CHAPTER XIII.

USES OF THE LIVER—DUCTLESS GLANDS.

Physiological anatomy of the liver—Distribution of the portal vein, the hepatic artery and the hepatic duct—Structure of a lobule of the liver—Arrangement of the bile-ducts in the lobules—Anatomy of the excretory biliary passages—Nerves and lymphatics of the liver—Mechanism of the secretion and discharge of bile—Quantity of bile—Uses of the bile—Properties and composition of the bile—Biliary salts—Cholesterine—Tests for bile—Excretory action of the liver—Formation of glycogen in the liver—Change of glycogen into sugar—Conditions which influence the quantity of sugar in the blood—Summary of the glycogenic action of the liver—Probable office of the ductless glands—Physiological anatomy of the spleen—Suprarenal capsules—Addison's disease—Thyroid gland—Myxœdema—Thymus—Pituitary body and pineal gland.

Physiological Anatomy of the Liver.

The liver has several uses in the economy, which are more or less distinct from each other. It secretes bile, a fluid concerned in digestion and containing at least one excrementitious product. Another office is the formation of glycogen, in which it acts as a ductless gland.

It is unnecessary, in this connection, to dwell upon the ordinary descriptive anatomy of the liver. It is sufficient to state that it is situated just below the diaphragm, in the right hypochondriac region, and is the largest gland in the body, weighing, when moderately filled with blood, about four and a half pounds (2 kilos.). Its weight is somewhat variable, but in a person of ordinary adipose development, its proportion to the weight of the body is about as one to thirty-two. In early life the liver is relatively larger, its proportion to the weight of the body, in the new-born child, being as one to eighteen or twenty (Sappey).

The liver is covered externally by peritoneum, folds or duplicatures of this membrane being formed as it passes from the surface of the liver to the adjacent parts. These constitute four of the so-called ligaments that hold the liver in place. The proper coat is a thin but dense and resisting fibrous membrane, adherent to the substance of the organ, but detached without much difficulty, and very closely united to the peritoneum. This membrane is of variable thickness at different parts of the liver, being especially thin in the groove for the vena cava. At the transverse fissure, it surrounds the duct, blood-vessels and nerves, and it penetrates the substance of the organ in the form of a vagina, or sheath, investing the vessels, and branching with them. This membrane, as it ramifies in the substance of the liver, is called the capsule of Glisson. It will be more fully described in connection with the arrangement and distribution of the hepatic vessels.

The substance of the liver is made up of lobules, of an irregularly ovoid or rounded form, and about $\frac{1}{25}$ of an inch (1 mm.) in diameter. The space which separates these lobules is about one-quarter of the diameter of the lobule and is occupied by the blood-vessels, nerves and ramifications of the hepatic duct. In certain animals, the pig and the polar bear, the division of the hepatic substance can be readily made out with the naked eye; but in man and in most of the mammalia, the lobules are not so distinct, although their arrangement is essentially the same. The lobules are intimately connected with each other, and branches going to a number of different lobules are given off from the same interlobular vessels; but they are sufficiently distinct to represent, each one, the general anatomy of the secreting portion of the liver.

At the transverse fissure, the portal vein, collecting the blood from the abdominal organs, and the hepatic artery, which is a branch of the cœliac axis, penetrate the substance of the liver, with the hepatic duct, nerves and lymphatics, all enveloped in the fibrous vagina, or sheath, known as the capsule of Glisson. The portal vein is by far the larger of the two blood-vessels, and its caliber may be roughly estimated as eight to ten times that of the artery.

The vagina, or capsule of Glisson, is composed of fibrous tissue in the form of a dense membrane, closely adherent to the adjacent structure of the liver, and enveloping the vessels and nerves, to which it is attached by a loose, areolar tissue. The attachment of the blood-vessels to the sheath is so loose that the branches of the portal vein are collapsed when not filled with blood; presenting a striking contrast to the hepatic veins, which are closely adherent to the substance of the liver and remain open when they are cut across. This sheath is prolonged over the vessels as they branch and it follows them in their subdivisions. It varies considerably in thickness in different animals. In man and in the mammalia generally, it is rather thin, becoming more and more delicate as the vessels subdivide, and it is entirely lost before the vessels are distributed between the lobules.

The vessels distributed in the liver are the following:

The portal vein, the hepatic artery and the hepatic duct, passing in at the transverse fissure, to be distributed in the lobules. The blood-vessels are continuous in the lobules with the radicles of the hepatic veins. The duct is to be followed to its branches of origin in the lobules.

The hepatic veins; vessels that originate in the lobules, and collect the blood distributed in their substance by branches of the portal vein and of the hepatic artery.

Branches of the Portal Vein, the Hepatic Artery and the Hepatic Duct.—These vessels follow out the branches of the capsule of Glisson, become smaller and smaller, and they finally pass directly between the lobules. In their course, however, they send off lateral branches to the sheath, forming the so-called vaginal plexus. The arrangement of the vessels in the sheath is not in the form of a true anastomosing plexus, although branches pass from this so-called vaginal plexus between the lobules. These vessels do not anastomose or communicate with each other in the sheath.

The portal vein does not present any important peculiarity in its course from the transverse fissure to the interlobular spaces. It subdivides, enclosed in its sheath, until its small branches go directly between the lobules, and in its course, it sends branches to the sheath (vaginal vessels), which afterward go between the lobules. The hepatic artery has three sets of branches. As soon as it enters the sheath with the other vessels, it sends off minute branches (vasa vasorum) to the walls of the portal vein, to the larger

branches of the artery itself, to the walls of the hepatic veins, and a very rich net-work of branches to the hepatic duct. In its course, the hepatic artery also sends branches to the capsule of Glisson (capsular branches), which, with branches of the portal vein, go to form the so-called vaginal plexus. From these vessels, a few arterial branches are given off, which pass between the lobules. The hepatic artery can not be followed beyond the interlobular vessels. The terminal branches of the hepatic artery are not directly connected with the radicles of the hepatic veins, but they empty into small branches of the portal vein within the capsule of Glisson.

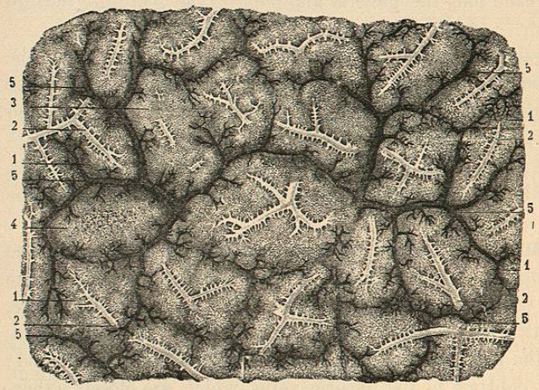

FIG. 130.—*Lobules of the liver, interlobular vessels and intralobular veins* (Sappey).

1, 1, 1, 1, 3, 4, lobules; 2, 2, 2, 2, intralobular veins injected with white; 5, 5, 5, 5, 5, interlobular vessels filled with a dark injection.

Interlobular Vessels.—Branches of the portal vein, coming from the terminal ramifications of the vessel within the capsule and from the branches in the walls of the capsule, are distributed between the lobules, constituting the greatest part of the so-called interlobular plexus. These are situated between the lobules and surround them; each vessel, however, giving off branches to two or three lobules, and never to one alone. They do not anastomose, and consequently they are not in the form of a true plexus. The diameter of these interlobular vessels varies between $\frac{1}{1440}$ and $\frac{1}{720}$ of an inch (17 and 34 μ). In this distribution, the blood-vessels are followed by branches of the duct, which are much fewer and smaller, measuring only $\frac{1}{2500}$ of an inch (10 μ), and some, even, have been measured that are not more than $\frac{1}{3000}$ of an inch (8 μ) in diameter.

Lobular Vessels.—From the interlobular veins, eight or ten branches are given off which penetrate the lobule. As the interlobular vessels are situated between different lobules, each one sends branches into two and sometimes three of these lobules; so that, as far as vascular supply is concerned, these divisions of the liver are never absolutely distinct.

After passing from the interlobular plexus into the lobules, the vessels immediately break up into an elongated net-work of capillaries, $\frac{1}{3000}$ to $\frac{1}{2200}$ of an inch (8 to 11 μ) in diameter, which occupy the lobules with a true plexus. These vessels are very abundant. The blood, having been distributed in the lobules by this lobular plexus, is collected by three or four venous radicles into a single central vessel situated in the long axis of the lobule,

called the intralobular vein. A single lobule, surrounded by an interlobular vessel, showing the lobular capillary plexus, and the central vein (the intralobular vein) cut across, is represented in Fig. 131.

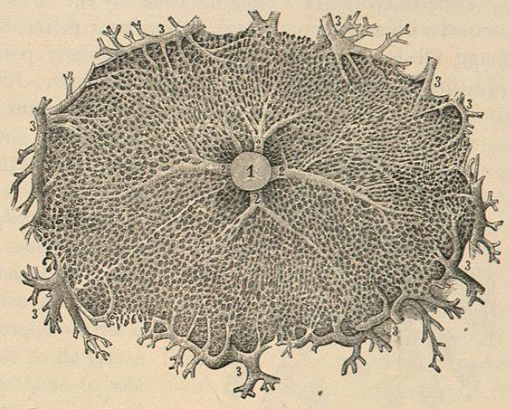

FIG. 131.—*Transverse section of a single hepatic lobule* (Sappey).

1, intralobular vein, cut across; 2, 2, 2, 2, afferent branches of the intralobular vein; 3, 3, 3, 3, 3, 3, 3, 3, 3, interlobular branches of the portal vein, with its capillary branches, forming the lobular plexus, extending to the radicles of the intralobular vein.

Intralobular Veins.—The capillaries of the lobules converge into three or four venous radicles (2, 2, 2, 2, in Fig. 131), which empty into a central vessel. This is the intralobular vein. If a liver be carefully injected from the hepatic veins, and if sections be made in various directions, it will be seen that the intralobular veins follow the long axis of the lobules, receiving vessels in their course, until they empty into a larger vessel situated at what may be called the base of the lobules. These latter are the sublobular veins. They collect the blood in the manner just described, from all parts of the liver, unite with others, becoming larger and larger, until finally they form the three hepatic veins, which discharge the blood from the liver into the vena cava ascendens.

The hepatic veins differ somewhat in their structure from other portions of the venous system. Their walls are thinner than those of the portal veins, they are not enclosed in a sheath, and they are very closely adherent to the hepatic tissue It has also been noted that the hepatic veins possess a well marked muscular tunic, very thin in man, but well developed in the pig, the ox and the horse, and composed of non-striated muscular fibres interlacing with each other in every direction.

In addition to the blood-vessels just described, the liver receives venous blood from vessels which have been called accessory portal veins, coming from the gastro-hepatic omentum, the surface of the gall-bladder, the diaphragm and from the anterior abdominal walls. These vessels penetrate at different points on the surface of the liver, and they may serve as derivatives, when the circulation through the portal vein is obstructed.

Structure of a Lobule of the Liver.—Each hepatic lobule, bounded and more or less distinctly separated from the others by the interlobular vessels, contains blood-vessels, radicles of the hepatic ducts and the so-called hepatic cells. The arrangement of the blood-vessels has just been described; but in all preparations made by artificial injection, the space occupied by the blood-vessels is exaggerated by excessive distention, and the difficulties in

the study of the relations of the ducts and the liver-cells are thereby much increased.

Hepatic Cells.—If a scraping from the cut surface of a fresh liver be examined with a moderately high magnifying power, the field of view will be found filled with rounded, ovoid or irregularly polygonal cells, measuring $\frac{1}{1500}$ to $\frac{1}{1000}$ of an inch (16 to 25 μ) in diameter. In their natural condition they are more frequently ovoid than polygonal; and when they have the latter form the corners are always rounded. These cells present one and occasionally two nuclei, sometimes with and sometimes without nucleoli. The presence of small, pigmentary granules gives to the cells a peculiar and characteristic appearance; and in addition, nearly all of them contain a few granules or small globules of fat. Sometimes the fatty and pigmentary granules are so abundant as to obscure the nuclei. The addition of acetic acid renders the cells pale and the nuclei become more distinct. The cells also contain more or less glycogen in the form of granules surrounding the nuclei.

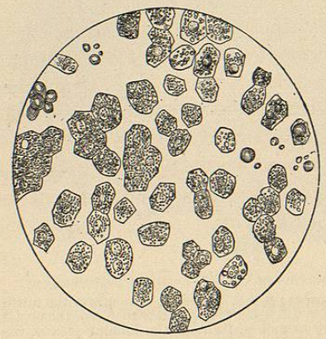

FIG. 132.—*Liver-cells from a human, fatty liver* (Funke).

Arrangement of the Bile-ducts in the Lobules.—In the substance of the lobules is a fine and regular net-work of vessels of nearly uniform size, about $\frac{1}{10000}$ of an inch (2 or 3 μ) in diameter, which surround the liver-cells, each cell lying in a space bounded by inosculating branches of these canals. This plexus is entirely independent of the blood-vessels, and it seems to enclose in its meshes each individual cell, extending from the periphery of the lobule to the intralobular vein.

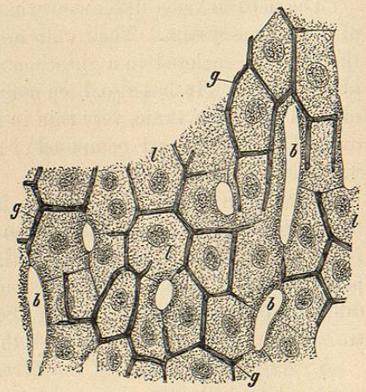

FIG. 133.—*Portion of a transverse section of an hepatic lobule of the rabbit; magnified* 400 *diameters* (Kölliker).

b, *b*, *b*, capillary blood-vessels; *g*, *g*, *g*, capillary bile-ducts; *l*, *l*, *l*, liver-cells.

The reticulated bile-ducts were discovered in the substance of the lobules, near their borders, by Gerlach, in 1848. It is evident, from an examination of his figures and description, that he succeeded in filling with injection that portion of the lobular net-work near the borders of the lobules, and he demonstrated the continuity of these vessels with the interlobular ducts; but he did not recognize the vessels nearer the centre of the lobule. It is now known that there are either canals or interspaces between the liver-cells in the lobules, and that these open into the interlobular hepatic ducts. It is still a question, however, whether these passages be simple spaces between the cells or true vessels lined with a membrane.

Anatomy of the Excretory Biliary Passages.—Between the lobules the ducts are very small, the smallest measuring about $\frac{1}{300}$ of an inch (8 μ) in diameter. They are composed of a delicate membrane lined with epithelium. The ducts larger than $\frac{1}{1200}$ of an inch (about 20 μ) have a fibrous coat, formed of inelastic with a few elastic elements, and in the larger ducts, there are, in addition, a few non-striated muscular fibres. The epithelium lining these ducts is of the columnar variety, the cells gradually undergoing a transition from the pavement-form as the ducts increase in size. In the largest ducts there is a distinct mucous membrane with mucous glands.

Throughout the extent of the biliary passages, from the interlobular canals to the ductus choledochus, are little utricular or racemose glands, varying in size in different portions of the liver. These are situated, at short intervals, by the sides of the canals. The glands connected with the smallest ducts are simple follicles, $\frac{1}{800}$ to $\frac{1}{400}$ of an inch (31 to 62 μ) long. The larger glands are formed of groups of these follicles, and they measure $\frac{1}{250}$ or $\frac{1}{100}$ of an inch (100 or 250 μ) in diameter. The glands are only found connected with the ducts ramifying in the substance of the liver, and they do not exist in the hepatic, cystic and common ducts. They are composed of a homogeneous membrane, lined with small, pale cells of epithelium. If the ducts in the substance of the liver be isolated, they are found covered with these little groups of follicles and have the appearance of an ordinary racemose gland, except that the acini are relatively small and scattered. This appearance is represented in Fig. 134.

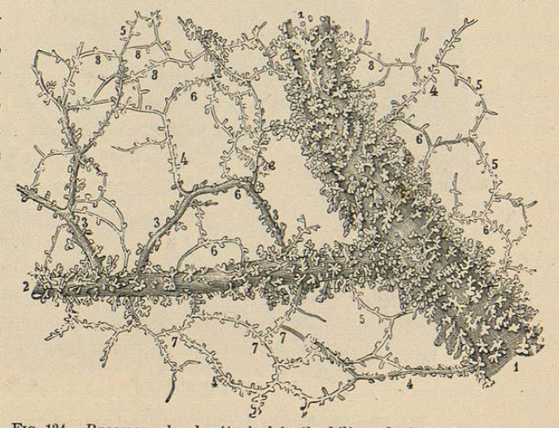

FIG. 134.—*Racemose glands attached to the biliary ducts of the pig; magnified* 18 *diameters* (Sappey).

1, 1, branch of an hepatic duct, with the surface almost entirely covered with racemose glands opening into its cavity; 2, branch in which the glands are smaller and less abundant; 3, 3, 3, branches of the duct with still simpler glands; 4, 4, 4, 4, biliary ducts with simple follicles attached; 5, 5, 5, 5, the same, with fewer follicles; 6, 6, 6, 6, 6, anastomoses in arches; 7, 7, 7, angular anastomoses; 8, 8, 8, 8, anastomoses by transverse branches.

The excretory biliary ducts, from the interlobular vessels to the point of emergence of the hepatic duct, present frequent anastomoses with each other in their course.

Vasa Aberrantia.—In the livers of old persons, and occasionally in the adult, certain vessels are found ramifying on the surface of the liver, but always opening into the biliary ducts, which have been called vasa aberrantia. These are never found in the fœtus or in children. They are appendages of the excretory system of the liver, and are analogous in their structure to the ducts, but are apparently hypertrophied, with thickened, fibrous walls, and present in their course irregular constrictions not found in the normal ducts. The racemose glands attached to them are always very much atrophied.

Gall-bladder, Hepatic, Cystic and Common Ducts.—The hepatic duct is formed by the union of two ducts, one from the right and the other from the left lobe of the liver. It is about an inch and a half (38 mm.) in length and joins at an acute angle with the cystic duct, to form the ductus communis choledochus. The common duct is about three inches (76 mm.) in length, of the diameter of a goose-quill, and it opens into the descending portion of the duodenum. It passes obliquely through the coats of the intestine, and opens into its cavity, in connection with the principal pancreatic

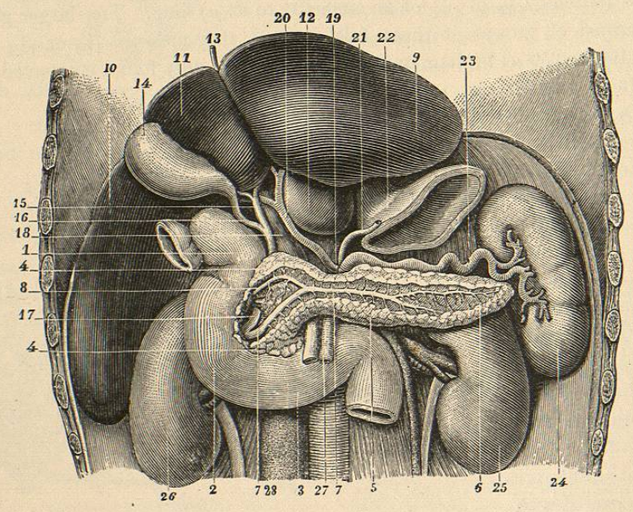

FIG. 135.—*Gall-bladder, hepatic, cystic and common ducts* (Sappey).

1, 2, 3, duodenum; 4, 4, 5, 6, 7, 7, 8, pancreas and pancreatic ducts; 9, 10, 11, 12, 13, liver; 14, *gall-bladder*; 15, *hepatic duct*; 16, *cystic duct*; 17, *common duct*; 18, portal vein; 19, branch from the cœliac axis; 20, hepatic artery; 21, coronary artery of the stomach; 22, cardiac portion of the stomach; 23, splenic artery; 24, spleen; 25, left kidney; 26, right kidney; 27, superior mesenteric artery and vein; 28, inferior vena cava.

duct. The cystic duct is about an inch (25 mm.) in length, and is the smallest of the three canals.

The structure of these ducts is essentially the same. They have a proper coat formed of ordinary fibrous tissue, a few elastic fibres and non-striated muscular fibres. The muscular tissue is not sufficiently distinct to form a separate coat. The mucous membrane is always found tinged yellow with

the bile, even in living animals. It is marked by a large number of minute excavations and is covered with cells of columnar epithelium. This membrane contains a large number of mucous glands.

The gall-bladder is an ovoid or pear-shaped sac, about four inches (10 centimetres) in length, one inch (25 mm.) in breadth at its widest portion, and capable of holding an ounce to an ounce and a half (30 to 45 c. c.) of fluid. Its fundus is covered entirely with peritoneum, but this membrane passes only over the lower surface of its body.

The proper coat of the gall-bladder is composed of ordinary fibrous tissue with a few elastic fibres. In some of the lower animals there is a distinct muscular coat, but a few scattered fibres only are found in the human subject. The mucous coat is of a yellowish color, with very small, interlacing folds which are very vascular. The mucous membrane of the gall-bladder has a general lining of columnar epithelium with a few goblet-cells. In the gall-bladder are found small, racemose glands, formed of four to eight follicles lodged in the submucous structure. These are essentially the same as the glands opening into the ducts in the substance of the liver, and they secrete a mucus which is mixed with the bile.

Nerves and Lymphatics of the Liver.—The nerves of the liver are derived from the pneumogastric, the phrenic, and the solar plexus of the sympathetic. The branches of the left pneumogastric penetrate with the portal vein, while the branches from the right pneumogastric, the phrenic and the sympathetic, surround the hepatic artery and the hepatic duct. All of these nerves penetrate at the transverse fissure and follow the blood-vessels in their distribution. They have not been traced farther than the final ramifications of the capsule of Glisson, and their exact mode of termination is unknown.

The lymphatics of the liver are very abundant. They are divided into two layers; the superficial layer, situated just beneath the serous membrane, and the deep layer. The superficial lymphatics from the under surface of the liver, and that portion of the deep lymphatics which follows the hepatic veins out of the liver, pass through the diaphragm and are connected with the thoracic glands. Some of the lymphatics from the superior, or convex surface join the deep vessels that emerge at the transverse fissure and pass into glands below the diaphragm, while others pass into the thoracic cavity.

The mode of origin of the lymphatics is peculiar. The superficial lymphatics are subperitoneal and are connected with spaces or canals in the general connective tissue of the liver. The deep lymphatics are supposed to originate by perivascular canals surrounding the blood-vessels of the lobules, which are connected with vessels in the walls of small branches of the hepatic and portal veins, afterward surrounding the larger vessels.

Mechanism of the Secretion and Discharge of Bile.—In its anatomy the liver differs greatly from other glandular organs, both secretory and excretory. The liver-cells are not enclosed in ducts, but are surrounded by a plexus of exceedingly small vessels which undoubtedly receive the bile as it is formed. The liver, also, is supplied with both venous and arterial blood, the venous blood largely predominating. In addition it is now recognized that the bile