or without fever, nausea, vomiting and abdominal pain. With various bacterial and viral pathogens causing the onset, diagnosis is made through physical assessment, measurement of urine specific gravity and stool samples to confirm the parasite (Keshav and Bailey [2013](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\27)). Treatment is dependent on the dehydration status of the child and their ability to have an oral intake. Management through oral re-hydration is key to prevent further dehydration (NICE [2015](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\40)).

**Constipation** is a very common reason for a child to present clinically (Lissauer et al [2012](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\32)), accounting for around 30% of consultations with paediatric gastroenterologists (Auth et al [2012](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\3)). Children with constipation usually present with one or more of the following: Two or fewer bowel movements each week; one episode of faecal incontinence per week; history of stool retention; painful, hard bowel movements; a large faecal mass in the rectum; large diameter stools which may block the toilet. Treatment is either pharmacological and/or non-pharmacological, involving oral laxatives, either osmotic (Macrogol, Lactulose) or stimulant (Sodium picosulphate), lubricants (sodium docusate), leading to enemas and rectal irrigations.

Time out 5

Consider a patient you cared for when their digestive system was constipated. How did this patient present? Were there any other issues surrounding their referral? What non-pharmacological methods could be used? Look at the ‘NICE guidelines on Constipation in children and young people: diagnosis and management’ and discuss with a colleague (NICE [2010](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\39))

3 – Obstructive disorders

The pyloric sphincter lies at the entrance to the duodenum and chyme is then pushed through the open pylorus by peristalsis into the duodenum at the beginning of the small intestines (Johnstone et al 2014). An overgrowth of this sphincter is known as **Pyloric Stenosis**, which causes an obstruction to gastric emptying (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)). Infants will present usually around the 5th/6th week of life, with projectile vomiting after feeding, dehydration and weight loss. The sphincter muscle is palpable on abdominal examination, presenting as a hard ‘olive’ in the abdomen, and is a diagnostic feature, although ultrasound will rule out other differential diagnoses (Jobson and Hall [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\25)). Treatment is immediate correction of the dehydration, fluid and electrolyte loss, and possible metabolic alkalosis, which could potentially have an impact on the respiratory function in a neonate (Taghavi et al [2017](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\51)). Surgery to dilate the hypertrophied muscle follows.

Volvulus and intussusception

A volvulus is where a loop of intestine twists around itself, which therefore results in an obstructed bowel: a child will present with abdominal distension, bloody stools (due to the occlusion of the blood supply), pain, bilious vomiting, and constipation. Treatment is surgery (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)). Conversely, Intussusception is one of the most common cause of intestinal obstruction in the neonatal period, and the most common abdominal emergency in children under the age of 2 years. The proximal bowel invaginates into a distal segment, usually the ileum passing into the caecum (Lissauer et al [2012](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\32)). One way to visualise this is to imagine a rubber glove, and poking a ‘finger’ in on itself. Infants and children will present with severe pain, possible bile stained vomit, a sausage shaped mass, often palpable, abdominal distension, and a classical redcurrant jelly stool, comprising blood stained mucous. Again, surgery is indicated.

Time Out 4

Consider how you would explain the diagnosis of pyloric stenosis to a parent, and why the infant projectile vomits. How would you manage their anxiety?

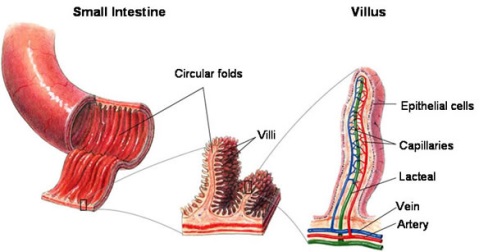
4 – Malabsorption

The small intestines are prior to the large intestines, and consist of three parts: the duodenum, jejunum and ileum (Griffiths 2015). It is approximately 6-7m long and its main function is absorption of nutrients and continued digestion. Once the chyme has been passed through the pylorus to the duodenum, it is then mixed with bile and pancreatic juice. Throughout the small intestines, an alkaline fluid containing electrolytes, mucus and water is secreted to aid digestion and movement of the chyme (McCance and Huether 2016).

The small intestines plays a pivotal role in the absorption of nutrients; with cells designed to maximise absorption (Figure 6). The absorption of these nutrients occurs by two processes; Diffusion, which moves nutrients from high concentration to low, using no metabolic energy, and active transport that moves nutrients from low concentration to high, using metabolic energy in the form of ATP (McCance and Huether 2016). The mucosa and submucosa are covered in circular folds; villi, which are finger-like projections approximately 0.5-1.5mm, long (Johnstone et al 2014). The villi contain capillaries that then transport the absorbed nutrients to the liver to be processed and stored for energy use. The surface of the epithelial cells that cover the villi are covered in microvilli; these microvilli greatly increase the surface area for nutrient absorption and produce digestive enzymes (McCance and Huether 2016).

The chyme is moved through the small intestines by segmentation contractions of the smooth muscle and passed through the duodenum, jejunum and ileum to the ileocaecal valve at the beginning of the large intestines (Johnstone et al 2014).

Figure 11. Small intestine



**Coeliac disease** is an autoimmune disorder that mostly affects the small intestine, and is where an individual develops an immune reaction to gluten (Lebwohl et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\30)), which is a protein found in wheat, barley and rye. Symptoms will appear once a baby starts to be weaned: slowing down of growth can appear in severe cases, but most clinical signs include diarrhoea, poor appetite, lethargy and a distended abdomen (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)). Treatment involves a strict gluten free diet, and the involvement of a dietician is vital: supplements may be needed, including iron, calcium, vitamin D and folate (Thomas et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\52)).

**5 – Inflammatory disorders**

Crohn’s disease

Crohn’s disease (CD) can affect any part of the intestine and causes chronic inflammation through the wall of the tract; often in various segments along the tract leaving healthy areas in-between (Keshav and Bailey 2013). It is a chronic inflammatory bowel disease (IBD) with no cure and an unclear aetiology. It is predominately diagnosed in young people, with a peak between the ages of 10-19 (Smith and Gettings [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\48)), with an incidence of around 6 in 100,000 children (Gasparetto and Zilbauer [2014](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\17)). The signs and symptoms can include a low grade pyrexia, weight loss, lethargy, bloody diarrhoea, abdominal pain and cramping after eating (Johnstone et al 2014). NICE ([2019](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\41)) guidance covers the management for CD and aims to maintain or improve quality of patient’s lives and reduce their symptoms (NICE [2019](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\41)). It is important that the information provided is age appropriate to support young people diagnosed with CD.

Appendicitis

Appendicitis is an inflammation of the appendix, which is a projection from the caecum in the large intestines (Keshav and Bailey 2013). The incidence affects around 6 per 100,000 people per year, with the highest incidence among children and adolescents (Gorter et al [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\19)) The cause of appendicitis is unknown but is thought to be due to stools, foreign bodies or a tumour obstructing the appendix, which increases bacterial infection and inflammation (McCance and Huether 2016). The symptoms often begin with epigastric pain, which then moves to localised right lower quadrant pain, nausea, vomiting and fever often follow. Biochemically, an elevated C-reactive protein (CRP) level could be indicative of a perforated appendix, and a raised white blood cell count can also be found (Glass and Rangel [2016](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\18)). Treatment options include antibiotics and surgery to remove the inflamed or possibly perforated appendix (Keshav and Bailey 2013).

**Pancreatitis** is inflammation of the pancreas, which can be life threatening (Knight & Williams, 2019), and should always be considered as a possible diagnosis when the child presents with abdominal pain, which is usually in the upper abdominal area under the ribs. Aetiology for pancreatitis in children is due to certain medications, trauma, infections (eg post mumps), or congenital structural abnormalities, such as choledocal cysts (Suzuki, Sai, & Shimizu, 2014). Treatment focuses on providing nutritional support, analgesics, antibiotics and pancreatic protease inhibitors.

6 - Other gastrointestinal problems

**Necrotizing enterocolitis** (NEC) is the most common gastrointestinal emergency in premature infants, and is seen in up to 13% of infants born before 37 weeks (Agnoni & Lazaros Amendola, 2017) and is where parts of the intestine die, resulting in intestinal perforation and peritonitis (Veal, McAlinden, & Crawford, 2018). Nearly half of the infants diagnosed will require surgery.

**Liver problems** in children are rare, but neonatal jaundice is common (see Biolgoical Basis to Child Health: The Liver).

**Abdominal pain** is very common in children, and it may be difficult for the children to describe the pain adequately (Veal et al [2018](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\53)). There are many differential diagnoses for the reason behind abdominal pain, some of which have already been discussed, including constipation and appendicitis. Intussusception and volvulus also present with abdominal pain, and differential diagnoses must be considered between the sexes, such as ovarian cysts, ectopic pregnancy or pelvic inflammatory disease in girls, or torsion of the testes in boys. Age related abdominal pain also needs to considered (see Table 2).

A screenshot of a cell phone

Description automatically generated

Table 2: Differential diagnosis of abdominal pain by age (Reust & Williams, 2016).

A full and detailed history needs to be asked of the child and parent/caregiver, including pain onset and location, presence of blood or mucous in the stool, or unusual stools; associated symptoms such as vomiting, loss of appetite, vomiting bile, or change in diet also need to be considered (Barnes [2003](file:///\\chenas03.cadmus.com\smartedit\Normalization\IN\INPROCESS\4)), or even psychosocial issues.

Conclusion

This article has introduced the reader to the anatomy and physiology of the GI system; being able to understand the normal structure and function enables the children’s nurse to better respond to changes in the system. Common GI conditions in children have been discussed, as well as pertinent issues to consider when caring for any child. The effective functioning of the GI system is essential to life and gastrointestinal disturbances are a common occurrence in children. As a nurse caring for children and young people, it is essential to have an awareness of the system and how it can influence a child’s health.

Quiz - 10 questions

1. What is GOR?

a. Stomach acids regurgitating to the mouth

b. Reflux of chyme from the stomach

c. Projectile vomiting in an infant

d. Trapped wind in the GI tract

2. Where does the mechanical digestion processes begin and end?

*a. Mouth to anus*

b. Oesphagus to anus

c. Oesphagus to small intestines

d. Mouth to large intestines

3. Where is protease NOT made?

*a. Salivary glands*

b. Stomach cells

c. The pancreas

d. The small intestine

4. What symptoms would a child have if they had gastroenteritis?

a. Bloody diarrhoea

b. Pyrexia

*c. Diarrhoea and vomiting*

d. Painful, hard bowel movements

5. Where is the liver situated?

a. Under the diaphragm in the lower right quadrant of the abdominal cavity

b. Under the diaphragm in the upper right quadrant of the abdominal cavity

c. Under the diaphragm in the middle of the abdominal cavity

d. Under the diaphragm in the upper left quadrant of the abdominal cavity

6. The secretion of enzymes in the pancreas is regulated by what hormones?

*a. Secretin and cholecystokin*

b. Amylase and cholecystokin

c. Secretin and pepsin

d. Protease and cholecystokin

7. Name the structure that is designed for absorption in the small intestines

*a. Villi*

b. Ileum

c. Epithelial cells

d. Microbes

8. How much bile does the gall bladder approximately hold?

a. 10-20mL of bile

b. 30-60mL of bile

c. 60-90mL of bile

d. 20-50mL of bile

9. Name the symptoms of constipation

a. Nausea

b. Difficulty passing stools

c. Bloody stools

d. Bile stained vomit

10. Appendicitis is an inflammation of what?

a. Colon

b. Appendix

c. Ileocecal value

d. Small intestines

Time out 6

Now that you have completed the article you might like to write a reflective account as part of your revalidation.

References

Abrahamse E, Minekus M, van Aken G et al (2012) Development of the digestive system-experimental challenges and approaches of infant lipid digestion. Food Digestion. 3, 1-3, 63-77. doi: 10.1007/s13228-012-0025-x

Alamri N, Hussain A, Alzein E et al (2017) Leptin as a potential biomarker for childhood obesity. EC Paediatrics, 3.5, 435-446.

Auth M, Vora R, Farrelly P et al (2012) Childhood constipation. BMJ. 345, e7309. doi: 10.1136/bmj.e7309

Barnes K (Ed) (2003) Paediatrics: A Clinical Guide for Nurse Practitioners. Butterworth Heinemann, Edinburgh.

Bavikatte G, Sit P, Hassoon A (2012) Management of drooling of saliva. British Journal of Medical Practitioners. 5, 1, a507.

Boeckxstaens G, Camilleri M, Sifrim D et al (2016) Fundamentals of neurogastroenterology: physiology/motility–sensation. Gastroenterology. 150, 6, 1292-1304.e2. doi: 10.1053/j.gastro.2016.02.030

Boore J, Cook N, Shepherd A (2016) Essentials of Anatomy and Physiology for Nursing Practice. Sage, London.

Brewer S, Seth S (2018) Stool characteristics explained. Nursing Made Incredibly Easy!. 16, 3, 14-19. doi: 10.1097/01.NME.0000531881.86401.f6

Camelo Chaves E, De Castro M, Magalhães Moreira T et al (2017) Nursing care for children with gastrostomy: integrative review. International Archives of Medicine. 10, 154, 1-8. doi: 10-3823/2424

Chamley C, Carson P, Randall D et al (2005) Developmental Anatomy and Physiology of Children: A Practical Approach. Elsevier, Oxford.

Churgay C, Aftab Z (2012) Gastroenteritis in children. Part 1: diagnosis. American Family Physician. 85, 11, 1059-1062.

Duderstadt, K (Ed) (2014) Pediatric Physical Examination: An Illustrated Handbook. Second edition. Elsevier, Missouri MO.

Eidelman C, Abdel-Rahman S (2016) Pharmacokinetic considerations when prescribing for children. International Journal of Pharmacokinetics. 1, 1, 69-80. doi: 10.4155/ipk-2016-0001

Estai M, Bunt S (2016) Best teaching practices in anatomy education: a critical review. Annals of Anatomy - Anatomischer Anzeiger. 208, 151-157. doi: 10.1016/j.aanat.2016.02.010

Forero Zapata L, Pappagallo M (2018) Esophageal atresia and tracheoesophageal fistula. New England Journal of Medicine. 379, 7, e11. doi: 10.1056/NEJMicm1801712

Gangopadhyay A, Pandey V (2015) Anorectal malformations. Journal of Indian Association of Pediatric Surgeons. 20, 1, 10-15. doi: 10.4103/0971-9261.145438

Gasparetto M, Zilbauer M (2014) Paediatric inflammatory bowel diseases: brief update on current practice and future perspectives. Paediatrics and Child Health. 24, 11, 501-505. doi: 10.1016/j.paed.2014.04.009

Glass C, Rangel S (2016) Overview and diagnosis of acute appendicitis in children. Seminars in Pediatric Surgery. 25, 4, 198-203. doi: 10.1053/j.sempedsurg.2016.05.001

Gorter R, Eker H, Gorter-Stam M et al (2016) Diagnosis and management of acute appendicitis. EAES consensus development conference 2015. Surgical Endoscopy. 30, 11, 4668-4690. doi: 10.1007/s00464-016-5245-7

Griffiths M (2015) Crash Course Gastrointestinal System. Fourth edition. Elsevier, London.

Hamilton-Shield J, Sharp D (2015) Is the childhood obesity crisis over in England? Archives of Disease in Childhood. 100, 3, 212-213. doi: 10.1136/archdischild-2014-307870

Hendry C, Farley A, McLafferty E et al (2014) The digestive system: Part 2. Nursing Standard. 28, 25, 37-44. doi: 10.7748/ns2014.02.28.25.37.e7459

Irving S, Rempel G, Lyman B et al (2018) Pediatric nasogastric tube placement and verification: best practice recommendations from the NOVEL project. Nutrition in Clinical Practice. 33, 6, 921-927. doi: 10.1002/ncp.10189

Issenman R, Filmer R, Gorski P (1999) A review of bowel and bladder control development in children: how gastrointestinal and urological conditions relate to problems in toilet training. Pediatrics. 103, 6, 1346-1352.

Jobson M, Hall N (2016) Contemporary management of pyloric stenosis. Seminars in Pediatric Surgery. 25, 4, 219-224. doi: 10.1053/j.sempedsurg.2016.05.004

Johnstone C, Hendry C, Farley A et al (2014) The digestive system: part 1. Nursing Standard (Royal College of Nursing (Great Britain): 1987). 28, 24, 37-45. doi: [10.7748/ns2014.02.28.24.37.e7395](http://dx.doi.org/10.7748/ns2014.02.28.24.37.e7395)

Keshav S, Bailey A (2013) The Gastrointestinal System at Glance. Second edition. Wiley-Blackwell, Oxford.

Khan F, Hashmi A, Islam S (2019) Insights into embryology and development of omphalocele. Seminars in Pediatric Surgery. 28, 2, 80-83. doi: 10.1053/j.sempedsurg.2019.04.003

Kluth D, Fiegel H, Metzger R (2011) Embryology of the hindgut. Seminars in Pediatric Surgery. 20, 3, 152-160. doi: 10.1053/j.sempedsurg.2011.03.002

Lebwohl B, Sanders DS, Green P (2018) Coeliac disease. The Lancet. 391, 10115, 70-81. doi: 10.1016/s0140-6736(17)31796-8

Lewis S, Heaton K (1997) Stool form scale as a useful guide to intestinal transit time. Scandinavian Journal of Gastroenterology. 32, 9, 920-924. doi: 10.3109/00365529709011203

Lissauer T, Clayden G, and Craft A (Eds). (2012) Illustrated Textbook of Paediatrics. Mosby Elsevier, Edinburgh.

Marseglia L, Manti S, D’Angelo G et al (2015) Gastroesophageal reflux and congenital gastrointestinal malformations. World Journal of Gastroenterology. 21, 28, 8508-8515. doi: 10.3748/wjg.v21.i28.8508

McCance K, Huether S (2016) Pathophysiology: The Biologic Basis for Disease in Adults and Children. Seventh edition. Elsevier Mosby, Oxford.

McErlean L (2017) Fundamentals of Anatomy and Physiology for Nursing and Healthcare Students (M. Nair and I. Peate Eds). Second edition. John Wiley and Sons, West Sussex.

Miall L, Rudolf M, Smith D (2012) Paediatrics at a Glance. Third edition. Wiley-Blackwell, Oxford.

Neal-Kluever A, Fisher J, Grylack L et al (2019) Physiology of the neonatal gastrointestinal system relevant to the disposition of orally administered medications. Drug Metabolism and Disposition. 47, 3, 296-313. doi: 10.1124/dmd.118.084418

Nesbitt I (2016) The patient with gastrointestinal disease. Surgery (Oxford)). 34, 8, 416-419. doi: 10.1016/j.mpsur.2016.04.017

National Institute for Health and Clinical Excellence (2010) Constipation in Children and Young People: Diagnosis and Management. NICE, London.

National Institute for Health and Clinical Excellence (2015) Intravenous Fluid Therapy in Children and Young People in Hospital. NICE, London.

National Institute for Health and Clinical Excellence (2019) Crohn’s Disease: Management. NICE, London.

Penn S, Kerr J (2014) Childhood obesity: the challenge for nurses. Nursing Children and Young People. 26, 2, 16-21. doi: 10.7748/ncyp2014.03.26.2.16.e398

Peter S, Gill F (2008) Development of a clinical practice guideline for testing nasogastric tube placement. Journal for Specialists in Pediatric Nursing. 14, 1, 3-11. doi: 10.1111/j.1744-6155.2008.00161.x

Pradhan G, Samson S, Sun Y (2013) Ghrelin: much more than a hunger hormone. Current Opinion in Clinical Nutrition and Metabolic Care. 16, 6, 619-624. doi: [10.1097/MCO.0b013e328365b9be](http://dx.doi.org/10.1097/MCO.0b013e328365b9be)

Reid S, Westbury C, Guzys A et al (2020) Anticholinergic medications for reducing drooling in children with developmental disability. Developmental Medicine and Child Neurology. 62, 3, 346-353. doi: 10.1111/dmcn.14350

Rybak A, Pesce M, Thapar N et al (2017) Gastro-esophageal reflux in children. International Journal of Molecular Science. 18, 8, 1671. doi: 10.3390/ijms18081671

Schum T, Kolb T, McAuliffe T et al (2002) Sequential acquisition of toilet-training skills: a descriptive study of gender and age differences in normal children. Pediatrics. 109, 3, e48. doi: 10.1542/peds.109.3.e48

Smith C, Gettings S (2016) Reshaping policy to deliver holistic care for adolescents with Crohn’s disease. Nursing Children and Young People. 28, 10, 19-24. doi: 10.7748/ncyp.2016.e723

Steer C, Emond A, Golding J et al (2009) The variations in stool patterns from 1 to 42 months: a population-based observational study. Archives of Disease in Childhood. 94, 3, 231-233. doi: 10.1136/adc.2007.130849

Sundarram A, Murthy T (2014) Alpha amylase productions and applications: a review. Journal of Applied and Environmental Microbiology. 2, 4, 166-175. doi: 10.12691/jaem-2-4-10

Taghavi K, Powell E, Patel B et al (2017) The treatment of pyloric stenosis: evolution in practice. Journal of Paediatrics and Child Health. 53, 11, 1105-1110. doi: 10.1111/jpc.13736

Thomas P, Tighe M, Beattie R (2018) Coeliac disease in children. BMJ (Clinical Research Ed.). 363, k3932. doi: 10.1136/bmj.k3932

Veal Z, McAlinden O, Crawford D (2018) Care of children and young people with gastrointestinal problems. In J Price, O McAlinden (Eds), Essentials of Nursing Children and Young People. Sage Publishing, London, 438-455.

Verla M, Style C, Olutoye O (2019) Prenatal diagnosis and management of omphalocele. Seminars in Pediatric Surgery. 28, 2, 84-88. doi: 10.1053/j.sempedsurg.2019.04.007

Webster S, de Wreede R (2016) Embryology at a Glance. Wiley Blackwell, Oxford.

Whittlesea C, Hodson K (2019) Clinical Pharmacy and Therapeutics. Sixth edition. Elsevier, China.

Yu G, Zheng Q, Li G (2014) Similarities and differences in gastrointestinal physiology between neonates and adults: a physiologically based pharmacokinetic modeling perspective. The AAPS Journal. 16, 6, 1162-1166. doi: 10.1208/s12248-014-9652-1

Agnoni, A., & Lazaros Amendola, C. (2017). Necrotizing enterocolitis: Current concepts in practice. *JAAPA, 30*(8), 16-21. doi:10.1097/01.JAA.0000521131.85173.f9

Bekkali, N., Hamers, S., Reitsma, J., van Toledo, L., & Benninga, M. (2009). Infant Stool Form Scale: development and results. *Journal of Pediatrics 154*(4), 521 - 526.

Bevan, A. L. (2019). Disorders of the Digestive System. In E. Gormley-Fleimg & I. Peate (Eds.), *Fundamentals of Children’s Applied Pathophysiology: An Essential Guide for Nursing and Healthcare Students* (pp. 257 - 278). Chichester: Wiley Blackwell.

Borowitz, K. C., & Borowitz, S. M. (2018). Feeding Problems in Infants and Children: Assessment and Etiology. *Pediatr Clin North Am, 65*(1), 59-72. doi:10.1016/j.pcl.2017.08.021

Campbell, D., & Dolby, L. (2018). *Physical Examination of the Newborn: At a Glance*. Chichester: Wiley Blackwell.

Chadha, A., & Cobb, A. R. M. (2019). Development of Cleft Lip and Palate. In *Clinical Embryology* (pp. 111-118).

Chen, J., Jacox, L. A., Saldanha, F., & Sive, H. (2017). Mouth development. *Wiley Interdiscip Rev Dev Biol, 6*(5). doi:10.1002/wdev.275

Duarte, G. A., Ramos, R. B., & Cardoso, M. C. (2016). Feeding methods for children with cleft lip and/or palate: a systematic review. *Braz J Otorhinolaryngol, 82*(5), 602-609. doi:10.1016/j.bjorl.2015.10.020

Heine, R. G., AlRefaee, F., Bachina, P., De Leon, J. C., Geng, L., Gong, S., . . . Rogacion, J. M. (2017). Lactose intolerance and gastrointestinal cow's milk allergy in infants and children - common misconceptions revisited. *World Allergy Organ J, 10*(1), 41. doi:10.1186/s40413-017-0173-0

Jones, M., & Volcano, J. (2018). Cleft Lip and Palate: Audit Review. In: Institute of Medical Illustrators.

Ke, M., Wu, X., & Zeng, J. (2015). The treatment strategy for tracheoesophageal fistula. *J Thorac Dis, 7*(Suppl 4), S389-397. doi:10.3978/j.issn.2072-1439.2015.12.11

Knight, J., & Williams, N. (2019). Gastrointestinal tract 3: the duodenum, liver and pancreas. *Nursing Times, 115*(8), 56 - 60.

NHS. (2020). Tongue tie. Retrieved from <https://www.nhs.uk/conditions/tongue-tie/>

RCM. (2018). Position Statement: Infant Feeding. In. Royal College of Midwives.

Reust, C. E., & Williams, A. (2016). Acute abdominal pain in children *American Family Physician, 93*(10), 830 - 837.

Shields, T. M., & Lightdale, J. R. (2019). Vomiting in Children. *Pediatrics in Review, 39*(7), 342 - 358.

Srinivasan, A., Al Khoury, A., Puzhko, S., Dobrich, C., Stern, M., Mitnick, H., & Goldfarb, L. (2019). Frenotomy in Infants with Tongue-Tie and Breastfeeding Problems. *Journal of Human Lactation, 35*(4), 706 - 712.

Stephens, C. (2019). Baby poop color: Causes and when to see a doctor. *Medical News Today*, 1- 6.

Suzuki, M., Sai, J. K., & Shimizu, T. (2014). Acute pancreatitis in children and adolescents. *World J Gastrointest Pathophysiol, 5*(4), 416-426. doi:10.4291/wjgp.v5.i4.416

Szilagyi, A., & Ishayek, N. (2018). Lactose Intolerance, Dairy Avoidance, and Treatment Options. *Nutrients, 10*(12). doi:10.3390/nu10121994

Veal, Z., McAlinden, O., & Crawford, D. (2018). Care of children and young people with gastrointestinal problems. In J. N. Price & O. McAlinden (Eds.), *Essentials of Nursing Children and Young People* (pp. 438 - 455). London: Sage Publishing

Webster, S., & de Wreede, R. (2016). *Embryology at a glance* (2nd ed.). Oxford: Wiley Blackwell.

Wei, C., & Gregory, J. W. (2009). Physiology of normal growth. *Paediatris and Child Health, 19*(5), 236 - 240.