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Gastrointestinal System

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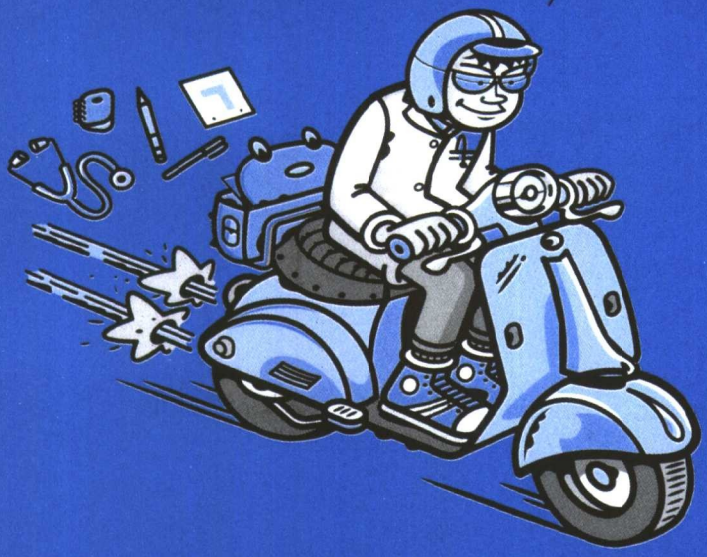

Series editor
Daniel Horton-Szar
BSc (Hons) MBBS (Hons)
GP Registrar
Northgate Medical Practice
Canterbury
Kent

Faculty advisor
Paul M Smith
MD, FRCP
Retired Consultant Gastroenterologist
Llandough and University Hospital of Wales, Cardiff

Gastrointestinal system

SECOND EDITION

Melanie Sarah Long
BSc (Hons) Biochemistry and Immunology
4th year Medical Student
St. George's Hospital Medical School
Tooting, London

First Edition Author
Elizabeth Cheshire

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Preface

Medical students are expected to take in, digest and regurgitate an awful lot of information! Medical training is now split into discrete systems, each containing anatomy, embryology, histology, physiology, pathology, pharmacology and clinical knowledge on that particular system. Traditional textbooks tend to cover only a particular subject, such as anatomy, but encompass all systems.

So, with this book, I aim to provide a good broad knowledge of the gastrointestinal system, which will be useful on the wards and fare the student well for exams, particularly for those who like to 'cram' the week before!

Hopefully, this book will lessen your exam stress!

Melanie Sarah Long

The gastrointestinal system includes the gut, the liver, the biliary system and the pancreas, and has profited by being the subject of many diagnostic and scientific advances in the last forty years. This book brings together all the relevant knowledge necessary to pass the final MB or the MRCP in a concise and simple format.

Paul M Smith
Faculty Advisor

In the six years since the First Editions were published, there have been many changes in medicine, and in the way it is taught. These Second Editions have been largely rewritten to take these changes into account, and keep Crash Course up to date for the twenty-first century. New material has been added to include recent research and all pharmacological and disease management information has been updated in line with current best practice. We have listened to feedback from hundreds of students who have been using Crash Course and have improved the structure and layout of the books accordingly: pathology material has been closely integrated with the relevant basic medical science; there are more multiple-choice questions and the clarity of text and figures is better than ever.

The principles on which we developed the series remain the same, however. Medicine is a huge subject, and the last thing a student needs when exams are looming is to waste time assembling information from different sources, and wading through pages of irrelevant detail. As before, Crash Course brings you all the information you need, in compact, manageable volumes that integrate basic medical science with clinical practice. We still tread the fine line between producing clear, concise text and providing enough detail for those aiming at distinction. The series is still written by medical students with recent exam experience, and checked for accuracy by senior faculty members from across the UK.

I wish you the best of luck in your future careers!

Dr Dan Horton-Szar
Series Editor (Basic Medical Sciences)

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Finally, thank you Abi, for putting up with my complaining!

Figure acknowledgements

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Dedication

For my family.

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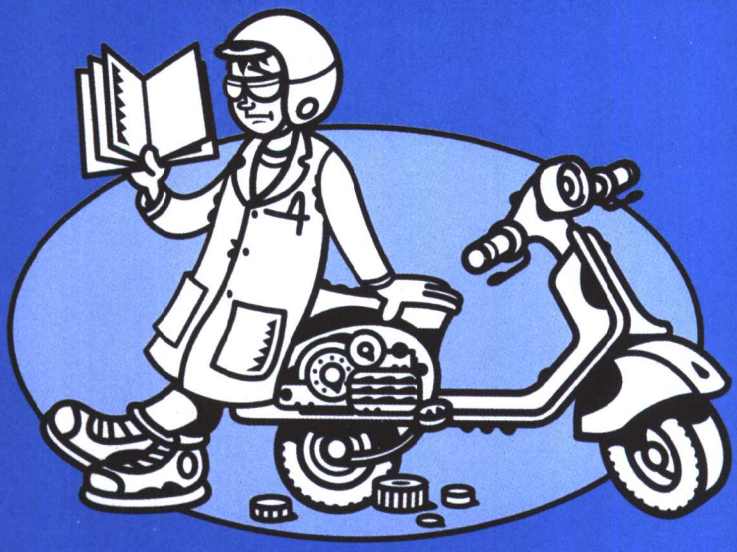

BASIC MEDICAL SCIENCE OF THE GASTROINTESTINAL SYSTEM

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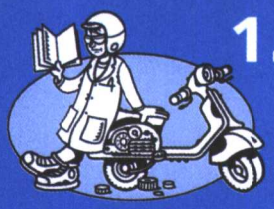

1. Overview of the Gastrointestinal System

Anatomical overview

The gastrointestinal (GI) system (Fig. 1.1) develops entirely from the endoderm in the embryo. It maintains a basic structure throughout its length (Fig. 1.2), with a mucosal layer, submucosa, muscular layer, and adventitia or serosa. There are also intrinsic submucosal and mucosal nerve plexuses (Meissner's plexus and Auerbach's plexus), the activity of which is moderated by extrinsic innervation.

The gastrointestinal tract takes in, breaks down, and absorbs food and fluids. The system has different specialized regions to perform these functions. Food is moved through the tract by gravity and peristalsis.

Peristalsis is a wavelike movement that propels food along the gut by the coordinated contraction of muscle in one area and relaxation in the next. A series of sphincters prevent any backflow of food (reflux) (Fig. 1.3).

Reflexes occurring in different parts of the tract act with hormonal and neuronal factors to control the speed of food movement through the tract. The contents move through the tract at a rate at which they can be processed.

Functions of the gastrointestinal tract

The functions of the GI tract are given in Fig. 1.4. Other functions involved in food digestion are:

- Storage of waste material in the sigmoid colon and rectum.

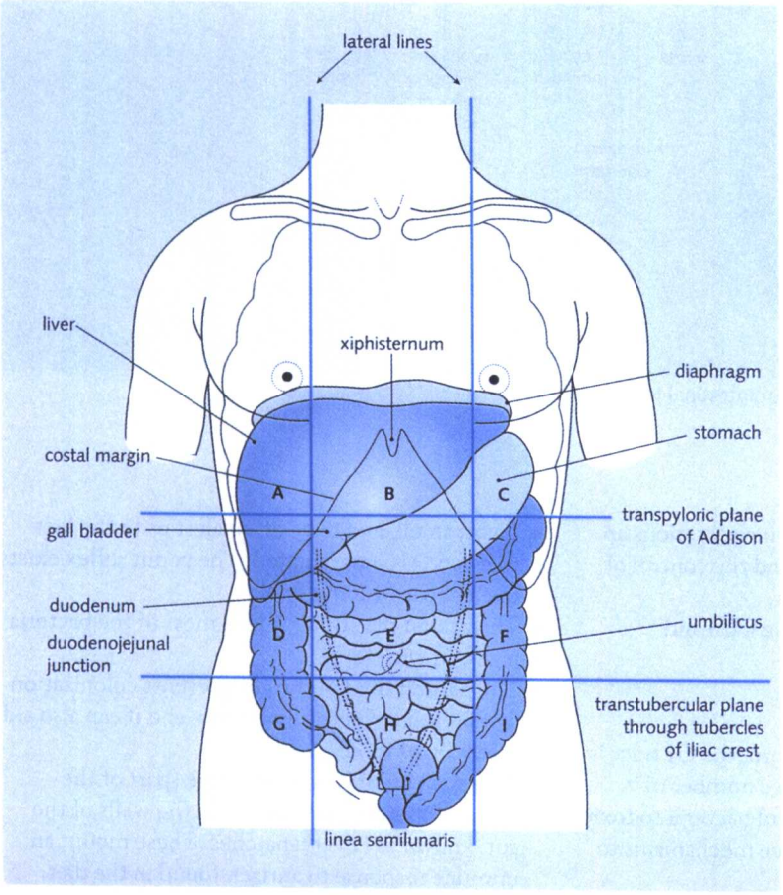

Fig. 1.1 Anatomy of the gastrointestinal tract, showing its surface markings. The transpyloric plane of Addison passes midway between the jugular notch and the symphysis pubis, and midway between the xiphisternum and the umbilicus. It passes through the pylorus, the neck of the pancreas, the duodenojejunal flexure, and the hila of the kidneys. Surface regions: A right hypochondriac; B epigastric; C left hypochondriac; D right lumbar; E umbilical; F left lumbar; G right iliac fossa; H hypogastric; I left iliac fossa.

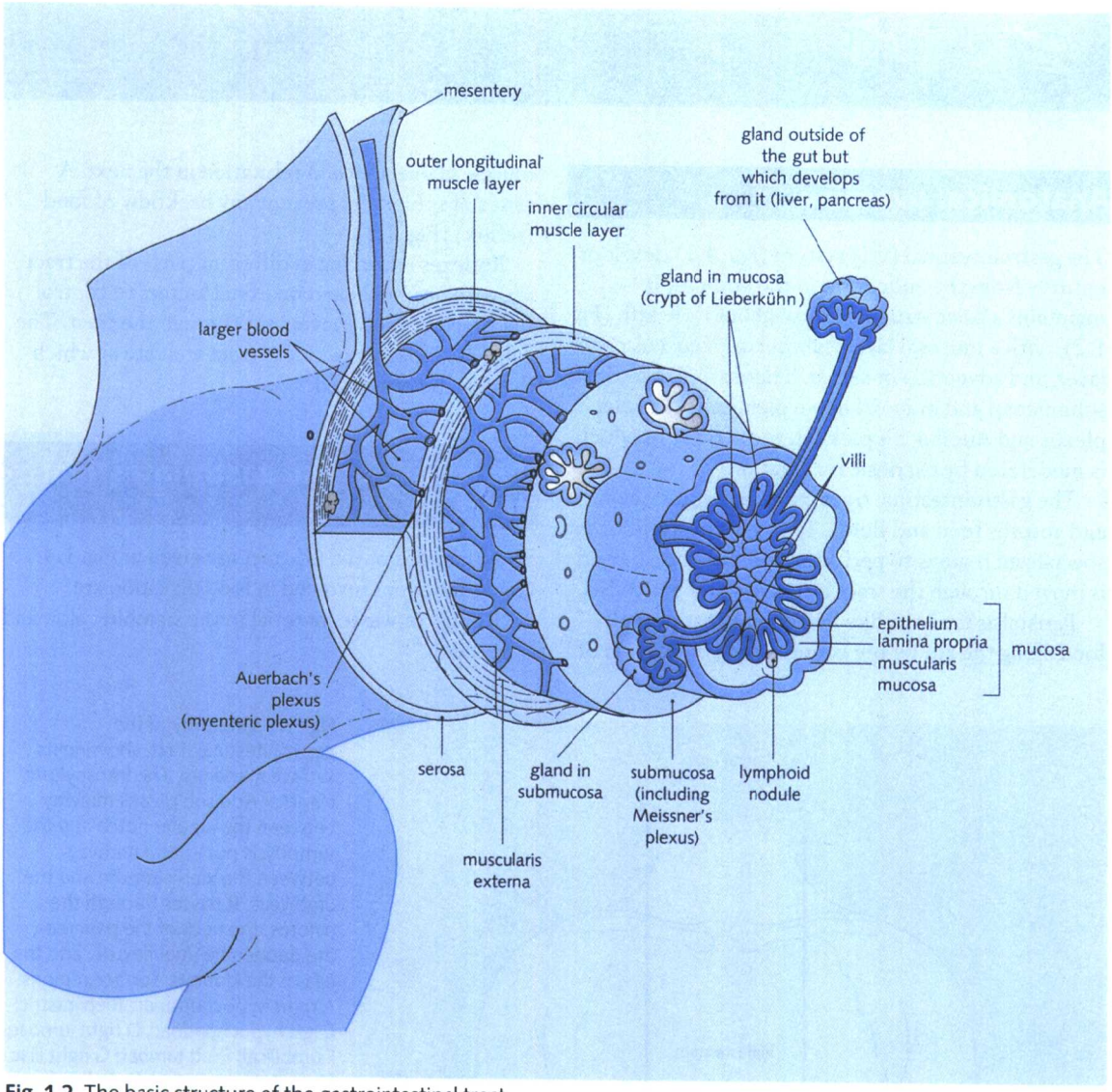

Fig. 1.2 The basic structure of the gastrointestinal tract.

- Exocrine, endocrine, and paracrine secretions are all involved in active digestion and the control of digestion and motility in the gut.
- Some GI peptide hormones have local and systemic effects (see Fig. 5.11).
- Excretion of waste products.

Although it is an internal structure, the GI tract is not sterile, and it is presented with a number of insults on a daily basis, from harmful bacteria to toxic substances. It requires good defence mechanisms to deal with these:

- Sight, smell, and taste often alert us to the fact that food is contaminated. The vomit reflex exists to eject harmful material.
- The acid in the stomach kills most of the bacteria ingested with food.
- The natural flora of the gut prevents colonization by potentially harmful bacteria, and it can also aid digestion of food.
- Aggregations of lymphoid tissue (part of the immune system) are present in the walls of the gut, known as Peyer's patches. These mount an immune response to antigen found in the diet.

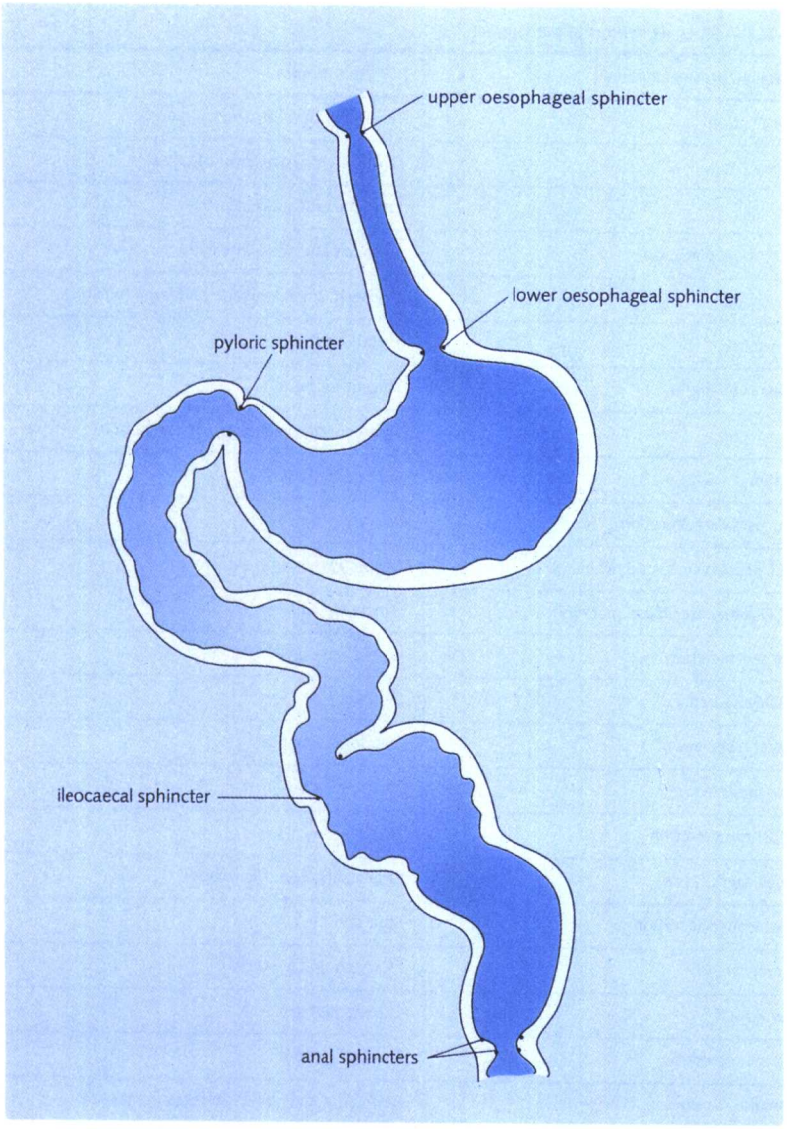

Fig. 1.3 Sphincters of the gastrointestinal tract.

Constituents of food

The body requires food as a source of energy, minerals, and vitamins. These are essential for growth, maintenance, and repair. The main food groups are carbohydrates, fat, and protein. These are oxidized to generate high energy bonds in ATP (adenosine triphosphate) and to provide materials for building new tissues.

Excess food, stored as fat, leads to obesity and associated diseases such as ischaemic heart disease and non-insulin-dependent diabetes. Men and women have different patterns of fat distribution in the body. When deprived of food, an average 70 kg man may survive for 5–6 weeks on body fat stores provided he is able to drink water. Blood glucose levels drop during the initial few days, then rise and stabilize (the brain needs a constant supply of glucose, although other organs are better able to utilize other forms of energy). During prolonged fasting, the body will also break down muscle, including heart muscle, to provide energy. This may lead to death from cardiac failure. Most patients do not die from starvation directly, but from the inability to fight off infectious disease.

Fat

Dietary fat is chiefly composed of triglycerides (esters of free fatty acids and glycerol, which may be

Functions of the GI tract		
Function	**Mechanism/process involved**	**Where it occurs**
Digestion of food	i) Mastication	Mouth: with teeth and tongue
	ii) Swallowing	Oropharynx: relaxation of UOS
	iii) Mixing	Stomach and small intestine
	iv) Enzymatic digestion	Stomach and small intestine
	v) Absorption	Stomach, small intestine and large intestine
Motility	i) Peristalsis	Throughout gut
	ii) Mass movement	Throughout gut
Storage of food waste		Stomach, sigmoid colon, and rectum
Excretion	Defecation	Rectum and anus
Exocrine secretions	i) Mucus/saliva secretion	Salivary gland
	ii) HCl/pepsin/mucus secretion	Gastric glands of stomach
	iii) HCO_3/amylase/lipase secretion	Pancreas
	iv) Bile salt secretion	Liver
Endocrine secretions	i) Gastrin secretion	Stomach
	ii) Secretin secretion	Duodenal mucosa
	iii) Insulin secretion	Pancreas
Paracrine secretions	Somatostatin secretion	Mucosa
Defence	i) Smell, sight, taste	Oral cavity, cephalic region
	ii) Gastric acid secretion	Stomach
	iii) Vomit reflex	Stomach up to mouth
	iv) Gut flora	Throughout gut
	v) Mucus secretion	Throughout gut
	vi) Immune response	Peyer's patches, macrophages in mucosa
	vii) Secretion of IgA	Mucosal secretions

Fig. 1.4 A summary of the functions of the gastrointestinal (GI) tract. (UOS, upper oesophageal sphincter.)

saturated, monounsaturated, or polyunsaturated). The essential fatty acids are linoleic acid and α-linoleic acid, which cannot be manufactured and so must be obtained from our diet.

The body is efficient at manufacturing fats (triglycerides, sterols, and phospholipids), and it will lay down subcutaneous fat stores even on low-fat diets.

Dietary fat provides 37 kJ (9 kcal) of energy per gram. Fat intake should be less than 35% of the total energy intake.

Carbohydrate

Dietary carbohydrates comprise the polysaccharides, starch, disaccharides (mainly sucrose and lactose), monosaccharides (glucose, fructose and galactose), and non-starch polysaccharides (previously called fibre).

Carbohydrates are a cheap form of food, and they can be taken in excess, often limiting the intake of other food constituents. Carbohydrates provide 17 kJ (4 kcal) of energy per gram.

Protein

Protein is composed of amino acids, nine of which are essential for protein synthesis and nitrogen balance.

We need 0.75 g protein per kilogram of body weight per day, but in developed countries most people exceed this.

In developing countries, where protein is less readily available, combinations of certain foods can provide enough of the essential amino acids even though those foods, on their own, are low in some amino acids.

Examples of good combinations are maize and legumes, or baked beans on toast!

Water

Fluid intake and oxidation of food provides water for the body. About 1 L of water is needed per day to balance insensible losses such as sweating, metabolism, and exhalation of water vapour (more water is required in hot climates).

Excess water is excreted in the urine by the kidneys; inadequate intake leads to dehydration.

Minerals

Minerals are chemicals that must be present in the diet to maintain good health; over 20 have so far been identified (e.g. iron and calcium).

Trace elements (e.g. zinc, copper, and iodine) are substances that, by definition, are present in the body in low concentrations (less than 100 parts per million) and include some minerals. It is not yet known whether all trace elements are essential for health.

Vitamins

Vitamins are classified as fat soluble or water soluble; vitamins A, D, E, and K are fat soluble, the other vitamins are water soluble.

Fat soluble vitamins are stored in fatty tissue in the body (mainly in the liver), and they are not usually excreted in the urine.

The absorption of fat soluble vitamins is dependent upon the absorption of dietary fat: deficiency can occur in cases of fat malabsorption.

Body stores of water soluble vitamins (other than vitamin B_{12}) are smaller than stores of fat soluble vitamins. They are excreted in the urine and deficiencies of water soluble vitamins are more common.

A summary of the nutrient groups is given in Fig. 1.5.

For further information, see the companion volume on *Metabolism and Nutrition* in the *Crash Course* series.

Summary of nutrients in the diet

Food group		Source	Digested	Absorbed
Fats		Meats, oil, butter, etc.	Small intestine	Small intestine
Carbohydrates	Polysaccharides, starch, etc.	Sugary food, potatoes, pasta, etc.	Mouth and small intestine	Small intestine
	Non-starch polysaccharides (NSPs i.e. fibre)	Plant foods	Usually undigestable, some colonic bacteria can digest NSPs	Not absorbed
Protein		Meat, pulses, etc.	Stomach and small intestine	Small intestine
Minerals		Meat, milk, vegetables, cereals	Not digested	Small intestine
Vitamins	Fat soluble (A,D,E and K)	Meat, fish, and vegetable oils	Not digested	With fat
	Water soluble	Milk, meat, fruit, and vegetables	Not digested	Small intestine

Fig. 1.5 A summary of the nutrient groups obtained from the diet. (NSPs, non-starch polysaccharides.)

Development of the gastrointestinal tract

The GI tract is the main organ system derived from the endodermal germ layer. The formation of the tube is largely passive; it depends on the cephalocaudal and lateral folding of the embryo.

The yolk sac produces blood cells and vessels, and it is the site of haematopoiesis for the first 2 months from conception. Later, it becomes inverted and incorporated into the body cavity. The folding of the embryo constricts the initial communication between the embryo and the yolk sac.

The remnant of this communication is the vitelline duct, which normally disappears *in utero*. Where it persists (as it does in about 2% of the population), it is known as a Meckel's diverticulum.

The gut tube divides into foregut, midgut, and hindgut, each of which has its own blood supply (Fig. 1.6). The superior mesenteric artery is in the umbilicus. The gut tube starts straight but twists during development and the midgut grows rapidly, with the developing liver occupying most of the space.

There is not enough room in the fetal abdomen to accommodate the rapidly developing gut. The gut herniates between weeks 7–11 of gestation, continuing its development outside the abdominal cavity.

It undergoes a clockwise rotation of 180° and what was the inferior limb becomes the superior limb (and vice versa). It then undergoes a 270° turn anticlockwise so that the caecum lies under the liver. The tube then elongates again so that the caecum points downwards. Sometimes the caecum remains pointing up instead of down, which makes diagnosis of appendicitis difficult!

The falciform ligament lies in front of the liver, and the lesser omentum lies behind the liver. The liver and pancreas develop from endodermal diverticula that bud off the duodenum in weeks 4–6 (see Fig. 4.5).

Much of the mouth (including the muscles of mastication and tongue) and the oesophagus develop from the branchial arches.

The muscles of mastication, mylohyoid, and anterior belly of digastric develop from the first (mandibular) arch, supplied by the trigeminal nerve (V).

The anterior two thirds of the tongue develop from three mesenchymal buds from the first pair of branchial arches. The posterior belly of digastric develops from the second arch, supplied by the facial nerve (VII).

Stylopharyngeus develops from the third arch, supplied by the glossopharyngeal nerve (IX).

Cricothyroid, the constrictors of the pharynx, and the striated muscles of oesophagus develop from the fourth and sixth arches, supplied by branches of the vagus nerve (X). The fifth arch is often absent. The developmental stages are shown in Fig. 1.7.

Divisions of the primitive gut tube

Divisions of gut	Blood supply	Nerve supply	Components
Foregut	Coeliac artery	Vagus	Pharynx Oesophagus Stomach Proximal half of duodenum Gives rise to: liver gall bladder pancreas
Midgut	Superior mesenteric artery	Vagus	Distal half of duodenum Jejunum Ileum Caecum Ascending colon Proximal two thirds of transverse colon
Hindgut	Inferior mesenteric artery	Pelvic splanchnic	Distal one third of transverse colon Descending colon Sigmoid colon Proximal two thirds of anorectal canal

Fig. 1.6 Divisions of the primitive gut tube.