THE DEVELOPMENT OF THE LOBUS QUADRATUS OF THE LIVER, WITH SPECIAL REFERENCE TO AN UNUSUAL ANOMALY OF THIS LOBE IN THE ADULT.

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IN view of the interest associated with the modifications which the lobes and the fissures of the human liver have undergone during the process of evolution, any specimen which would appear to throw light on the problem deserves the closest examination. In the past much of our knowledge has been derived from a study of the anatomy of the organ in the fœtus, in man's nearest allies—the anthropoid apes, and in other more generalised forms. In recent years, too, much has been done to trace the phylogenetic and ontogenetic development of the lobes and fissures of the liver in human and other embryos, and in the well-known publications of A. Thomson (1), Mall (2), Ruge (3), Rex (4), Bradley (5), de Burlet (6), and others, not only has the development of the lobes and fissures received attention, but also the arrangement of the vascular system within the organ during its early stages of growth, and in the adult.

Apart from de Burlet's publication I have not, however, been able to find any special reference to the development of the lobus quadratus in the human liver, or to its influence on the fossæ on either side of it. It is to these points more particularly that I wish to direct attention, since it is generally held that the lobus quadratus is merely a quadrilateral area of the visceral surface of the liver, bounded by certain fossæ, and of no comparative morphological interest. It was the apparent absence of this lobe in a specimen obtained from the practical anatomy rooms in this University that suggested an investigation as to when and how it appeared in the normal human liver. As a matter of fact, a small tubercle was present in this liver, which, after comparison with the models of the liver from early embryos, was clearly the representative of the lobus quadratus. It will be convenient if this specimen be briefly described before proceeding with the account of the models which have been made to explain the anomaly.

The specimen was obtained from a male subject, aged 60 years, the cause of death being certified as bronchitis. On the visceral surface of the organ (fig. 1), the division into right and left lobes is indicated ventrally by a deep cleft occupied by the gall-bladder. The lobus Spigelii and the pro-

cessus caudatus are well marked and distinct, and it is noteworthy that the former is larger than usual and has a form closely resembling that found in a 11·25 mm. embryo. Of the fissures four are clearly defined: (1) the right lateral, (2) the fissure limiting ventrally the processus pyramidalis, (3) the fissure partly limiting the processus caudatus, and (4) a deep depression—the fossa for the ductus venosus. On pulling the gall-bladder—the fundus and body of which were entirely surrounded by peritoneum and quite free—downwards and backwards from the fossa (fig. 2),

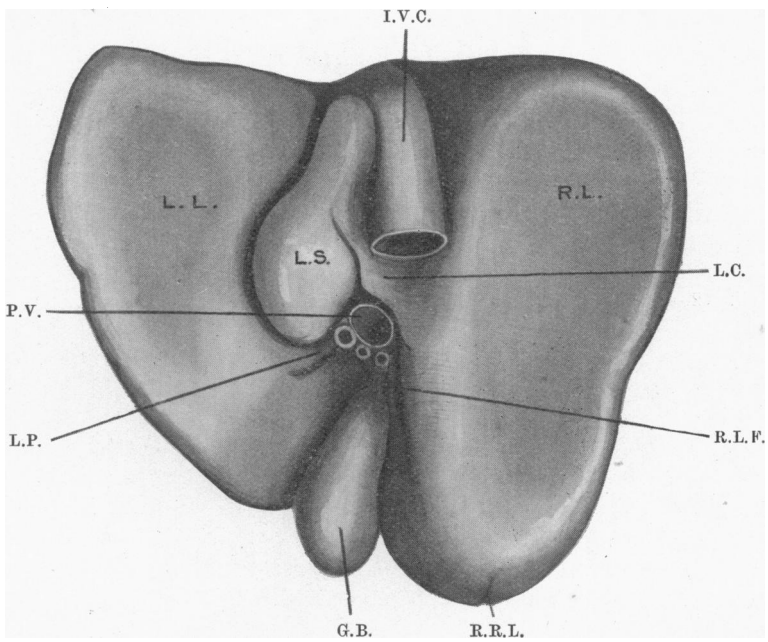

FIG. 1.—Visceral aspect of adult liver with rudimentary lobus quadratus.

three structures stand out clearly: the round ligament, a small rounded tubercle which, as already stated, represents the lobus quadratus, and a connecting ridge of tissue, partly hepatic and partly fibrous, joining the tubercle to the under surface of the left lobe. The significance of this connecting ridge will become evident after an examination of the model of the liver from a 11·25 mm. embryo. In fig. 3 a view of the liver from the front is shown, with the relations to one another of gall-bladder, ligamentum teres, rudimentary quadrate lobe, and an area designated the "uncovered area." This uncovered area is a portion of the right lobe, which would, one imagines, have been subjacent to the lobus quadratus, had the latter been of the normal size.

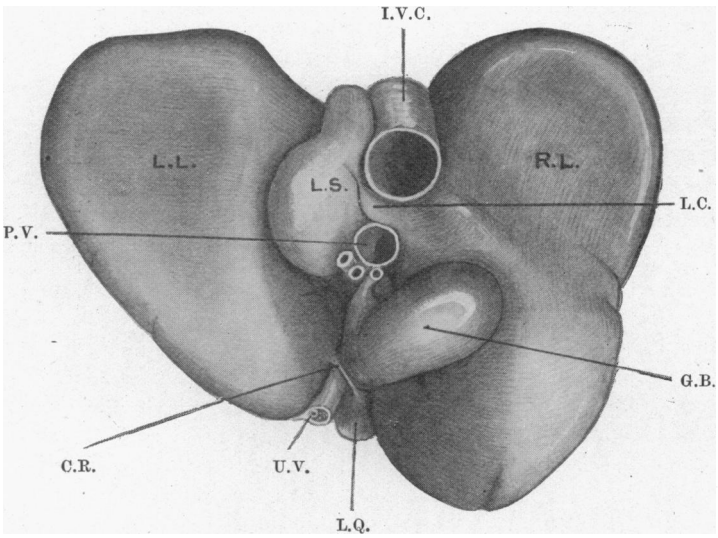

FIG. 2.—The same, with gall-bladder pulled away to show the ligamentum teres and rudimentary quadrate lobe.

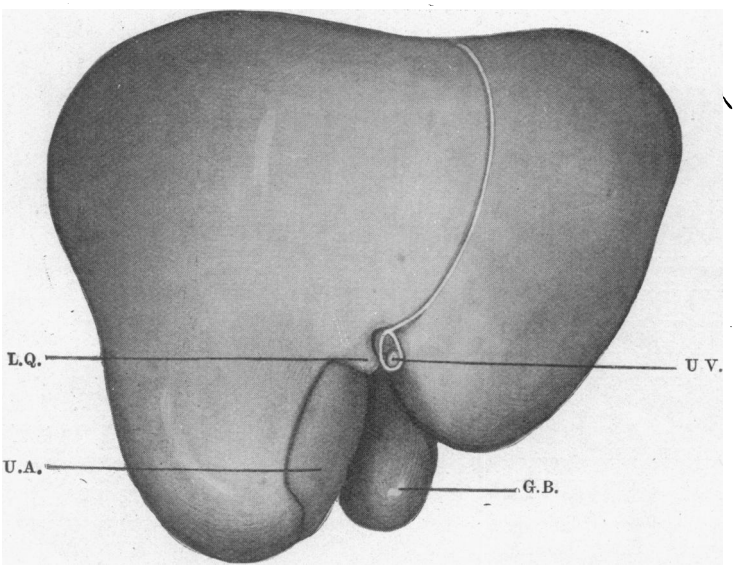

FIG. 3.—The same, seen from the front.

In the generalised mammalian liver we recognise six lobes (Flower) (7), R. central, L. central, R. lateral, L. lateral, L. Spigelii, and L. caudatus, the line of the ligamentum teres being taken in this case as the median plane. The right central lobe lies between the median plane and the right lateral fissure, and the gall-bladder is placed usually somewhere near the middle of the lobe on the visceral surface. It can therefore be said to be composed of two parts: (1) between the fossa for the gall-bladder and the right lateral fissure, and (2) between the fossa for the gall-bladder and the median plane. On referring to fig. 1 it will be seen that in the specimen just described the first part is present and appears quite normal, whilst the second part (fig. 2) is rudimentary and appears as the small rounded tubercle previously referred to.[1] If this interpretation be correct, then it would appear that one portion of the right central lobe, the median (L. quadratus), exhibits an interesting malformation, and it is one of the objects of this paper to show that it is, in fact, in a condition of arrested development. The condition, permanent in this specimen, is transitory in embryos in the fifth week. Moreover, it somewhat resembles the arrangement of parts in the adult pig, in which the quadrate lobule is a relatively small process, and the rest of the right lateral lobe is of large size.

Anomalies in the lobulation of the liver are by no means uncommon, and variations in the size and form of the lobus quadratus have been described by several observers. In Rolleston's (8) first case, in which the right lobe was small and the left lobe large, the lobus quadratus was three times the size of the remainder of the under surface of the right lobe. In a second specimen the gall-bladder was placed below the lobus quadratus instead of being on its right side, whilst in a third case described by him the lobus was rudimentary, being represented by a small strip of liver tissue only. In a case described by Barclay-Smith (9) the gall-bladder was abnormally placed and the lobus quadratus appeared in its usual position, whilst Hochstetter (10) has described and figured two cases of abnormally placed gall-bladder with absence of the lobus quadratus. Ruge's admirable papers (3) are well known, and in them will be found an enormous number of observations referring to abnormalities of the lobes and fissures of the human liver. In one of them he has dealt specially with the abnormal folds, fissures, and accessory lobules found in connexion with the lobus pre-portalis (L. quadratus), but there does not appear to be any case at all resembling the one described above.

It will be convenient to describe next the three wax models of the

[1] That the fossa (or fissure) separating these two parts in fig. 2 is the fossa vesicæ felleæ is shown by the attachment of the neck of the gall-bladder by a mesentery to its floor.

human liver figured in the text, of which the following details may be noted:—

Specimen I. Greatest length of embryo 7 mm. Sections 10 μ. Magnification of model 50 times.

„ II. Greatest length of embryo 11·25 mm. Sections 10 μ. Magnification of model 37·5 times.

„ III. Greatest length of embryo 16 mm. Sections 10 μ. Magnification of model 50 times.

In recent years several models have been made and illustrations published to show the form of the liver in the human embryo. Of these mention should be made particularly of the reconstructions by Bromann (11), Mall (2), and H. M. de Burlet (6). In his monograph on *The Bursa Omentalis*, published in 1904, Bromann shows figures of models of the liver of four human embryos measuring 3 mm., 5 mm., 8 mm., and 11·7 mm. respectively. Mall, in his paper on the *Structural Unit of the Liver* (1906), gives a detailed account of the early development of the liver, and shows illustrations of models of the organ from embryos 24 mm. long, 17½ mm. long, and a second one 24 mm. long. The growth of the quadrate lobe, however, is not specially traced in either of these publications, attention being directed to other matters. The material for de Burlet's paper on "Die äusseren Formverhältnisse der Leber beim menschlichen Embryo" (1910) comprises five specimens, of the following lengths respectively (1) 4·75 mm.; (2) 10 mm.; (3) 18 mm.; (4) 23 mm.; and (5) 32 mm. It will thus be seen that the models figured in the present paper fall into the intervals between the first three of the last-named series, and as the subsequent description will show, it is in embryos about 33 days old, *i.e.* 11·25 mm. long, that the interval on the visceral surface between the gall-bladder and the vena umbilicalis becomes occupied by a mass of liver cells, forming a small rounded tubercle, the forerunner of the lobus quadratus.

Specimen I.

Upon the ventral aspect (fig. 4) is an extensive area, where the liver and septum transversum are united, corresponding to the interval between the two layers of the ligamentum falciforme, which are continuous below round the vena umbilicalis. To the right is the mass of tissue (mesenchyme) in which lies the gall-bladder. This tissue is continuous on the one side with the omentum minus (fig. 5), and on the other with the ligamentum falciforme, the whole forming the so-called ventral mesentery.[1]

[1] In this connexion it is interesting to note that, as Professor A. Keith kindly pointed out to me, the gall-bladder in the cassowary (*Casuarius bennetti*) is situated in the omentum minus.

The right lobe is larger than the left, and the quadrate lobe is not present. From the upper border a large vein emerges, the ductus venosus Arantii,

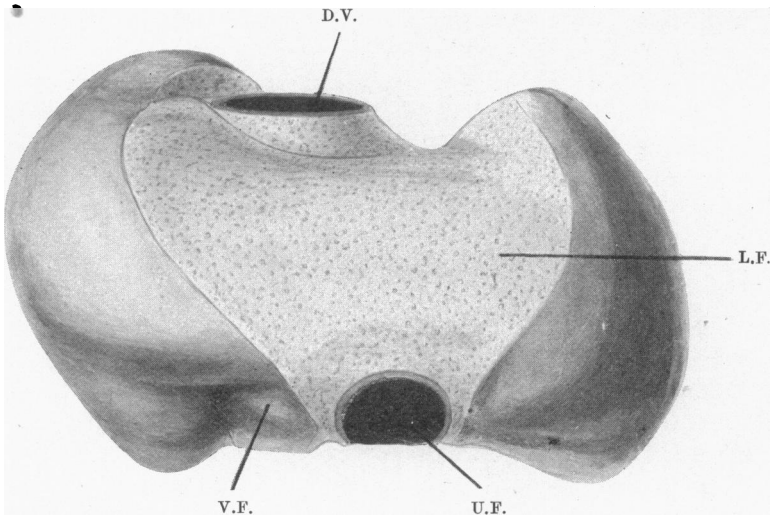

FIG. 4.—Specimen I., 7 mm. Model of liver seen from the ventral aspect. × 50.

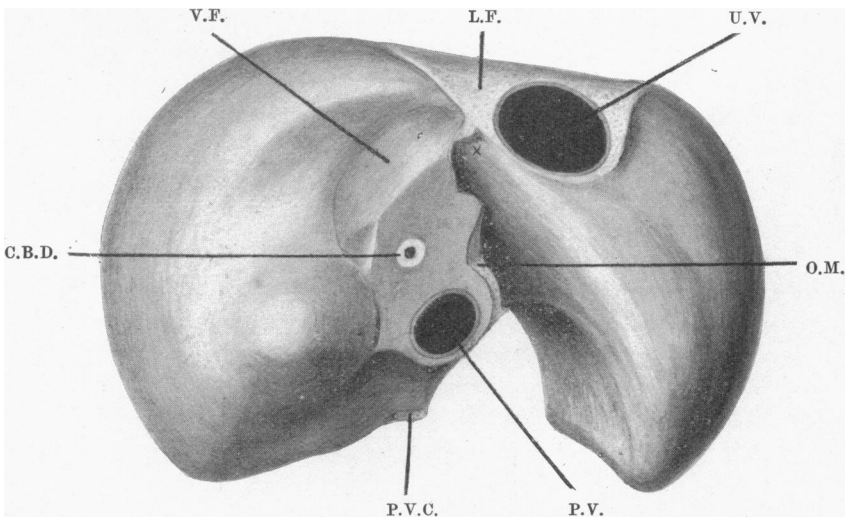

FIG. 5.—Same model as in fig. 4, seen from the caudal aspect. × 50.

which passes through the septum transversum to open into the right auricle. In fig. 5, which shows the model from the caudal aspect, some of

these points are brought out more clearly, and between the gall-bladder and the vena umbilicalis (marked with X) is seen the point where the quadrate lobe begins to differentiate. Dorsally (fig. 6) is the attachment of the omentum minus, with an area corresponding to the future lobus Spigelii on its right, and on the right of this again the plica venæ cavæ (*Nebengekröse*). Between these two mesenteries the pouch of peritoneum which foreshadows the bursa omentalis is formed as a diverticulum. The part between the liver and the alimentary tube is the recessus hepato-entericus, and the blind cranial end, which is prolonged so as to lie between

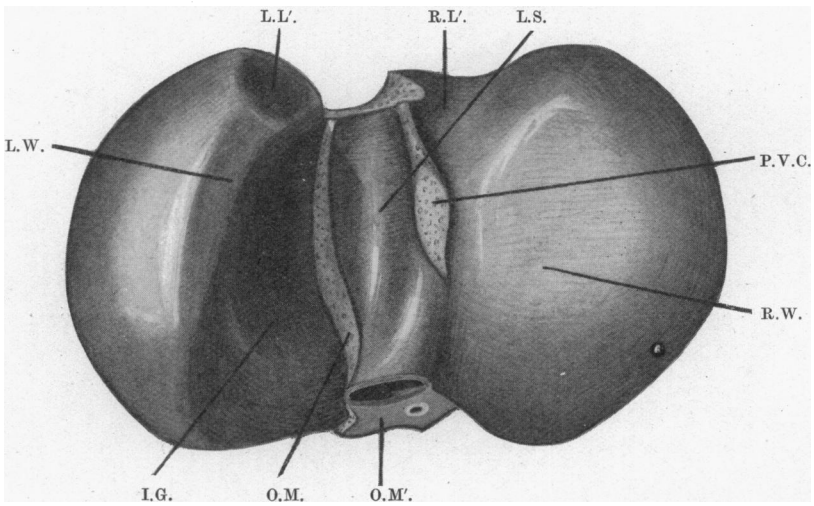

FIG. 6.—The same model as figs. 4 and 5, seen from the visceral surface. × 50.

the right lung bud and the alimentary tube, is the recessus pneumato-entericus. As the portion of the alimentary canal, with which this latter part of the recess is related, is the right side of the future œsophagus, it is sometimes termed the peri- or para-œsophageal cœlom. At the caudal end of the *Nebengekröse* is the foramen epiploicum. Here the general peritoneal cavity comes into communication with the recessus hepato-entericus by a long narrow passage across the back of the liver. The various areas of contact with neighbouring organs are sufficiently indicated in the figure.

SPECIMEN II.

The main features to be observed in fig. 7, which shows the model from the ventral aspect, are (1) the appearance of a small tubercle between the gall-bladder and the vena umbilicalis, the beginning of the lobus quad-

ratus; (2) the consequent pushing of the vena umbilicalis somewhat to the left; and (3) the prolongation of the caudal part of the right lobe into the abdominal cavity as an irregular process which comes into relation with the intestine. The irregular character of this extension is better seen in Specimen III. Mall (2) has drawn attention to a similar disposition in his models, and remarks "that in its growth the liver may atrophy in one portion and expand in another, the aberrant bile-ducts marking those portions of the liver which have been shifted. They are present in those

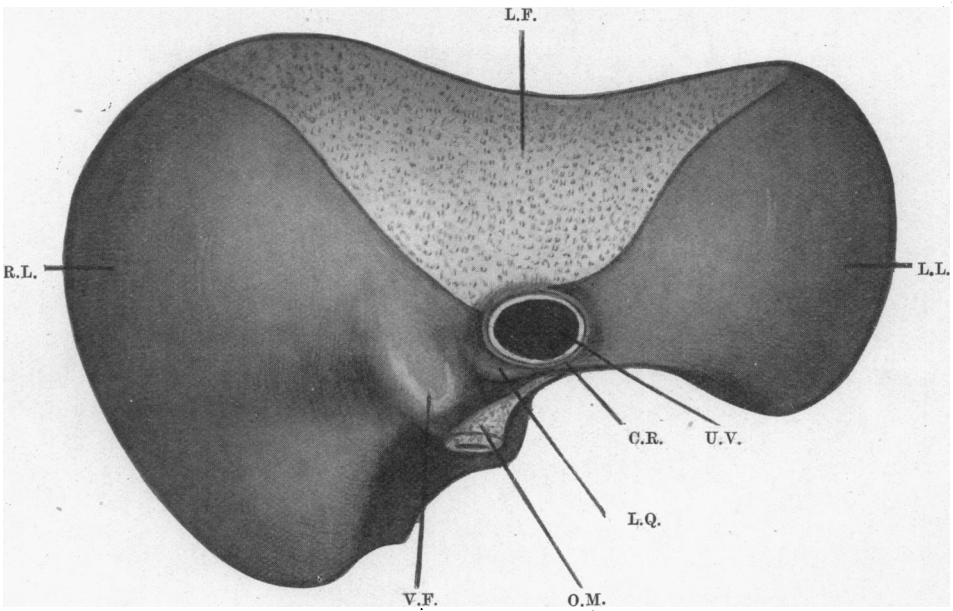

FIG. 7.—Specimen II., 11·25 mm. Model of liver, seen from the ventral aspect. ×37·5.

portions of the liver which had to make way for encroaching organs. Not only must large masses of the liver disappear entirely, but also smaller areas throughout the liver, especially along the trunk of the main vessels, as the liver is growing from its centre towards its periphery."

Although the incisura umbilicalis with the ligamentum falciforme and the fossa sagittalis sinistra are taken as the line of division between the right and left lobes of the liver in the adult, this is not borne out by the developmental history of the organ, or by injection experiments through the portal vein, as Rex's beautiful illustrations show. Nevertheless it is a highly convenient mode of description, and because of this its retention is justified. Cantlie (12) demonstrated in 1897 that a line drawn from the fundus of the gall-bladder to the exit of the hepatic veins divides the liver

into equal portions, the right and left lobes, and illustrated his contention by an interesting pathological specimen in which disease had destroyed the true right lobe, leaving the left lobe intact and greatly hypertrophied, and by other evidence. The embryological data supplied by my models support this view. It has been shown in Specimen I. that the line of attachment of the so-called ventral mesentery appears as a continuous attachment both on the ventral and dorsal aspects of the liver, and that the gall-bladder is placed in mesenchyme which is continuous with the

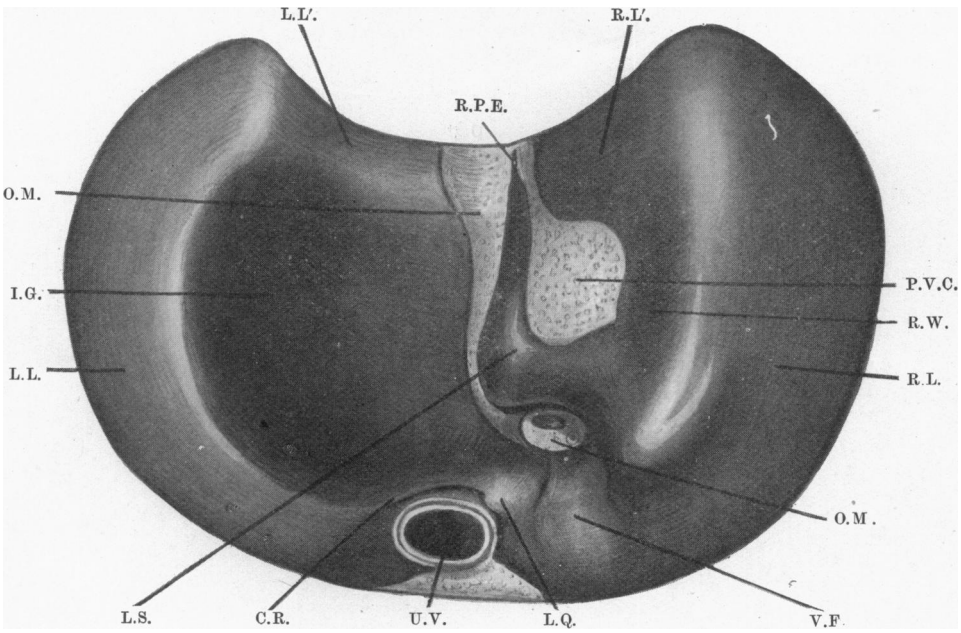

FIG. 8.—Same model as fig. 7, seen from the visceral surface. ×37·5.

omentum minus. The omentum minus is thin until we come to the portal fissure, where it forms a relatively thick mass. Together with the gall-bladder it can be regarded as the true median plane of the liver on the dorsal and caudal aspects. From the mesenchyme enveloping the gall-bladder a fold (fig. 5) runs cranially, as already stated, and joins the ligamentum falciforme, thus continuing the median plane on to the ventral surface. From this point the median plane can be indicated only in an arbitrary way, since, over a large area of the ventral surface, liver and septum transversum are fused together. However, if a line be drawn (fig. 4) from the fold just mentioned to the left border of the ductus venosus, it joins the cranial end of the omentum minus. The area which is marked X in fig. 5

is to the left of the fold, and is clearly a part of the left lobule. This is the preportal area, and indicates the place where the lobus quadratus will begin to develop.

On the dorsal surface (fig. 8) the attachment of the omentum minus is a conspicuous landmark. Further to the right is the plica venæ cava, and the foramen epiploicum in relation to its free caudal end. Between these two mesenteries is the bursa omentalis and the lobus Spigelii. The bursa omentalis at this stage is still called the recessus hepato-entericus, and its blind cranial end the recessus pneumato-entericus. The latter is becoming smaller in this specimen preparatory to being pinched off to form a closed sac, the bursa infracardiaca (see fig. 10), which lies, when present, in the adult just above the diaphragm, between the lung and the right side of the œsophagus. In a specimen of left diaphragmatic hernia in an adult recently examined here in the post-mortem room, this bursa was readily found on the right side, and measured $1\frac{1}{2}$ inches in length.[1] The quadrate lobule is well seen growing ventrally between the vena umbilicalis and the gall-bladder, and connected by a prominent ridge across the vein dorsally to another prominent ridge which forms the lateral boundary of the impressio gastrica on the left lobe. In fig. 2 the corresponding ridge has been noted. Its connexions and its relation to the ligamentum teres make it comparable with the ridge just described.

Specimen III.

Fig. 9 is a view of the liver from the ventral aspect. For a short distance, passing obliquely upwards and to the right from the vena umbilicalis, the two layers of the ligamentum falciforme have come together, or, in other words, the separation of the liver from the septum transversum is here practically completed. The fundus of the gall-bladder still reaches the ventral edge of the liver, and, owing to the development of the lobus quadratus on the left and the squarish mass of liver substance which is elevated between two deep impressions for the small intestine on the right, it now appears to be sunk in a cleft—the beginning of the deep cystic fissure,—which is such a striking feature of the liver of the fœtus towards the middle of the third month. In Specimens I. and II. it will have been noted that the gall-bladder with its investing mesenchyme, whilst being embedded in the under surface of the liver, presents one side, relatively extensive, which is superficial, and it is only as we approach the seventh week that a further sinking in becomes apparent. In reality it is the growth of liver substance on either side of it which in part, at any rate,

[1] The bursa is also well developed in the chacma baboon, and lies between the azygos lobe of the lung and the œsophagus.

produces the appearance of being placed in a cleft. In Mall's embryo 24 mm. (No. 10), *i.e.* about the end of the eighth week, the model of the liver shows the gall-bladder in a deep fossa, and the fundus some distance away from the ventral border.

In his well-known paper on the fissures of the human liver, Professor A. Thomson (1) draws special attention to the disposition of the gall-bladder in the fœtus at the end of the second month. At this period the gall-bladder lies in a well-marked fissure, and the fundus reaches a point about midway between the porta and the ventral border. Further, in 41

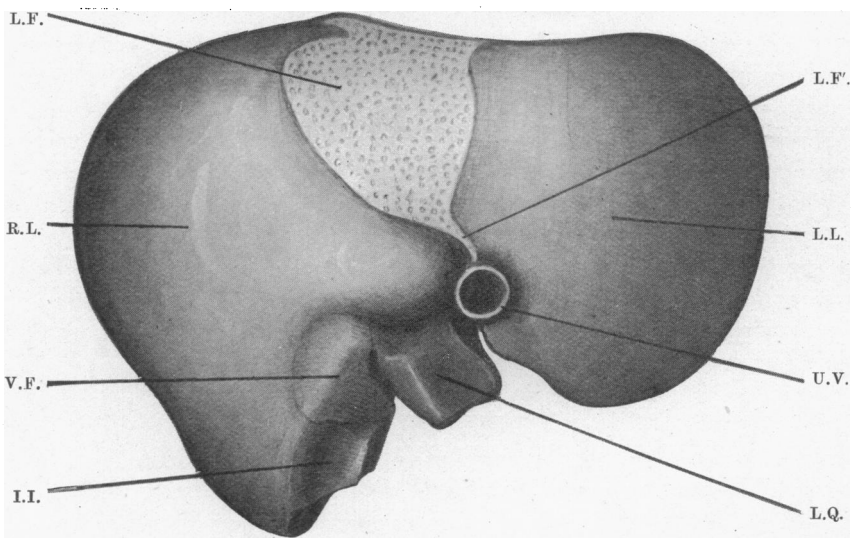

FIG. 9.—Specimen III., 16 mm. Model of liver, seen from the ventral aspect. × 25.

per cent. of all the cases examined, fœtal and adult, a fissure, continuous with the former, extended in front of the fundus as far as the ventral edge of the liver. This corresponds, in fact, with the fissure which Ruge (2) later on designated the fissura precystica. A. Thomson came to the conclusion, and rightly so, as my models show, that the gall-bladder developed in a fissure which extends forwards to the ventral border of the liver. He, however, came to regard the precystic fissure as preceding the appearance of the gall-bladder. From a study of my models it will be evident that up to the end of the sixth week the gall-bladder occupies the whole extent of the fissure. In older specimens it would appear that, owing to the liver and gall-bladder growing at different rates, the gall-bladder soon comes to occupy the position as shown in Mall's models (eighth week),

and in the earliest specimen figured by A. Thomson. If this view is correct, then the fissura precystica would represent the most ventral portion of the early cystic depression.

The lobus quadratus is in Specimen III. a well-developed lobule placed between the gall-bladder and the vena umbilicalis, and projecting ventrally for some distance. Uneven on the ventral surface, smooth and concave on the visceral surface, where it is moulded over the pyloric portion of the stomach, it is attached to the liver above and on its right; elsewhere it is free. A groove running from the gall-bladder on the right to the vena umbilicalis on the left limits it above (fig. 9). On its right edge is a small tubercle, whilst to the left it is flattened. De Burlet in his Object III. finds the tubercle on the left margin, not on the right, and names it the lobulus parumbilicalis. In each case it is probably an area of liver substance growing along a line of least resistance. In the specimen now described it would be, if a name were given to it, a lobulus paravesicalis.

A Thomson found that a small lobule, connected with the lobus quadratus on the visceral surface and adjacent to the fissura umbilicalis, was a common feature in the fœtal livers which he examined. He also met with it in anthropoids, and frequently in the adult human liver. Apparently it corresponds with the lobulus parumbilicalis which de Burlet found in his Object III. Ruge has suggested that some of these small outgrowths in adults are produced mechanically, and are in some way to be associated, causally, with the respiratory movements of the diaphragm. He has also described as a lobulus parumbilicalis a small outgrowth on the *left* lobe adjacent to the fissura umbilicalis A good example of this type is to be seen in the Museum of the Royal College of Surgeons, London.

There is no trace apparently of the right lateral fissure in Specimen III., but the possibility of it coinciding with the fossa of the gall-bladder must be remembered. If the fissure were present, as it is in de Burlet's Object II. (though it is absent in Object III.), then there seems no doubt that this process (fig. 10, L.Q.) would represent the lobus quadratus. When, however, the fissure is absent, the interpretation is more difficult. In such a case it may be regarded as representing a large part, and exceptionally the whole of the right central lobe. The abnormal adult specimen described above demonstrates, if the interpretation there given is right, that the right central lobe can and does develop as two moieties —right and left of the gall-bladder fossa. The right moiety is in fact a part of the right lobe, and has shared in the general growth and expansion of this lobe; on the other hand, the left moiety—lobus quadratus—seems to have some independence, and may be a small process as in the liver of

the adult pig, and in the abnormal specimen described above, or its growth may be precocious as in Specimen III., in the average normal human adult, and in many other mammals. In other words, as C. Bradley (5) has pointed out, the "lobus quadratus" appears to be of little importance in some animals, whilst in others it is evidently of much more moment. What may be the reason of this difference it is difficult to say. But as the lobe receives special vessels from the recessus umbilicalis, it seems reasonable to suppose that the size and number of the vessels will have

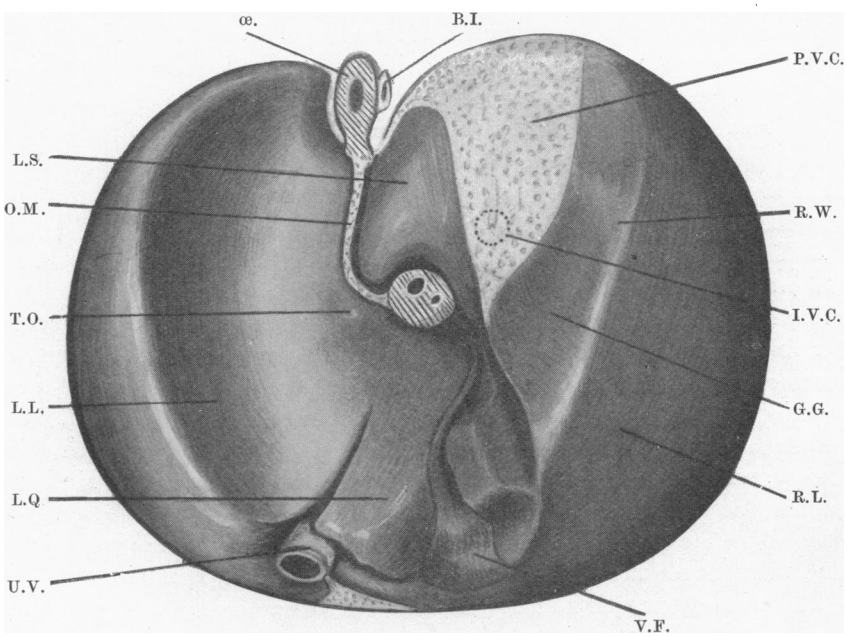

FIG. 10.—Same model as fig. 9, seen from the visceral surface. × 25.

some influence in determining the extent of its development. In this connexion I may quote the observation of Rex (4) in full:—"Ich möchte das Astwerk des R. umbilicalis in ein rechtseitiges und ein linksseitiges Scheiden. Das rechtseitige Astwerk versorgt jenem Abschnitt des mittleren Lappens welcher links von der Fossa cystica zu liegen kommt. Dieser Abschnitt entspricht dem 'Lobus' quadratus der ungelappten Organe." What Rex observed in the adult human organ, F. P. Mall has confirmed in the embryo. At the end of the fifth week vessels radiate from the recessus umbilicalis "into the middle and left lobules of the liver," *i.e.* just at the time when the quadratus lobule makes its appearance.

On the visceral surface (fig. 10) the extent of the preportal area can be

well seen, and a comparison made between it and the corresponding area in Specimen II. (fig. 8). On the right is the gall-bladder, and on the left the umbilical fissure. The latter, whilst extending to the ventral edge of the liver, stops short some distance in front of the porta, owing to the presence of a bridge of liver substance uniting the quadrate to the rest of the left lobe. In Specimens I. and II. the vena umbilicalis lies in a tunnel of liver substance, whilst in Specimen III. it is lying in a deep groove or fossa. The groove is incompletely covered over by the growth of two lips, one being the left lateral border of the quadrate, the other being a part of the left lobule. In Mall's three models, and in three of de Burlet's, *i.e.* in six cases, an open fissure occurred once only. Is the canal in which the vein runs in these cases an extension of the primary tunnel, or has it been formed secondarily by union of the lips over the fissure? Further, is the fissure present in my Specimen III. the result of a breaking down of the floor of a tunnel, or has it been formed by the growth of the lobus quadratus, as this grows from the region of the portal in a ventral direction? It is impossible to answer these questions finally from a study of my small series of models. All I can do is to state what I find in the specimens. The bridge over the fissura umbilicalis near to the porta is apparently primary, and on comparison with fig. 8 it will be seen that it is placed at the original point of junction of lobus quadratus with the left lobule, or, in other words, it indicates the area of the left lobule from which the lobus sprung. On microscopical examination there is no sign of an intervening raphé. The latter might be expected if the bridge had been formed by fusion of two lips. With regard to the fissura umbilicalis itself, it is not possible to speak so definitely. On examining the opposed lips of the fissure, there is a small area over which there is no peritoneum—where, indeed, it looks as if the tissue had recently broken down. This is near the bridge; elsewhere the peritoneum is a definite feature along the lips. One is thus precluded from stating that the fissure is primary in its whole course. On the other hand, it may be that the lips can unite for limited distances and then break down again. Obviously a large series of models about this period are necessary before any definite pronouncement can be made. However, should further investigation show that the open fissura umbilicalis at or about this stage—*i.e.* from five to six weeks—is a "primary" fissure, meaning, by that term, a fissure formed as the lobus quadratus extends ventrally with its left margin free from the beginning, then there would seem good ground for regarding the lobus in man as something more than merely a quadrilateral area. Having these and other distinctive characters, the term "lobus," as applied to it in the consolidated organ such as occurs in man, would then appear to be justified.

Other features to be noted on the visceral surface of Specimen III. are the extensive area free from peritoneum, the plica venæ cavæ, with the orifice for the vena cava shown diagrammatically as it leaves the liver to enter into relation with veins on the posterior body wall. The lobus Spigelli is assuming more the form found in the adult, with a wide notch between the processus papillaris and the processus caudatus. The bursa omentalis extends dorsally behind the lobus Spigelii as far as the cranial limit of this lobe, where the blind end presents an uneven termination. Here are two minor recesses (seen also in Specimen II.), and from the dorsal one of the two the bursa infracardiaca has been pinched off to form the closed sac lying on the right side of the œsophagus, represented much strengthened in the figure, as the wall was too thin to model.

Therefore, although the lobus quadratus is not bounded by "true" fissures, yet, as these models show, it appears as a distinct process which develops into a definite hepatic area. This process grows as an extension of the left lobule, and at a different time and in a different way than the part of the right central lobe between the gall-bladder and the right lateral fissure. It may remain small or develop into a considerable area.

Finally, it may be noted that the pancreas obtained from the subject in which the abnormal liver was found also presented an interesting anomaly. The dorsal and ventral masses of the pancreas had failed to unite in the usual way; the duct of the dorsal pancreas was the main duct, and opened on a normal papilla minor, and the duct of the ventral pancreas opened, in common with the ductus choledochus, on the papilla major. No anastomosis between the two ducts could be traced.

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EXPLANATION OF FIGURES.

B.I. bursa infracardiaca.
C.B.D. ductus choledochus.
C.R. connecting ridge from lobus quadratus to left lobe.
D.V. ductus venosus Arantii.
G.B. gall-bladder.
G.G. area of contact, genital gland.
I.G. impressio gastrica.
I.I. impressio intestinalis.
I.V.C. inferior vena cava.
L.C. processus caudatus.
L.F. area of fusion between septum transversum and liver.
L.F'. ligamentum falciforme.
L.L. left lobe of liver.
L.L'. area of contact, left lung.
L.P. processus pyramidalis.
L.Q. lobus quadratus.
L.S. lobus Spigelii.
L.W. area of contact with Wolffian body.
O.M. omentum minus.
œ. œsophagus.
O.M'. thick mass of mesenchyme continuous with omentum minus.
P.V. vena porta.
P.V.C. plica venæ cavæ.
R.L.F. right lateral fissure.
R.L. right lobe of liver.
R.L'. area of contact, right lung.
R.P.E. recessus pneumato-entericus.
R.R.L. marginal rest of right lateral fissure.
R.W. area of contact, right Wolffian body.
T.O. tuber omentale.
U.A. uncovered area of right lobe.
U.V. vena umbilicalis sinistra.
V.F. mesenchyme surrounding gall-bladder.