# Anatomy of the liver

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## Abstract

The liver is a fascinating organ that possesses many unusual features, both anatomical and functional. It is the largest and heaviest of the solid glandular organs in the body with a rich blood supply which is derived from an unusual combination of two sources: one arterial, the other venous. In its functions the liver is immensely versatile. Indeed no other single organ in the body comes close to matching the liver for sheer range and intensity of metabolic, synthetic, haemopoietic and immunological activities. The normal liver has an impressive capacity for regeneration. In the past 60 years, and particularly in the last three decades, there has been a progressive and very considerable expansion in our knowledge and understanding of the vascular and functional anatomy of the liver. These advances in anatomical knowledge along with numerous technical and technological developments have had a great impact on the current state of hepatic surgery and are the principal factors underlying the sophistication and precision that define modern hepatic surgery. In this article, a description of the gross external and topographical anatomy of the liver is followed by an account of hepatic functional anatomy and hepatic blood supply.

**Keywords** Functional anatomy; hepatic artery; hepatic lobes; hepatic veins; liver segments; porta hepatis; portal vein

## External features (Figure 1a and b & Figure 4 on page 000 of this issue)

The liver is the largest and heaviest glandular organ in the body, being somewhat heavier in the male than in the female. In the average adult it weighs 1.5 kg (approx. 2% of body wt). In health the liver has a deep burgundy colour (reflecting its rich vascularity), a smooth surface and a soft-to-firm and floppy consistency.

The liver lies high up in the abdominal cavity occupying most of the right hypochondrial region. It extends into the epigastric region and into the medial part of the left hypochondrium. The liver is, for the most part, surrounded (and protected) by the lower circumference of the rib cage. It is enveloped in a thin connective tissue layer, termed Glisson's capsule. The capsule sends inward extensions which surround the branches of the hepatic artery, portal vein and biliary ducts as the latter enter or leave the liver. The visceral peritoneum envelops the liver and is applied to the surface of Glisson's capsule everywhere except where the gallbladder is interposed between the peritoneum and the cystic fossa of the liver, and over the so-called 'bare area' of the liver (described below) which is devoid of a peritoneal covering.

The liver is moulded to the under surface of the diaphragm, principally the right hemi-diaphragm, and is consequently somewhat wedge-shaped (Figure 1a & b). It may be said to

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possess two surfaces: diaphragmatic and visceral. The diaphragmatic surface is convex throughout and, for descriptive convenience, is subdivided into anterior, lateral, superior and posterior aspects which merge one into another without any demarcations (Figure 1a & b). The diaphragmatic surface is however clearly demarcated from the visceral (inferior) surface by the acute inferior border of the liver (see Figure 4 on page 000 of this issue).

## Lobes of the liver

On the diaphragmatic surface the attachment of the falciform ligament to the anterior and superior aspects of the diaphragmatic surface demarcates, rather unequally, the right lobe from the left lobe (Figure 1a). The latter is no more than a quarter or one-fifth the size of the right lobe. Two additional lobes, the quadrate lobe and caudate lobe, are evident when the inferior surface of the liver is examined.

## Visceral surface of the liver

As has been noted, the entire visceral surface of the liver is covered by visceral peritoneum except where the peritoneum is lifted off the hepatic surface by the gallbladder. The visceral surface of the liver is thus separated from all the viscera to which it is related, by the peritoneal cavity. The exception is the gallbladder which contacts the visceral surface of the liver directly without any intervening peritoneal layer.

The notable and readily observed features of the visceral surface are: (i) the porta hepatis; (ii) the gallbladder fossa (cystic fossa) which accommodates the gallbladder; (iii) fissures for the ligamentum teres and ligamentum venosum; (iv) quadrate lobe; and (v) caudate lobe. (Fig. 1b & Fig. 4 on page 000 of this issue).

The porta hepatis is a transverse fissure, 5 cm long, through which the right and left branches of the hepatic artery and right and left branches of the portal vein enter the liver and the right and left hepatic ducts accompanied by lymphatic vessels emerge from the liver.

The right extremity of the porta hepatis is just medial to the neck of the gallbladder whereas the left extremity lies adjacent to the junction between the ligamentum venosum and ligamentum teres (Fig. 4 on page 000 of this issue). Together, the two fissures effectively demarcate the right hepatic lobe from the left lobe on the inferior and posterior aspects of the liver. Two well-defined lobes are situated to the right of the fissures. Anterior to the porta hepatis, to the left of the gallbladder bed and to the right of the fissure for ligamentum teres (Fig. 4 on page 000 of this issue), and reaching as far as the anterior edge of the visceral surface is the quadrate lobe, while posterior to the porta hepatis, and to the right of the fissure for ligamentum venosum is the caudate lobe. Occasionally, a tongue-like projection of liver extends from the anterior edge of the liver just lateral to the fundus of the gallbladder. This anatomical variant is called Riedel's lobe.

## Viscera related to the inferior surface of the gallbladder

Apart from the gallbladder, viscera related to the inferior (visceral) surface of the right lobe, of the liver are the right colic flexure (i.e. hepatic flexure of colon), the right kidney enveloped

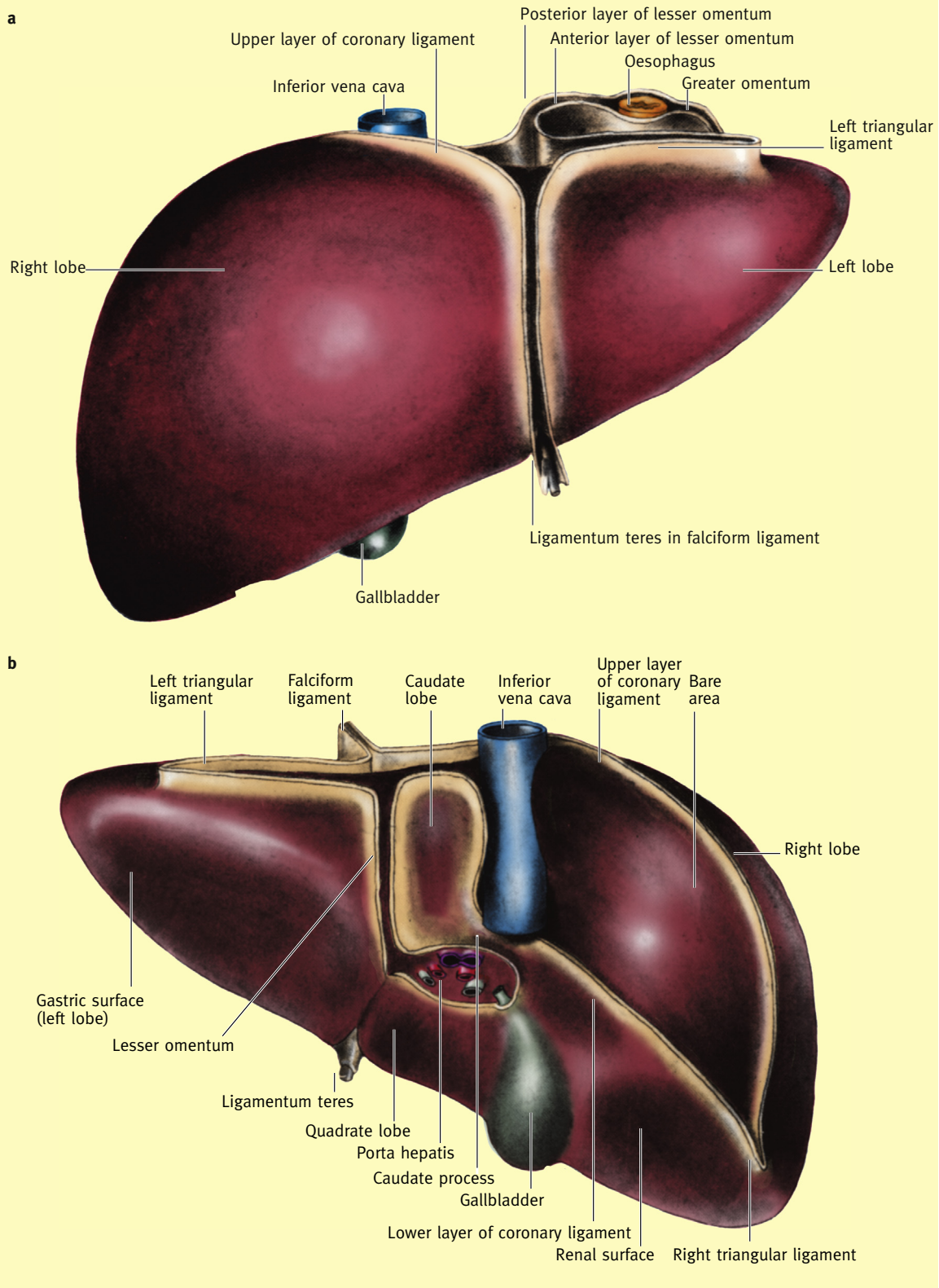## External features of the liver. (a) anterior view; (b) posterior view



**Figure 1**

in its fascial coverings, and immediately to the right of the neck of the gallbladder is the junction between the first and second parts of the duodenum. The visceral surface of the left lobe of the liver overlaps the lesser omentum and part of the anterior wall of the stomach. Posterosuperiorly this surface rests on the abdominal oesophagus (Figure on page 000 of this issue). The areas on the inferior surface of the liver which relate to various viscera are indicated in Figure 1b and on page 000 of this issue.

## Surface marking of the liver

An approximate surface representation of the liver can be outlined by an irregular triangle with somewhat convex margins, as follows. The upper margin of the liver extends from a point on the 5th left intercostal space 7—8 cm lateral to the midline, across to a point overlying the right 5th rib, inferolateral to the right nipple. This line lies at the level of the xiphisternal junction. The right margin, gently convex laterally, extends from the right extremity of the upper margin to a point 1 cm below the right costal margin in the midclavicular line. The inferior margin can be represented by an oblique line that joins the lower end of the right margin to the left extremity of the upper margin. The inferior margin will be seen to cross the epigastrium as it cuts across from one costal margin to the other. The normal liver is not palpable on clinical examination.

## Peritoneal attachments (Figure 1a & b)

Except for a small bare area on the posterosuperior aspect of the right lobe, the liver is completely enclosed in peritoneum. The bare area is circumscribed by the lines of attachment of the upper and lower layers of the coronary ligament and the right triangular ligament (Figure 1b). The falciform ligament runs to the liver from the posterior surface of the anterior abdominal wall. The lower edge (free border) of the falciform ligament is cord-like and is called the ligamentum teres. It contains the remnant of the fetal umbilical vein. The ligamentum teres passes from the umbilicus into its fissure on the inferior surface of the liver, while the sickle-shaped falciform ligament itself passes over the anterior surface of the liver onto the hepatic dome, where the two leaves of the falciform ligament separate; the right leaf continues as the upper layer of the coronary ligament, while the left leaf stretches out as the long narrow left triangular ligament, which joins the lesser omentum at the fissure for the ligamentum venosum (Figure 1b). The lesser omentum is a double-layered sheet of peritoneum, the superior attachment of which is to the margins of the porta hepatis and to the fissure for the ligamentum venosum. From this attachment the lesser omentum stretches across to the lesser curvature of the stomach.

## Stability of the liver

The stability of the liver in its normal position is maintained principally by the three major hepatic veins attached to the inferior vena cava. Other factors that help to stabilize the liver and maintain its position are the suspensory peritoneal 'ligaments' that run from the superior surface of the liver to the inferior surface of the diaphragm (coronary ligaments and right and left triangular ligaments) and to the posterior surface of the anterior abdominal wall (falciform ligament and ligamentum teres). The tone of the abdominal wall musculature may also make a contribution to the stability of the liver.

## Blood supply and venous drainage of the liver (Figure 2)

The liver is a very vascular organ which, in an average adult, receives 1.5 litres of blood per minute. This approximates to nearly 25% of the resting cardiac output. The liver is unusual among solid viscera in having both an arterial and a venous source of blood inflow, represented by the hepatic artery and portal vein, respectively. The portal vein provides 70—75% of the inflow while the hepatic artery supplies the remainder (25—30%). Blood from these two sources enters the hepatic sinusoids. As it flows through the sinusoids the blood undergoes marked changes in biochemical composition including a considerable reduction in oxygen saturation. This deoxygenated venous blood is returned by the hepatic veins to the inferior vena cava.
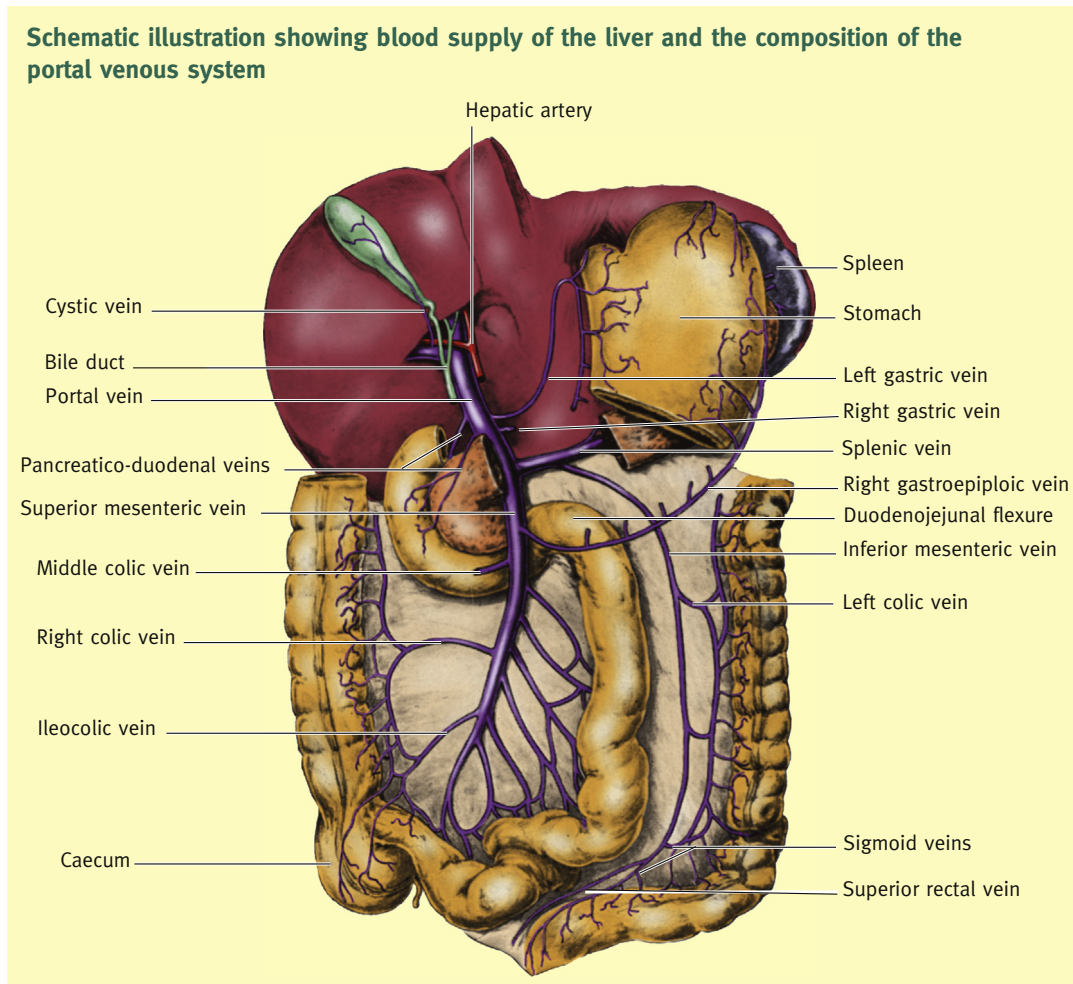
The portal vein and hepatic artery run towards the porta hepatis within the hepatoduodenal ligament (an alternative name for the free edge of the lesser omentum). The portal vein is 9—10 cm long and is formed immediately behind the neck of the pancreas by the confluence of the superior mesenteric vein and splenic vein (Figure 2). The latter receives the inferior mesenteric vein. Additionally, the right and left gastric veins drain directly into the portal vein. The portal vein is thus the final common pathway for blood returning from the territories of the superior mesenteric artery (midgut), inferior mesenteric artery (hindgut) and coeliac artery (foregut). All the veins, large and small, which eventually drain into the portal vein, directly or indirectly, collectively constitute the portal venous system. This entire portal venous system is devoid of valves. Being significantly less deoxygenated than systemic venous blood, the blood in the portal vein is an important source of oxygen to the hepatocytes. Indeed, the healthy liver can tolerate occlusion of the hepatic artery but not that of the portal vein, except very transiently.

On reaching the porta hepatis the portal vein divides into two branches, right and left, for the right and left hemilivers, respectively.

The hepatic artery proper is the continuation of the common hepatic artery from the point where the latter gives off the gastroduodenal artery and turns upwards to enter the free edge of the lesser omentum. A few centimetres before reaching the porta hepatis, the hepatic artery divides into the right and left hepatic arteries, respectively, for the right and left hemilivers (Figure 2).

## Venous drainage of the liver

Hepatic venous blood is returned to the inferior vena cava via the hepatic veins. There are three major hepatic veins: the right hepatic vein, the middle (or central) hepatic vein and the left hepatic vein (Figure 3). These pass in a posterosuperior direction through the liver substance to empty into the inferior vena cava which lies on the posterior surface of the liver, or at times within the liver substance itself. The middle hepatic vein is usually the smallest of the three, and often opens into the left vein just before the latter joins the inferior vena cava. In addition, a variable number of small, accessory veins run from the liver to drain directly into the inferior vena cava below the level of the openings of the main veins.
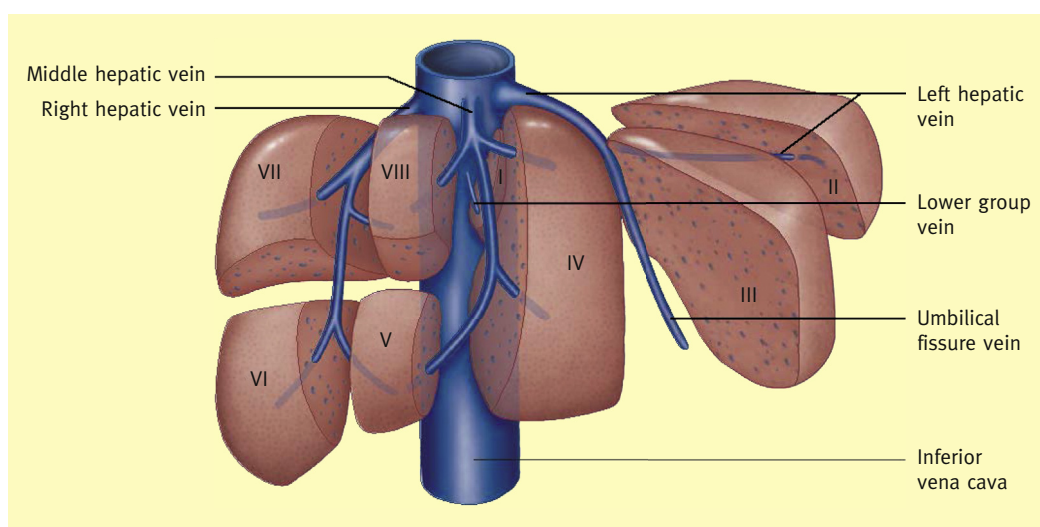
**Schematic illustration showing blood supply of the liver and the composition of the portal venous system**

Hepatic artery

Cystic vein

Bile duct

Portal vein

Pancreatico-duodenal veins

Superior mesenteric vein

Middle colic vein

Right colic vein

Ileocolic vein

Caecum

Spleen

Stomach

Left gastric vein

Right gastric vein

Splenic vein

Right gastroepiploic vein

Duodenojejunal flexure

Inferior mesenteric vein

Left colic vein

Sigmoid veins

Superior rectal vein

**Figure 2**

## Functional (segmental) anatomy of the liver

Modern hepatic surgery is based on a proper appreciation of the functional anatomy of the liver rather than on the gross lobar anatomy that is evident on external inspection of the liver. The initial elucidation of the functional anatomy of the liver was the result, largely, of the work of the French surgeon and anatomist, Claude Couinaud (1922−2008), who demonstrated that the liver could be subdivided on a functional basis into several segments



Middle hepatic vein

Right hepatic vein

Left hepatic vein

Lower group vein

Umbilical fissure vein

Inferior vena cava

VII  VIII  I  II  IV  III  V  VI

**Figure 3** The location of the principal hepatic veins and the relationship of the hepatic veins to the functional (segmental) anatomy of the liver.

and that the anatomical basis to this functional division of the liver was the vascular and biliary relationships within the liver. Couinaud further demonstrated that the functional segments bore very little correlation to any surface anatomical features or landmarks, and thus could not be deduced or indicated using surface landmarks. On a functional basis, the liver may be divided into two discrete 'halves', termed **hemilivers**. The two hemilivers are not exactly equal in size and volume. In fact, the right hemiliver is usually larger than the left and accounts for 55–60 % of the total mass of the liver. Each hemiliver receives the corresponding branch of the proper hepatic artery and of the main portal vein. The right and left hemilivers are 'demarcated' from each other by an oblique plane that intersects the gallbladder fossa and the fossa for the inferior vena cava. This oblique plane is variously termed the median portal scissura, midplane of the liver and Cantlie's line (three names for the same plane!) Lodged in the midplane of the liver is the middle hepatic vein.

The International Hepato-Pancreatico-Biliary Association (IHPBA), at its meeting in Brisbane in 2000, proposed a new terminology which is now used more-or-less worldwide. Under the new terminology, each hemiliver is divided into two sections (formerly known as 'sectors'). The two sections of the right hemiliver are termed the right anterior section and right posterior section. The plane of division between the two sections in the right hemiliver is known as the right intersectional plane (formerly known as the right portal fissure). In it is lodged the right hepatic vein. There are no surface landmarks that can be used to indicate this plane. The two sections of the left hemiliver are termed left medial section and left lateral section. The plane of division between the two sections in the left hemiliver is known as the left intersectional plane (formerly known as the left portal fissure). In it is lodged the left hepatic vein. As with the right hemiliver, there are no surface landmarks by which the left intersectional plane can be indicated with precision. In practice the left and right hepatic veins (which indicate the left and right intersectional planes, respectively) are identified by intra-operative ultrasonography or by reference to late-phase contrast-enhanced CT scans.

Each hepatic section can be sub-divided into segments. Under the recommendations of the *Brisbane terminology*, the eight segments are denoted by Arabic numerals (displacing the original Roman numerals). There are eight segments in all: two in each of the sections except in the left lateral section which has just one segment (Figure 3), segment 1 (synonymous with caudate lobe) does not belong to any section. The left medial section is divided by the fissure for ligamentum teres (also known as umbilical fissure) into two segments, namely, segment 3 and segment 4 (Figure 3).

Each segment has its individual blood supply and biliary drainage. This arrangement allows the surgeon to carry out precise segmental hepatic resections.

## Lymphatic drainage of the liver

Lymph from the liver flows initially into one or other of two networks of lymphatic channels: (i) a superficial lymphatic plexus which lies just inside Glisson's capsule and (ii) a deeply situated networks of lymphatics. Most of the superficial lymphatics from the posterior part of the liver converge towards the bare area whence they accompany the inferior vena cava and thus reach the posterior mediastinal lymph nodes. These nodes, in turn, drain into the thoracic duct. Superficial lymphatics from the posterior part of the left lobe of the liver drain into the left gastric nodes, that lie alongside the lesser curvature. Superficial lymphatics from the anterior part of the liver drain into the hepatic nodes. These lymph nodes are situated in the porta hepatis and transmit their lymph to the coeliac nodes at the origin of the coeliac arterial trunk.

The deep lymphatics of the liver form two trunks; an ascending trunk and a descending trunk. The former accompanies the hepatic veins and the inferior vena cave to drain eventually to the posterior mediastinal lymph nodes. The descending trunk passes through the porta hepatis to reach the hepatic nodes.

## Embryological development of the liver

A Y-shaped diverticulum arises from the ventral aspect of the very terminal part of the foregut, and grows in a ventral and cranial direction into the caudal part of the septum transversum. The two limbs of the 'Y' develop into the right and left hepatic ducts while the stem of the 'Y' develops into the common hepatic duct and common bile duct. A blind diverticulum sprouts out from the stem of the 'Y' and develops into the cystic duct and gallbladder.

The right and left hepatic ducts branch repeatedly and dichotomously within the caudal part of the septum transversum to form the segmental, interlobular and intralobular ducts and cords of hepatocytes. The caudal part of the septum transversum has the vitelline veins which form a rich venous plexus into which the hepatocytes grow. ◆

### FURTHER READING

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