

Mesenteric and peritoneal anatomy

J. CALVIN COFFEY, PETER DOCKERY, BRENDAN J. MORAN, AND BILL HEALD

Aim	11	<i>White line of Toldt</i>	22
Introduction	11	<i>Mesosigmoid</i>	25
Mesenteric anatomy	14	<i>Mesosigmoid: Transverse axis</i>	25
<i>Mesenteric root region</i>	14	<i>Mesosigmoidal angles</i>	25
<i>Mesentery in the right iliac fossa</i>	14	<i>Congenital adhesions</i>	26
<i>Small intestinal mesentery</i>	14	<i>Mesorectum</i>	28
<i>Right mesocolon</i>	16	<i>The peritoneal reflection</i>	28
<i>Adipovascular and avascular mesenteric regions</i>	16	<i>Flexural anatomy</i>	34
<i>Hepatic flexure</i>	17	<i>Duodenojejunal and ileocecal flexures</i>	34
<i>Transverse mesocolon</i>	20	<i>Hepatic flexure</i>	34
<i>Relationship between transverse mesocolon and greater omentum</i>	20	<i>Splenic flexure</i>	38
<i>Middle colic adipovascular pedicle</i>	20	<i>Colosigmoid and rectosigmoid flexures</i>	38
<i>Splenic flexure</i>	20	<i>Mesenteric conformation in general</i>	38
<i>Left mesocolon</i>	20	<i>Future directions</i>	38
<i>Inferior mesenteric adipovascular pedicle</i>	22	<i>Summary</i>	38
		<i>References</i>	38

There is pleasure in recognising old things from a new viewpoint.

Richard Feynman

AIM

The aim of this chapter is to summarize mesenteric and peritoneal structure in light of recent advancements in our understanding of both. A second aim is to indicate the relevance of both to current clinical practice.

INTRODUCTION

The magnification afforded by endoscopic techniques coupled with the resolution of modern displays has revolutionized our appraisal of living anatomy. Nevertheless, reference anatomic and embryologic texts continue to present classic anatomic descriptions. In keeping with this, classic descriptions of mesenteric and peritoneal anatomy continue to dominate reference texts. Sir Frederick Treves comprehensively described the human mesentery and peritoneum in a study spanning 100 cadavers in 1889 (Figure 2.1) [1].

His descriptions were first presented in a series of classic lectures and thereafter integrated in most reference anatomic, embryologic, surgical, and radiologic texts [1–11]. Treves laid down his understanding of mesenteric and peritoneal anatomy at a time when anatomic descriptions were providing a formal basis for safe and anatomic surgery (Figure 2.1) [1,9].

Treves correctly described the small intestinal mesentery as having a “mesenteric root” at the origin of the superior mesenteric artery. According to his descriptions, the small intestinal mesentery then fans out from the duodenum to terminal ileum. At the gastrointestinal margin, the mesentery elongates considerably. This contrasts considerably with the length of the “attachment” to the posterior abdominal wall. As per Treves, the mesenteric attachment extends across the posterior abdominal wall from duodenojejunal flexure to ileocecal level. As it does so, it obliquely traverses the aorta and inferior vena cava (Figure 2.2a and b) [1,12].

Treves described the right and left mesocolon as being absent in the majority of cases. If an anomalous right or left mesocolon was present, then this would be seen to attach in regions corresponding closely to the attachment of the right or left colon (Figures 2.1 and 2.2a,b). For example, the attachment of the right mesocolon corresponds to that of

Not for distribution -
Property of Taylor & Francis Group

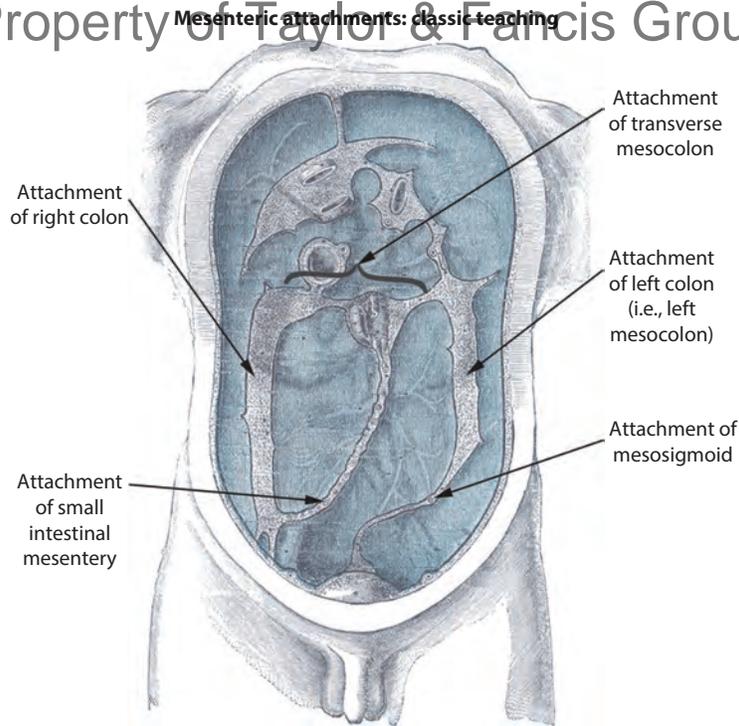


Figure 2.1 Schematic demonstrating the attachments of the mesentery as depicted by Treves. The small intestinal mesentery attaches along a diagonal line crossing the posterior abdominal wall from the fourth part of the duodenum to the ileocecal junction.

Mesentery and attachments: classic vs. current

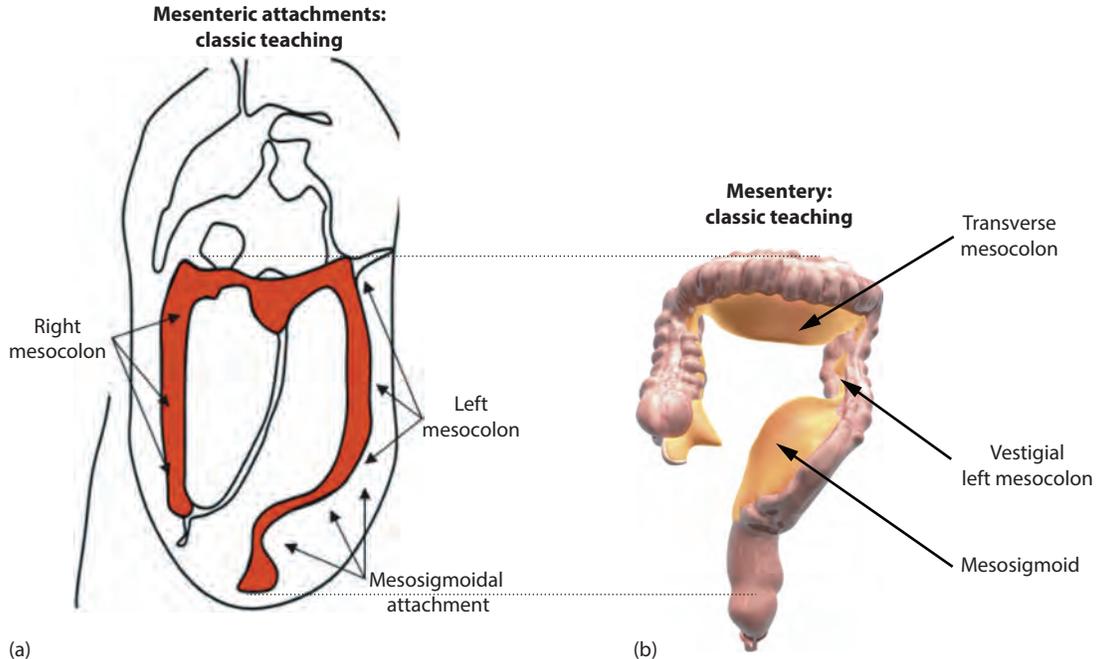


Figure 2.2 (a) Schematic summarizing Treves' descriptions of the attachment of the mesentery and mesocolon (red region). As per Treves, when an anomalous right mesocolon is present, it attaches along a vertical trajectory from the right iliac fossa to the hepatic flexure. The transverse mesocolon attaches along a horizontal line that traverses the upper part of the abdomen. When an anomalous left mesocolon is present, it attaches along a vertically oriented region, while the mesosigmoid attaches along a v-shaped line. The attachment of the mesorectum was not defined by Treves. (b) 2.5D snapshot from a 3D digital sculpture of the mesocolon (yellow) as depicted by Treves. The small bowel and associated mesentery have been conceptually removed for clarity. The right and left mesocolon are vestigial or near absent, while the transverse and sigmoid regions are substantial. The mesorectum is absent. Overall, the mesentery is fragmented and discontinuous. (Continued)

Not for distribution -

Property of Taylor & Francis Group

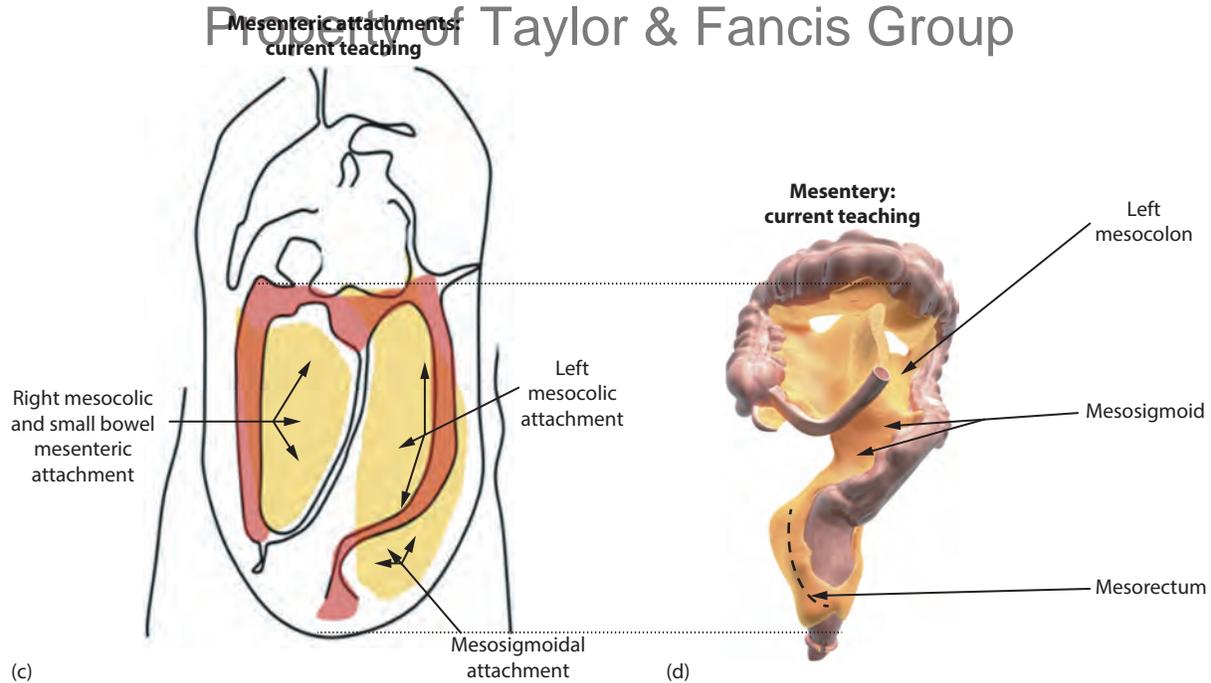


Figure 2.2 (Continued) **(c)** Schematic summarizing the attachment of the mesocolon (yellow region) as described by Toldt. The right mesocolon is always present and attaches over a broad region on the right side of the posterior abdominal wall. The left mesocolon is always present and attaches over a similarly broad region on the left side of the abdomen. The mesosigmoid is a distal continuation of the left mesocolon. **(d)** (See also QR 1/1.) 2.5D snapshot from a 3D digital sculpture of the mesocolon (yellow) as it is currently understood. The distal small bowel and associated mesentery have been retained in the illustration. The right and left mesocolon are substantial and continuous with adjacent regions of mesentery. The right mesocolon is continuous with the small intestinal mesentery medially and with the transverse mesocolon at the hepatic flexure. On the left, the left mesocolon, mesosigmoid, and mesorectum are similarly continuous. Overall, the mesentery is continuous from root region to the mesorectum.

the right colon, extending along a vertical orientation from the right iliac fossa to the subhepatic region. The attachment of the left mesocolon corresponds to that of the left colon, extending from the subsplenic region to the left iliac fossa (Figures 2.1 and 2.2a, b) [1]. To the present, many reference texts continue to describe these regions as the attachments of the right and left colon or mesocolon [3–5,13,14].

Treves' description of the transverse and sigmoid mesocolon was similar to that of the small intestinal mesentery. He described the transverse mesocolon as being "attached" along a horizontal trajectory to the upper part of the posterior abdominal wall (Figure 2.2a and b). He described the mesosigmoid as attaching to the posterior abdominal wall in the left iliac fossa. The attachment followed an inverted V shape, with the apex of the "V" providing an important landmark overlying the left ureter (where this crosses the bifurcation of the common iliac artery) (Figure 2.2a and b) [2,4,6,14,15].

The mesosigmoid, transverse mesocolon, and small intestinal mesentery were described as mobile, while the right and left mesocolon were described as absent (or vestigial) [4,6,8,9,13,14]. According to this, the mesenteric organ is fragmented (present in some regions, absent in others). If this description were correct, then one would expect to identify start and end points for each mesenteric region. These were never described, a point that is explained by their absence in the first place [10].

A question arises as to how Treves' generated his findings. His descriptions can be explained if one were to conceptually slice through the posterior region of the abdomen in a coronal plane, that is, (1) posterior to the right and left colon and (2) at the level where the small intestinal mesentery attaches to the posterior abdominal wall (Figures 2.1 and 2.2b). Doing this would generate the impression of a series of mesenteric insertions for the small intestine, transverse, and sigmoid mesocolon [10,16,17]. In addition, it would fail to identify the right and left mesocolon as well as the attached region of the mesosigmoid and mesorectum.

In 2012, our group refuted the findings of Treves demonstrating mesenteric continuity from small intestinal mesentery to mesorectal level (Figure 2.2c and d) [10]. This led to a general overhaul of our understanding of mesenteric anatomy [2]. We found that the small intestinal mesentery attaches to the posterior abdominal wall and extends laterally as the right mesocolon (Figures 2.2c, d, 2.3, 2.4). Along the line of attachment, a peritoneal reflection extends from the small intestinal mesentery to the posterior abdominal wall and bridges the gap between the two. The line along which the small intestinal mesentery attaches to the posterior abdominal wall (and continues laterally as the right mesocolon) extends diagonally from the duodenojejunal junction to the ileocecal level.

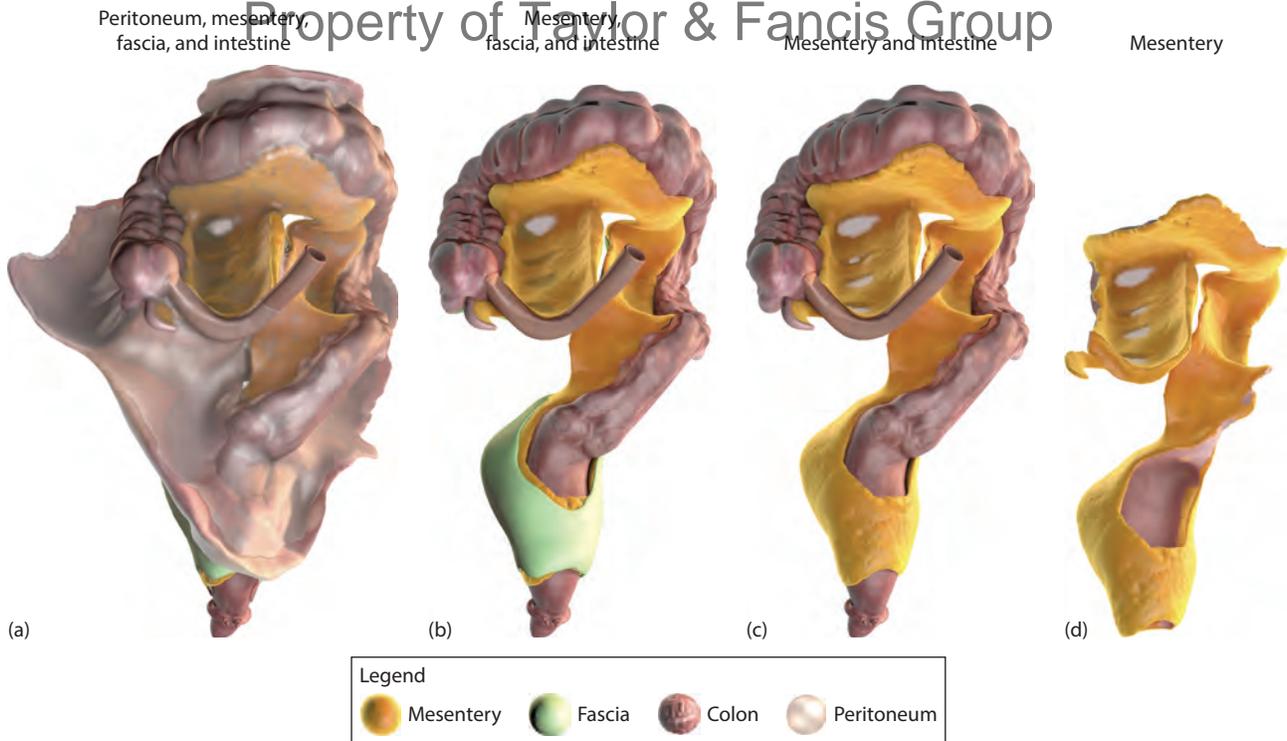


Figure 2.3 (a) (See also QR 2/1.) 2.5D snapshot from a 3D digital sculpture of the mesentery, associated peritoneal reflection, and large bowel. Just as the mesentery is contiguous so too is the peritoneal covering and associated large bowel. (b) Same model as in (a) but with peritoneum removed. (c) Same model as in (b) but with peritoneum and fascia removed. (d) Same model as in (c) but peritoneum, fascia, and colon removed.

MESENTERIC ANATOMY

Mesenteric root region

The following is a description of mesenteric anatomy as it is currently understood. Before commencing, it is important to define the terms “attachment” and “suspension.” “Attachment” refers to the flattening of the mesentery against the posterior abdominal wall so the mesentery becomes apposed to the retroperitoneum. As will be seen from the following, the mesentery does not “insert” into the posterior abdominal wall in any location. “Suspension” refers to the suspension of the mesentery to the posterior abdominal wall at vascular points of suspension.

The mesentery fans out from the “root region” where the superior mesenteric artery suspends it to the posterior abdominal wall. This was correctly described by Treves [1]. From this point, the mesentery expands, like a Chinese fan. In some regions, it is mobile while in others it is attached to (i.e., flattened against) the posterior abdominal wall. The continuous mesentery spans the intestine from duodenojejunal to anorectal junction.

Mesentery in the right iliac fossa

In the right iliac fossa, the mesentery tapers toward an apex at the ileocecal junction. This region of mesentery can be

arbitrarily called “the ileocecal mesenteric confluence,” a term that is descriptively useful (see section “Flexural anatomy”). A fatty appendage (the *mesoappendix*) extends from the under surface of the ileocecal mesenteric confluence (Figure 2.5a through c). Retromesenteric origin of the mesoappendix explains how the appendix often occupies a retrocecal location (the clinical relevance of this will be expanded on in Chapter 7) (Figure 2.5a through c). Treves correctly described the mesoappendix as originating from the under-surface of the mesentery in the ileocecal region [1,12].

The ileocecal mesenteric confluence is a substantive tissue mass separated from the retroperitoneum by Toldt’s fascia. When the abdomen is first entered, the confluence is obscured from direct view by a peritoneal reflection. This is an extension of the peritoneal reflection at the base of the small intestinal mesentery. Regions of the peritoneal reflection are of surgical and pathobiologic importance, as mobilization of the mesentery requires their division to permit access to surgical planes. In addition, they act as a mechanical barrier to the spread of submesenteric disease (see Chapters 6 and 7) [18].

Small intestinal mesentery

Though the base of the small intestinal mesentery (i.e., where it continues as the right mesocolon) is short, the intestinal margin of the small intestinal mesentery is approximately 4 ft in length [10,18]. As a result, the mesentery

Not for distribution -
Property of Taylor & Francis Group

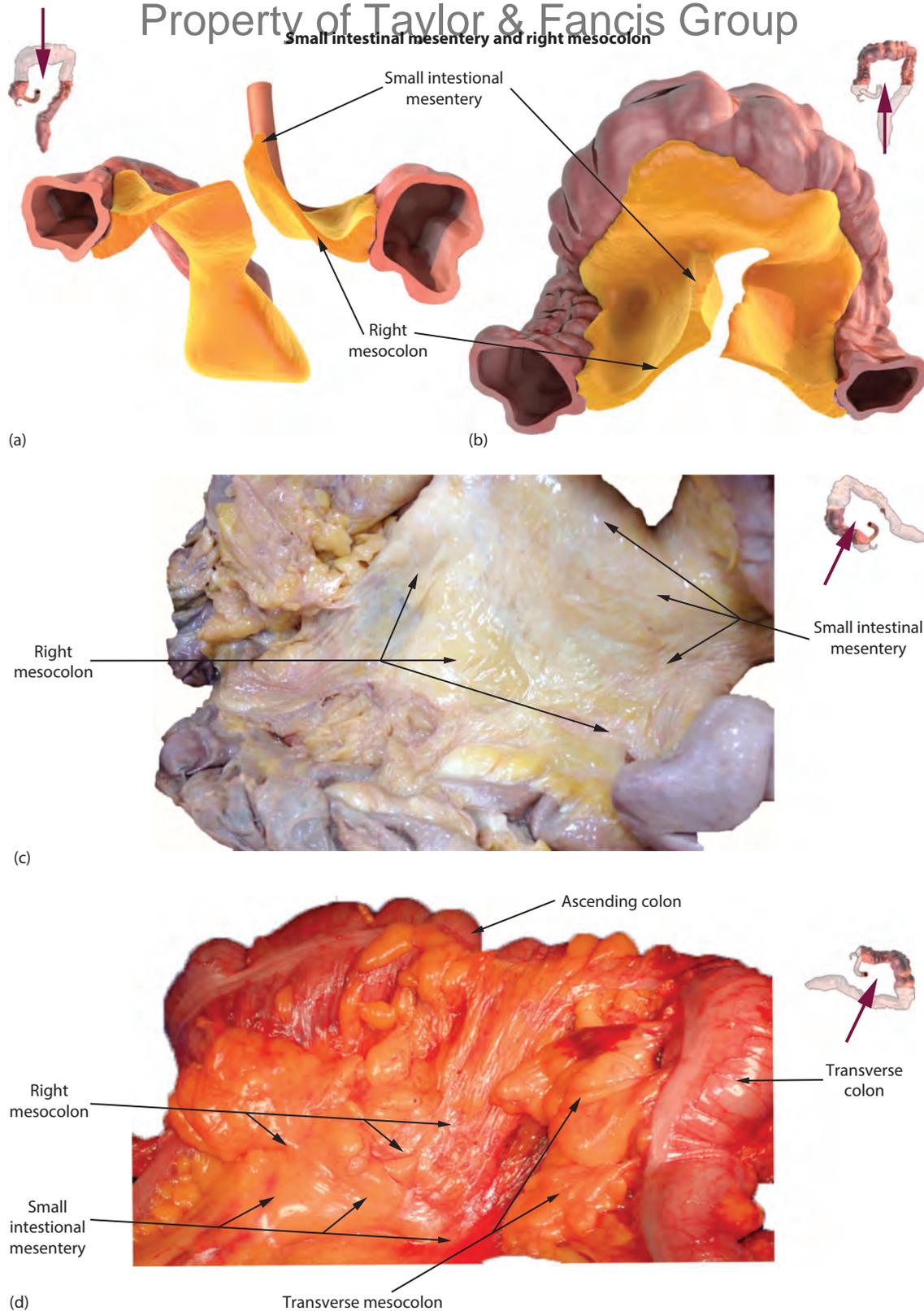


Figure 2.4 (a) (See also QR 3/1.) 2.5D snapshot of a 3D digital sculpture of the small bowel mesentery and right mesocolon. The model has been sectioned and the point of view is looking from above downward. The small intestinal mesentery is continuous with the right mesocolon. (b) (See also QR 4/1.) The model used in (a) has been sectioned through at the same level, but the point of view now is from below upward. The small intestinal mesentery is continuous with the right mesocolon. (c) Cadaveric demonstration of continuity between the small bowel mesentery and right mesocolon. (d) Intraoperative image depicting mesenteric and mesocolic continuity.

Not for distribution - Property of Taylor & Francis Group

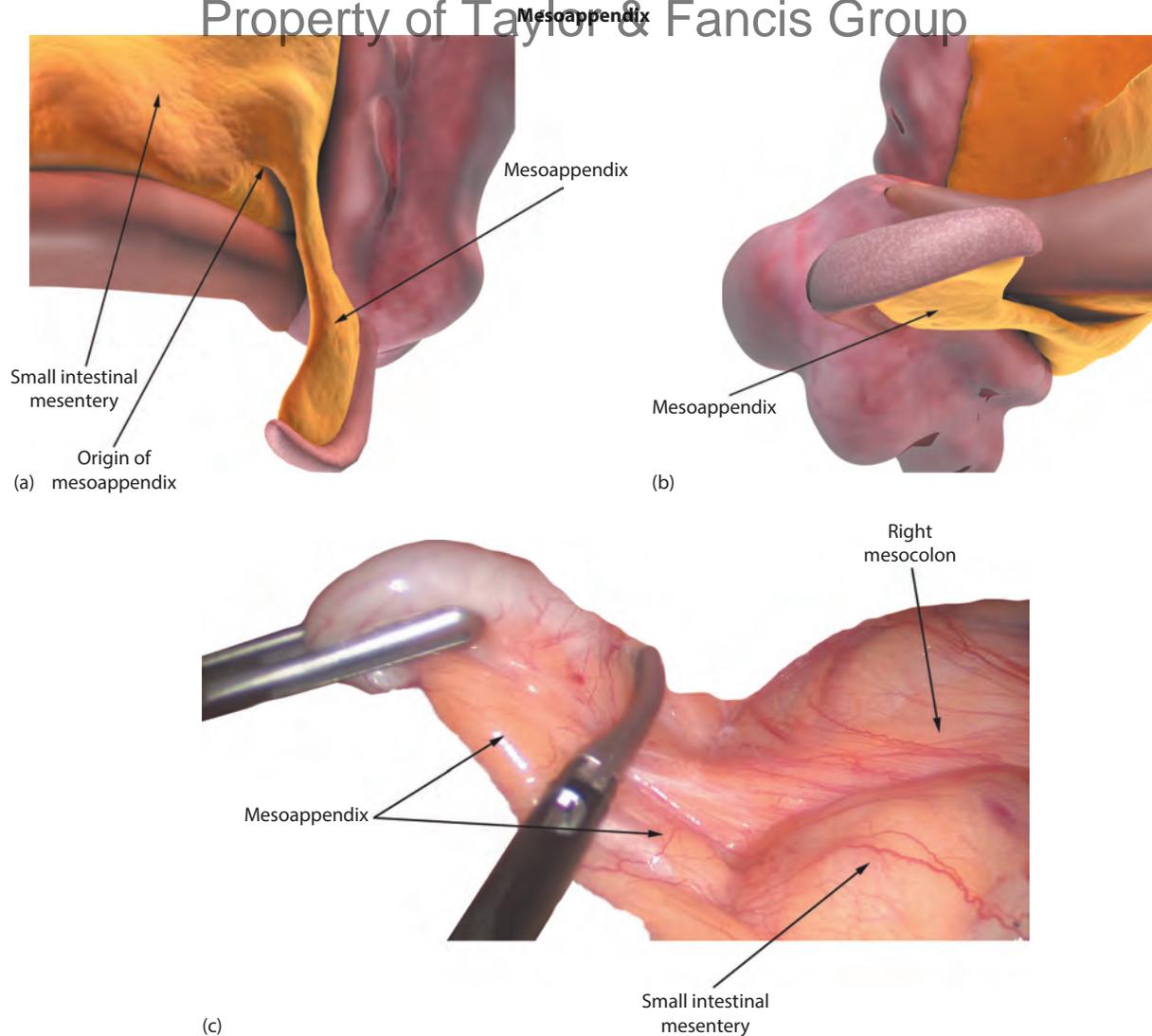


Figure 2.5 **(a)** 2.5D snapshot of a 3D digital sculpture of the mesentery at the ileocecal region. The mesoappendix arises from the undersurface of the mesentery. Given this origin, it is not surprising that the appendix frequently takes up a retrocecal position. **(b)** Digital model of mesentery indicating how the mesoappendix arises as an appendage, from the undersurface of the ileocecal mesenteric confluence. **(c)** Intraoperative image demonstrating the origin of the mesoappendix from the ileocecal region of mesentery.

elongates considerably from its base (Figure 2.6). In the undisturbed abdomen, it is packed in a concertina-like manner and readily adopts this position once returned intraperitoneally [10,18]. The disparity in length between the base of the mesentery and the mesenteric border of the intestinal tract means that the small intestinal mesentery cannot be unfolded and flattened out in its entirety (Figure 2.6).

Right mesocolon

In contrast to the small intestinal mesentery, the right mesocolon has a smaller surface area and volume. It extends from the base of the small intestinal mesentery to the mesenteric border of the right (ascending) colon. The right mesocolon is a substantive mesenteric region (Figure 2.4)

that is attached to (i.e., flattened against) the posterior abdominal wall but kept anatomically separate by Toldt's fascia (Figures 2.7a,d and 2.8a) [2,10,16]. Although this anatomic arrangement is exploited in safe colorectal surgery, these concepts have been adopted in one reference text, i.e. Gray's Anatomy [2].

Adipovascular and avascular mesenteric regions

In the region of the ileocolic vessels, increased mesenteric adiposity creates a near constant *adipovascular pedicle* (Figure 2.8b). Similar mesenteric thickening occurs throughout the mesocolon in association with major vessels such as the right, middle, and left colic vessels and

Not for distribution - Property of Taylor & Francis Group

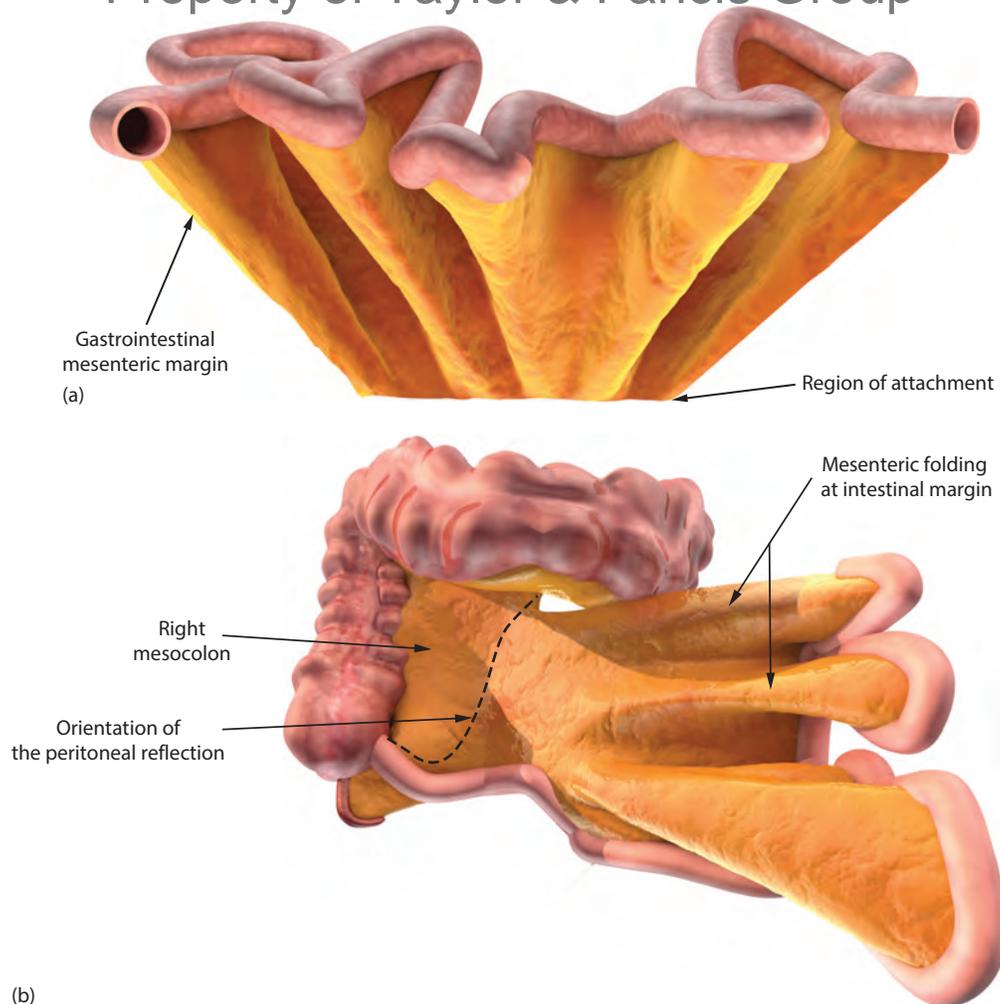


Figure 2.6 **(a)** 2.5D snapshot of a 3D digital sculpture of the small bowel and associated mesentery. At the base of the small bowel mesentery (i.e., where it continues as the right mesocolon) it is short in diagonal extent (dotted line). At the intestinal margin it elongates extensively in tandem with the small bowel. Together with the associated bowel it is compactly plicated into a finite intraperitoneal space. **(b)** (See also QR 1/1.) 2.5D snapshot of a 3D digital sculpture demonstrating continuity between the small intestinal mesentery and right mesocolon. The small bowel mesentery elongates extensively at its intestinal margin.

also at the inferior mesenteric/superior rectal artery. Adiposity increases around the marginal artery and thus along the full longitudinal extent of the intestinal margin of the mesentery. Between adipovascular pedicles, the mesentery thins out considerably and in some instances adipose tissue is absent (except in obese patients). These are the largely avascular *interpedicular regions*. They are of surgical importance as they are regions in which mesentery can be safely divided with minimal blood loss (Figure 2.8b) [18–21].

At the intestinal margin of the mesocolon (but not the small intestinal mesentery), mesenteric fat is similar to that of appendices epiploicae (Figure 2.9a and b). The latter arise from the serosa of the colon and are sufficiently turgid as to permit grasping and retraction using robotic or laparoscopic

instrumentation. In contrast, mesenteric fat is soft, friable, and easily bleeds (when denuded of overlying peritoneum) and as a result it is not suitable for direct grasping during laparoscopic or robotic surgery (if the surgeon wishes to avoid troublesome bleeding). Importantly, epiploical fat can be readily differentiated from mesenteric fat as it has a lobular appearance. In contrast, the surface of the mesentery is smooth and gently contoured.

Hepatic flexure

At the hepatic flexure, the right mesocolon narrows, separates from the abdominal wall at its intestinal margin, and continues as the hepatic component of the transverse mesocolon (Figures 2.7b and 2.10). Thus, the mesenteric

Not for distribution -

Property of Taylor & Francis Group

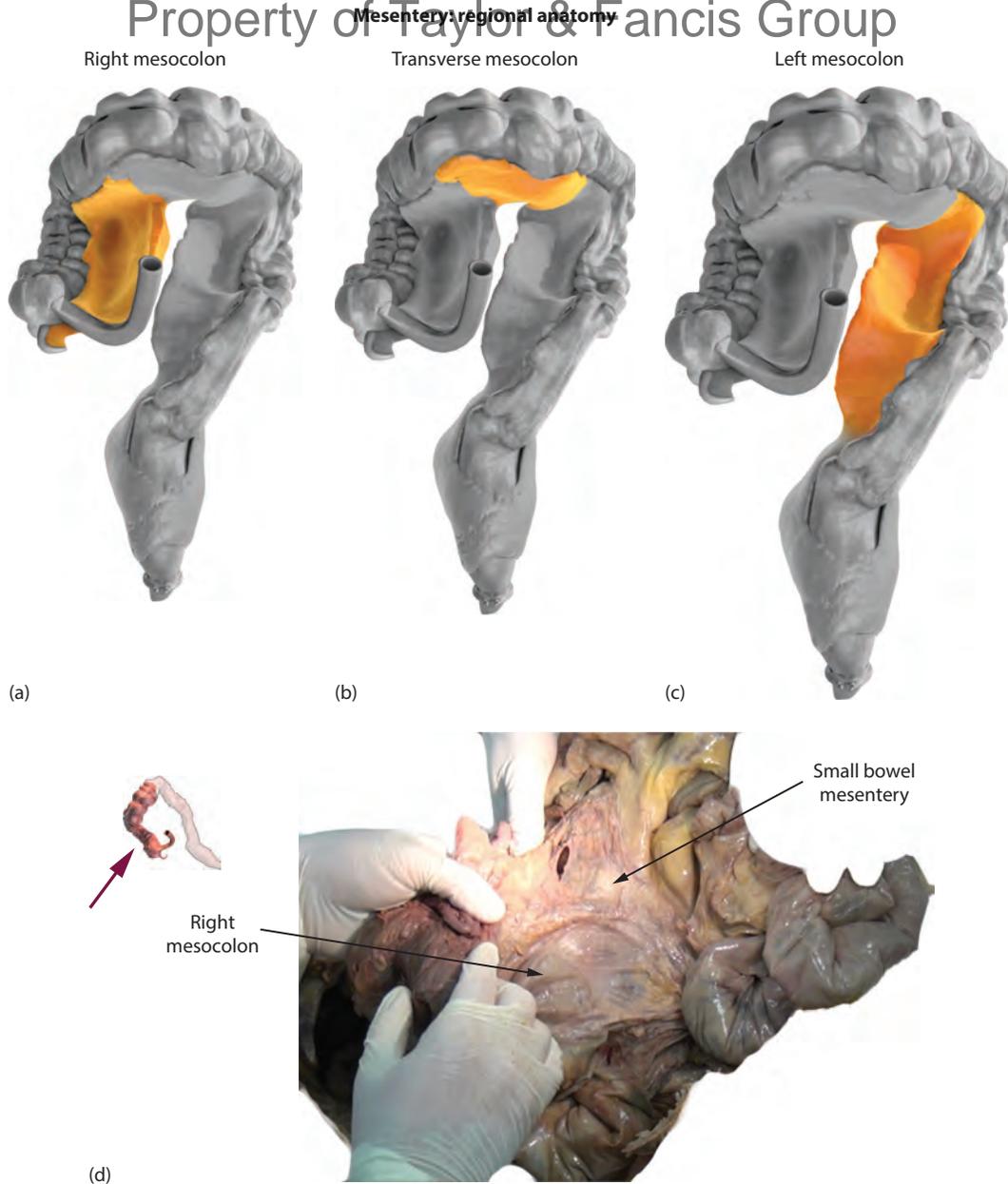


Figure 2.7 **(a–c)** (See also QR 1/2 and 3.) 2.5D snapshot of a 3D digital sculpture in which adjacent mesocolic regions are highlighted in yellow. The mesentery is an adipose structure that lacks distinct boundaries between contiguous zones. As a result, the optimal means of demonstrating zones is through color coding. In each snapshot, nonhighlighted mesentery is colored gray and the small intestinal mesentery has been removed to highlight the mesocolon. **(d)** Cadaveric example of the right mesocolon after it has been fully mobilized intact, from the retroperitoneum.

component of the hepatic flexure is a confluence between right and transverse mesocolon [18,20].

The mesenteric component of each flexure is best described in terms of radial and longitudinal axes. The radial axis of the hepatic flexure extends radially from the middle colic vascular pedicle to the intestinal margin of the mesentery. As it does so, the mesentery changes from attached (to the posterior abdominal wall) to nonattached and thus mobile (Figure 2.12a). The longitudinal axis

extends longitudinally from the right mesocolon to the transverse mesocolon. At the right mesocolic pole of the longitudinal axis, the mesentery is fully attached across its breadth. At the transverse mesocolic pole of the longitudinal axis, the mesentery is attached centrally but mobile at the intestinal margin. Thus, the mesenteric component of the hepatic flexure undergoes considerable conformational changes. These have implications for surgical mobilization and resection of the hepatic flexure.

Not for distribution - Property of Taylor & Fancis Group

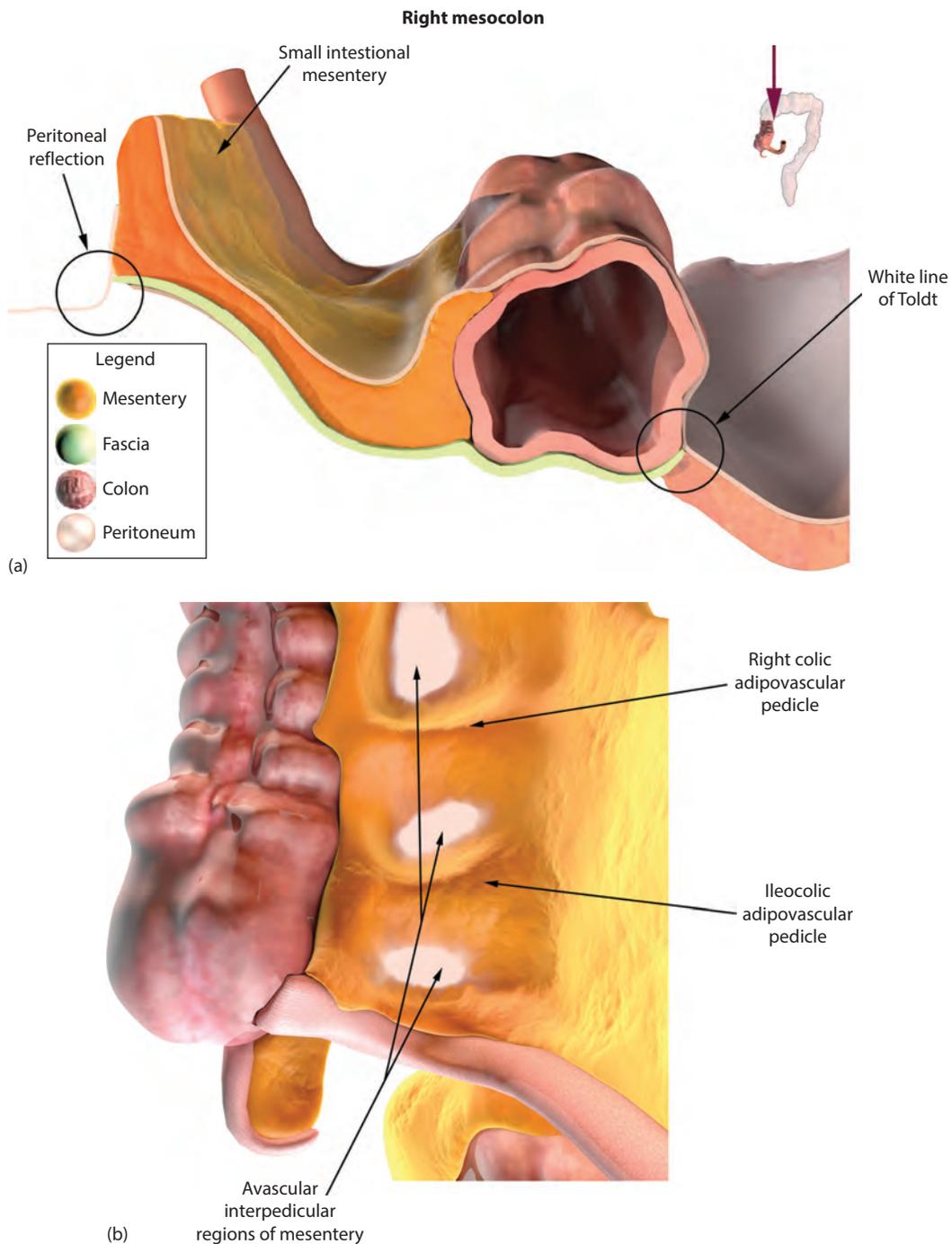


Figure 2.8 (a) (See also QR 3/1.) 2.5D snapshot of a 3D digital sculpture showing continuity between the small intestinal mesentery and the right mesocolon (viewed from above). In addition, the fascia that occurs between the right mesocolon and retroperitoneum (Toldt's fascia) is apparent. The fascia extends beneath the colon to form the colofascial plane and stops at the right peritoneal reflection, where it gives rise to the white line of Toldt (circle). The fascia also extends medially until it stops at the small bowel mesenteric peritoneal reflection. **(b)** Overview of the right mesocolon demonstrating adipovascular pedicles and avascular interpedicular areas. Adipose tissue is minimal in the interpedicular regions leading to their near translucent appearance.

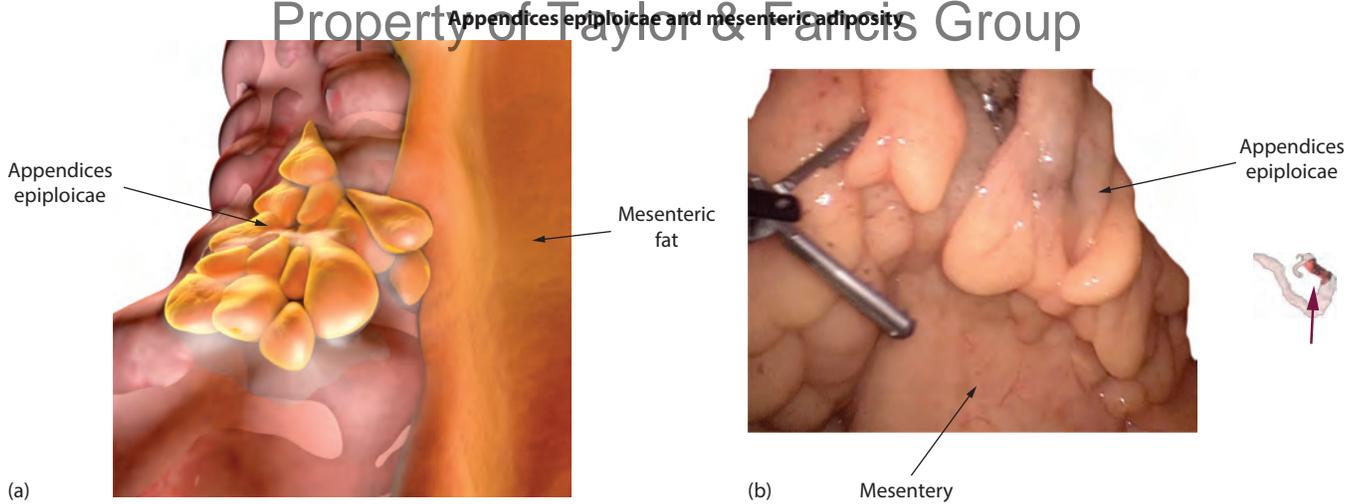


Figure 2.9 (a) 2.5D snapshot of a 3D digital sculpture demonstrating appendices epiploicae along the surface of the ascending colon. (b) Intraoperative photograph of appendices draped along the surface of the right colon. They are variable in shape and similar in color to nearby right mesocolon. They can be differentiated from nearby mesentery due to their lobular appearance.

Transverse mesocolon

The transverse mesocolon is best thought of as the structure generated where the mesenteric components of the hepatic and splenic flexure converge with the middle colic vascular pedicle (Figures 2.7b, 2.11, and 2.12). Its radial axis extends from the origin of the middle colic artery (i.e., at the superior mesenteric artery) to the intestinal margin of the mesentery. It changes from attached to mobile along this axis. Its longitudinal axis extends from the mesenteric component of the hepatic to the splenic flexure (Figure 2.12).

As with the small intestinal and sigmoid mesentery, the transverse mesocolon elongates dramatically at the intestinal margin. In this region, and due to elongation, it folds back on to itself and adopts a conformation that varies considerably. Although the transverse mesocolon does not have a formal insertion as depicted in classic anatomic appraisals, it does converge on the middle colic artery (see Chapter 3) (Figure 2.12) [18].

Relationship between transverse mesocolon and greater omentum

The transverse mesocolon and colon overlie the small intestinal mesentery, and the greater omentum overlies the upper surface of the transverse mesocolon. Extensive adhesions occur between the under surface of the greater omentum and the upper surface of the transverse mesocolon. As a result, the lesser sac is frequently obliterated where the transverse mesocolon and greater omentum are attached. This arrangement has surgical implications but is also likely to have pathobiologic significance in limiting the direct spread of intra-abdominal disease [2].

Middle colic adipovascular pedicle

As occurs in the right and left mesocolon, mesenteric fat is increased around the middle colic artery (*the middle colic adipovascular pedicle*) (Figure 2.12). On either side of this pedicle, the mesentery thins to the point of being translucent in individuals whose body mass index is low (i.e., *the avascular interpedicular regions*) [10,18].

Splenic flexure

At the splenic flexure, the transverse mesocolon continues distally as the left mesocolon (Figure 2.7c). As with the hepatic flexure, the splenic flexure is best considered in terms of radial and longitudinal axes. The radial axis extends radially from the middle colic vascular pedicle to the intestinal margin. As it does so, the mesentery changes from attached to the posterior abdominal wall, to nonattached and thus mobile (Figure 2.12b). The longitudinal axis extends longitudinally from the transverse to the left mesocolon. At the transverse pole of the longitudinal axis, the mesentery is attached at middle colic pedicle and mobile at the intestinal margin. At the left mesocolic pole of the longitudinal axis, the mesentery is fully attached across its breadth. Thus, the mesenteric component of the splenic flexure undergoes considerable conformational changes. These have implications for surgical mobilization and resection of the splenic flexure [18].

Left mesocolon

The left mesocolon is continuous with the transverse mesocolon at the splenic flexure. As one follows it distally, it rapidly expands in the axial plane (from the

Not for distribution - Property of Taylor & Francis Group

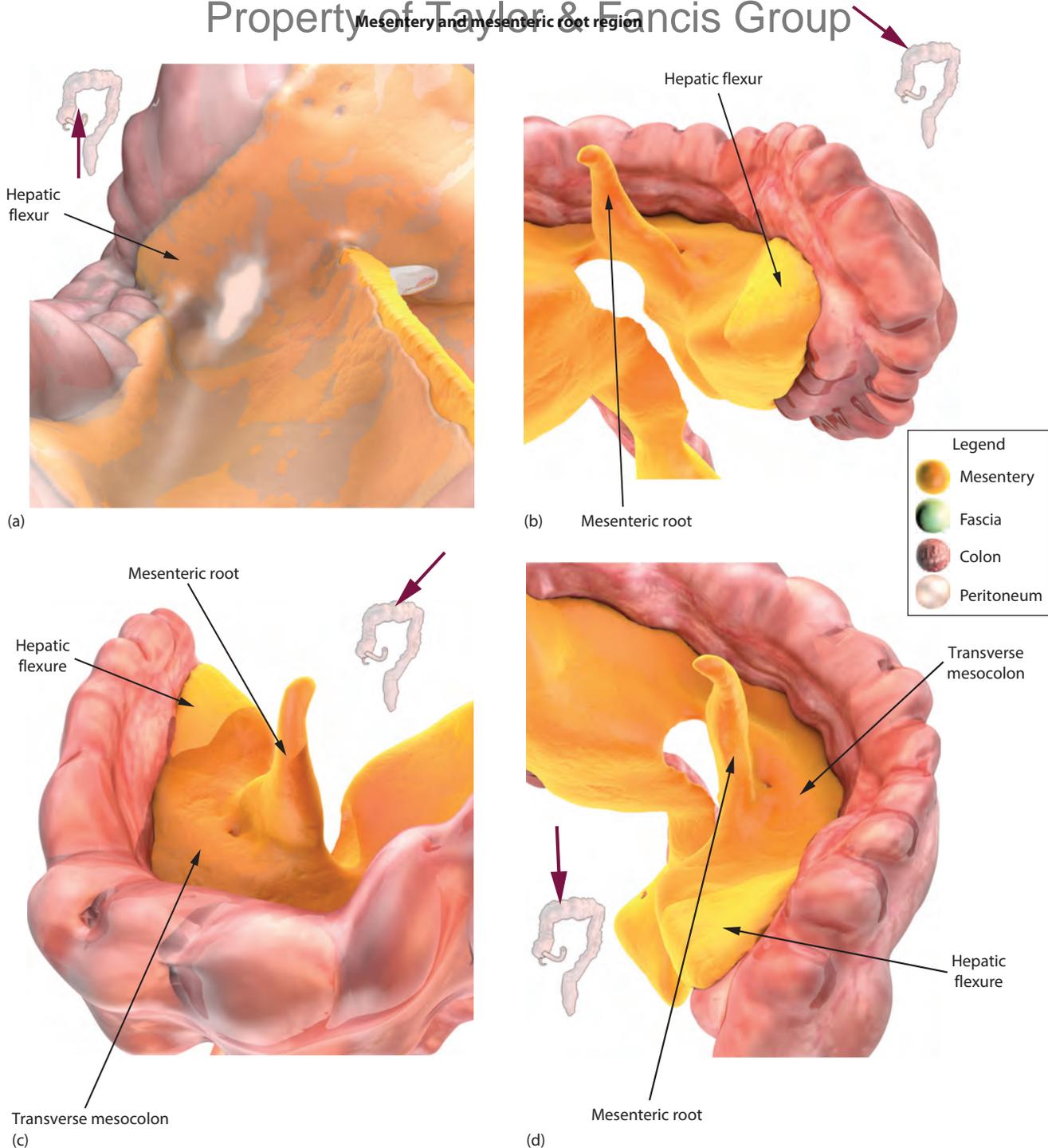


Figure 2.10 2.5D snapshots of a 3D digital sculpture showing how the right mesocolon narrows toward the hepatic flexure. **(a)** Anterior view. **(b)** (See also QR 1/4.) Posterior view from above. **(c)** Posterior view looking from medial to lateral. **(d)** Posterior view looking lateral to medial.

flexure). The full extent of the left mesocolon (i.e., from nonintestinal to intestinal margin) is attached (i.e., flattened against) to the posterior abdominal wall (Figures 2.7 and 2.13a through c). Toldt's fascia is interposed between it and the retroperitoneum (Figure 2.13a through c) and

also between the colon and the retroperitoneum (Figure 2.13b). Unlike the transverse mesocolon, the left mesocolon does not undergo elongation at the intestinal margin. Distally, the left mesocolon continues as the *attached* component of the mesosigmoid [10,18].

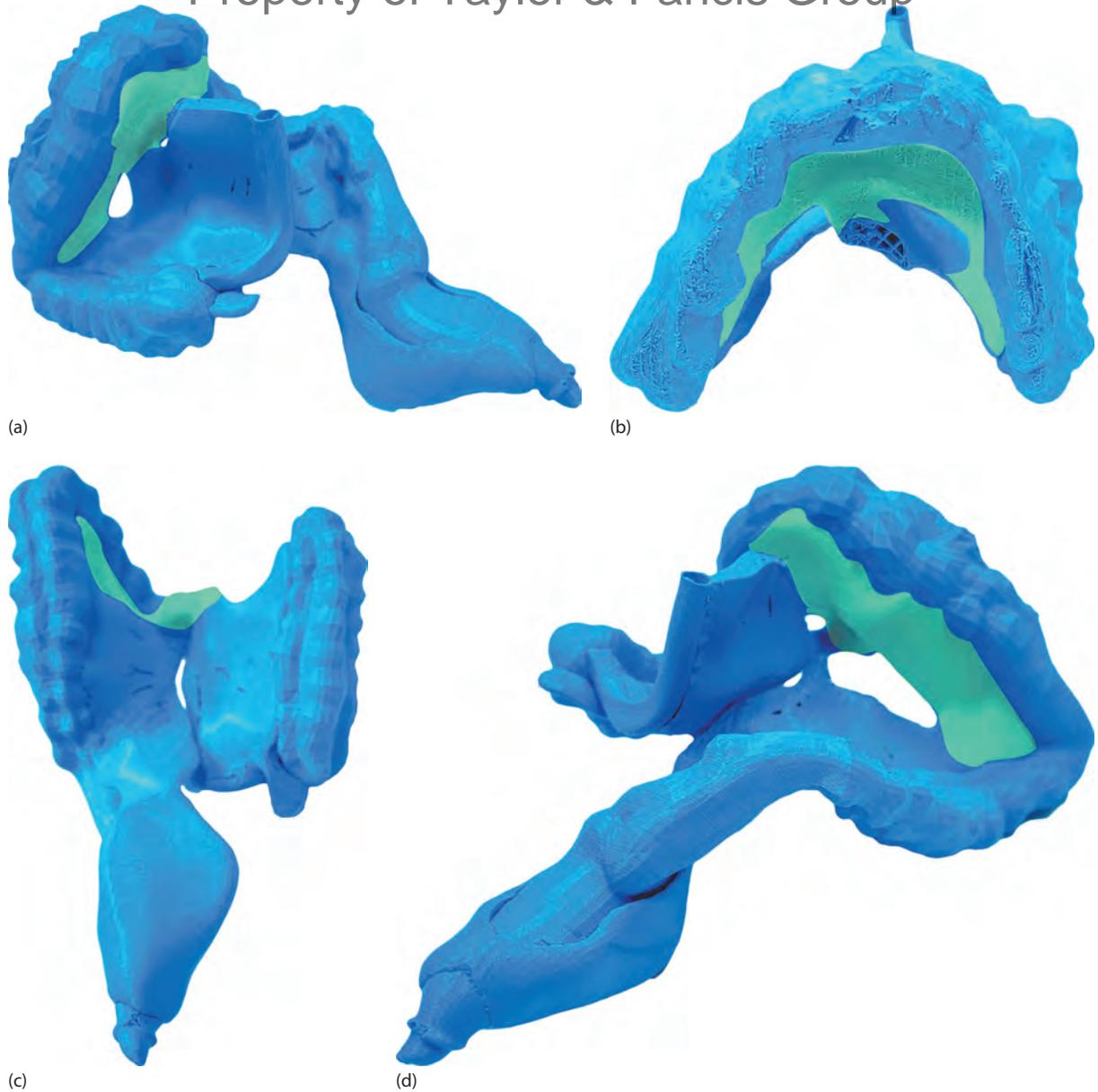


Figure 2.11 (a–d) (See also QR 1/2.) 2.5D snapshot of a 3D printed model of the mesocolon and colon demonstrating contiguity throughout its length from ileocecal junction to mesorectal level. The transverse mesocolon is colored green to demonstrate its appearance from different viewpoints.

Inferior mesenteric adipovascular pedicle

An accumulation of fat around the inferior mesenteric artery generates the *inferior mesenteric adipovascular pedicle*. In thin individuals, the left mesocolon cephalad to this pedicle is near translucent, while the mesocolon distal to the pedicle is generally thickened due mainly to the presence of sigmoidal vessels, the left colic, and the superior rectal arteries (Figure 2.14).

White line of Toldt

The right and left colon, located at the intestinal margins of the right and left mesocolon, are generally apposed to the retroperitoneum (Figure 2.15a and b). As with the mesocolon, they are maintained separate from it, by Toldt's fascia. The fascia extends under the mesocolon and colon and is limited by the peritoneal reflection where the white line of Toldt occurs (Figure 2.15a and b). The white line can be

Not for distribution -
Property of Taylor & Fancis Group

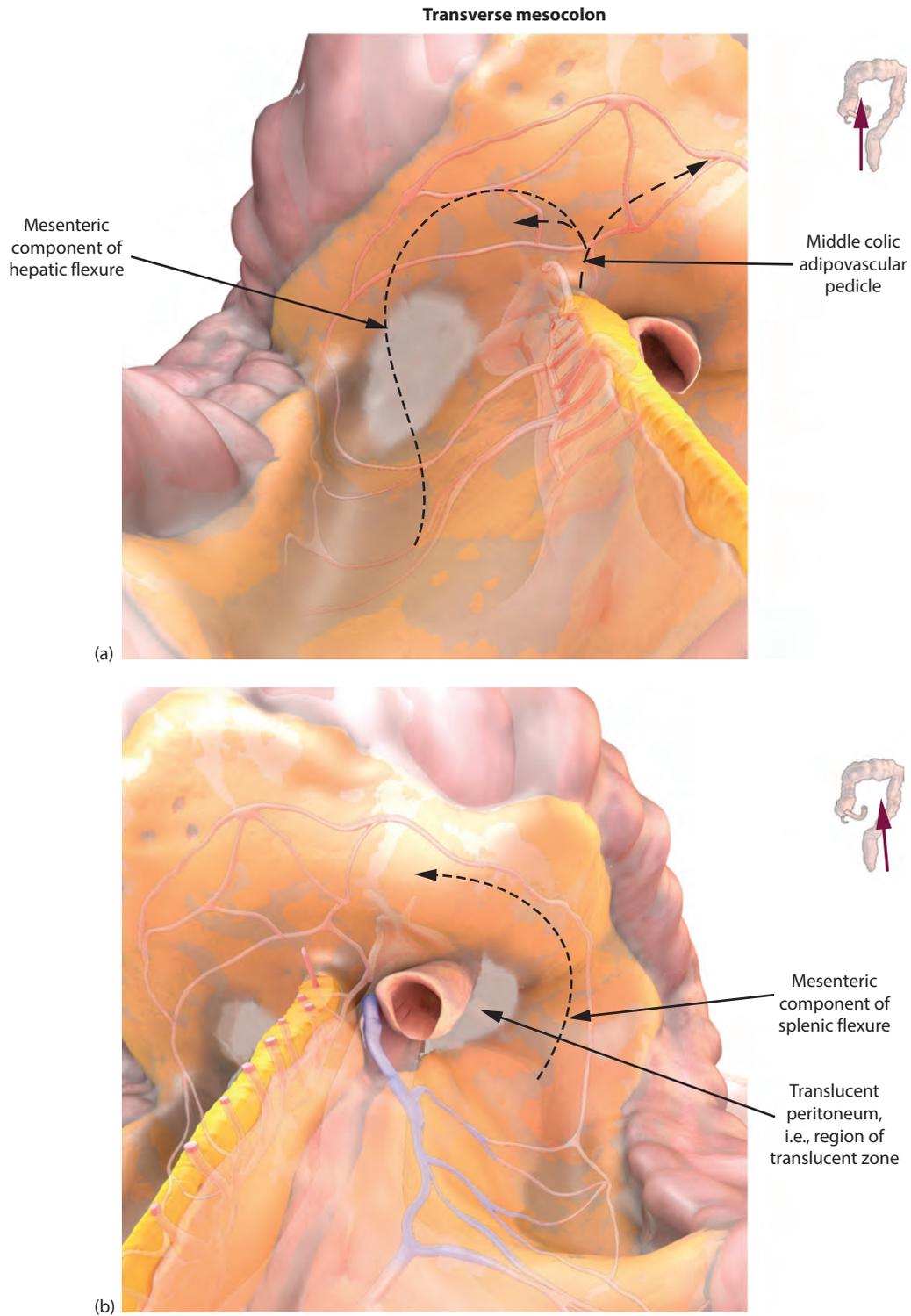


Figure 2.12 (a) (See also QR 1/6-8.) 2.5D snapshot of a 3D digital model in which the mesenteric components of the (a) hepatic and (b) splenic flexures converge on the middle colic adipovascular pedicle.

Not for distribution - Property of Taylor & Fancis Group

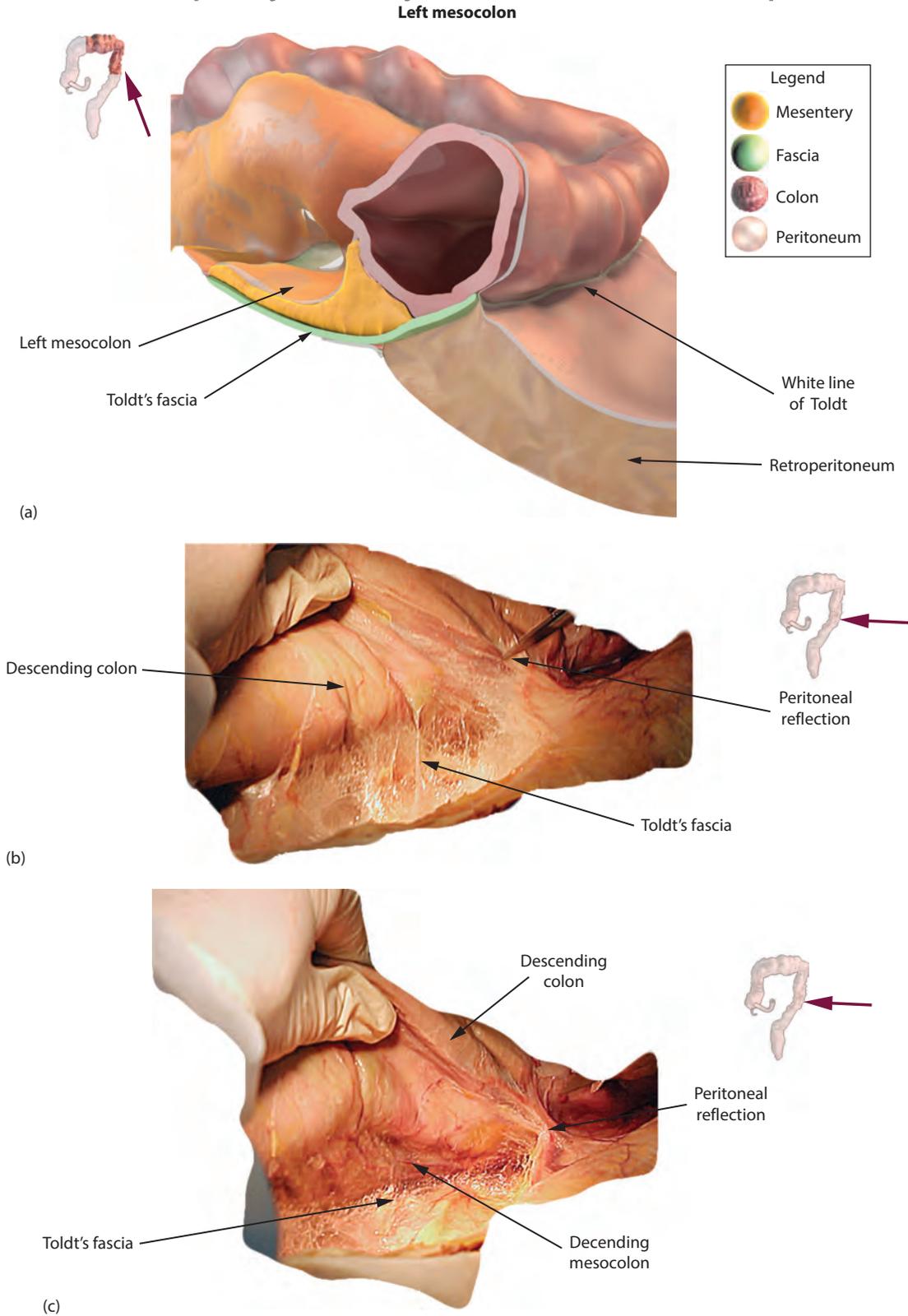


Figure 2.13 **(a)** (See also QR 4/2.) 2.5D snapshot of a 3D digital model demonstrating the left mesocolon. **(b)** Cadaveric image demonstrating Toldt's fascia posterior to the colon. This relationship becomes apparent after division of the overlying peritoneal reflection. **(c)** Once the colon has been separated from Toldt's fascia, the mesocolon and underlying fascia are exposed.

Not for distribution - Property of Taylor & Francis Group

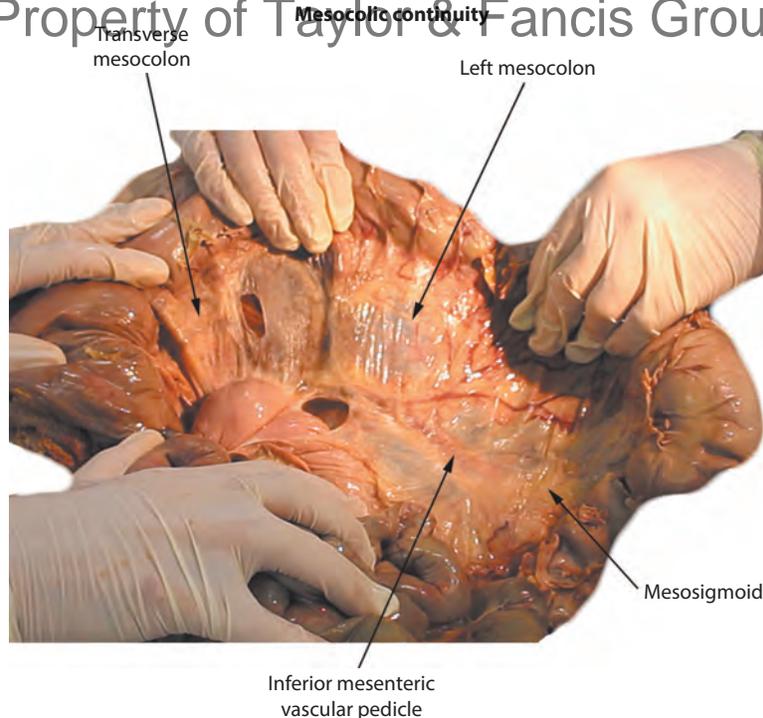


Figure 2.14 Cadaveric images of continuous transverse, left mesocolon, and mesosigmoid. Vascular pedicles and avascular interpedicular areas are apparent. A small window was inadvertently created in the transverse mesocolon.

observed whenever an interface occurs between peritoneal mesothelium and Toldt's fascia. For example, it can be observed beneath the right and left mesocolon. Thus, it is inaccurate to suggest that it is confined to the right and left peritoneal reflections. As will be seen in the chapters on right and left mesocoelectomy, the white line represents an anatomic landmark that may help the surgeon in deciding where to commence peritonotomy (i.e., peritoneal incision) (Figures 2.15 and 2.16) [18].

Mesosigmoid

The mesosigmoid is continuous distally with the mesorectum and proximally with the left mesocolon. It is best considered in terms of longitudinal and transverse axes. The longitudinal axis extends from the left mesocolon to the mesorectum and spans the attached region of the mesosigmoid. The transverse axis extends from the midline laterally.

Mesosigmoid: Transverse axis

The transverse axis varies in breadth depending on the level examined. At the junction between the descending and sigmoid colon, the transverse axis extends from the midline to the junction laterally and is fully apposed to the posterior abdominal wall. At the rectosigmoid junction, the transverse axis is narrow and again fully attached to

the posterior abdominal wall. In between these junctions, the sigmoid elongates and leaves the posterior abdominal wall, taking the mesosigmoid with it. This means that the transverse axis is attached medially and mobile laterally (Figure 2.16a and b) [10,16,20,21]. Where the mobile component detaches from the posterior abdominal wall a peritoneal reflection bridges the gap between the two. The line along which the mesosigmoid detaches has a diagonal orientation along the left iliac fossa. The associated peritoneal reflection has a similar orientation and extends from the junction between the descending and sigmoid colon to that between the sigmoid colon and rectum (Figure 2.16a and b) [9,10].

The mobile component of the mesosigmoid fans out in a manner similar to that of the transverse mesocolon and small bowel mesentery. In keeping with this property, the intestinal margin of the mobile component is considerably longer than the base region at which it is attached [9,10]. This differential in length is exaggerated in some individuals and predisposes to volvulus formation, where the sigmoid twists on its mesentery (see Chapter 7).

Mesosigmoidal angles

At the junction between the descending and the sigmoid colon, a mesenteric angle occurs, the *proximal mesosigmoidal angle* (Figure 2.17). At the junction between the sigmoid and rectum, a similar mesenteric angle occurs, the

Not for distribution -

Property of Taylor & Francis Group

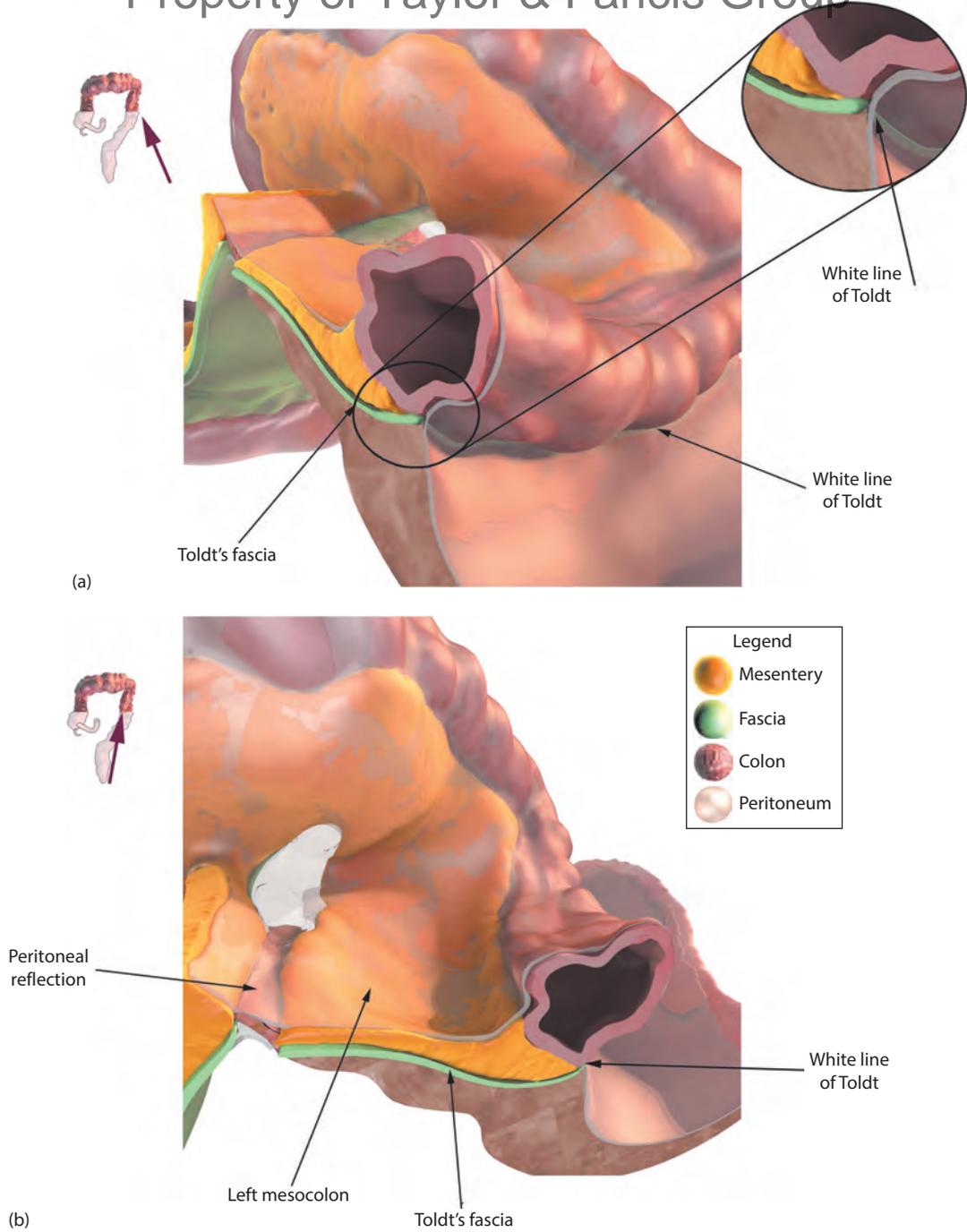


Figure 2.15 (a) (See also QR 6/5.) 2.5D snapshot of a 3D digital model demonstrating the left mesocolon (viewed from above) and descending colon, sectioned in such a manner as to permit identification of the mesocolon. (b) (See also QR 6/6.) 2.5D snapshot showing a section through the left mesocolon, viewed from below up. Toldt's fascia is shown as it extends from beneath the mesocolon, to beneath the colon, and thereafter to reach the left peritoneal reflection.

distal mesosigmoidal angle. These angles are of surgical and endoscopic significance (Figure 2.17).

Congenital adhesions

Frequently, the lateral aspect of the mesosigmoid is adherent to the parietal peritoneum of the left iliac fossa across

focal congenital adhesions. While in some individuals these adhesions are absent, in others they are plentiful and form a band resembling the peritoneal reflection. It is this band that surgical trainees (and indeed sometimes highly experienced colorectal surgeons) can mistake as the starting point for lateral to medial mobilization of the mesosigmoid.

Not for distribution -
Property of Taylor & Fancis Group

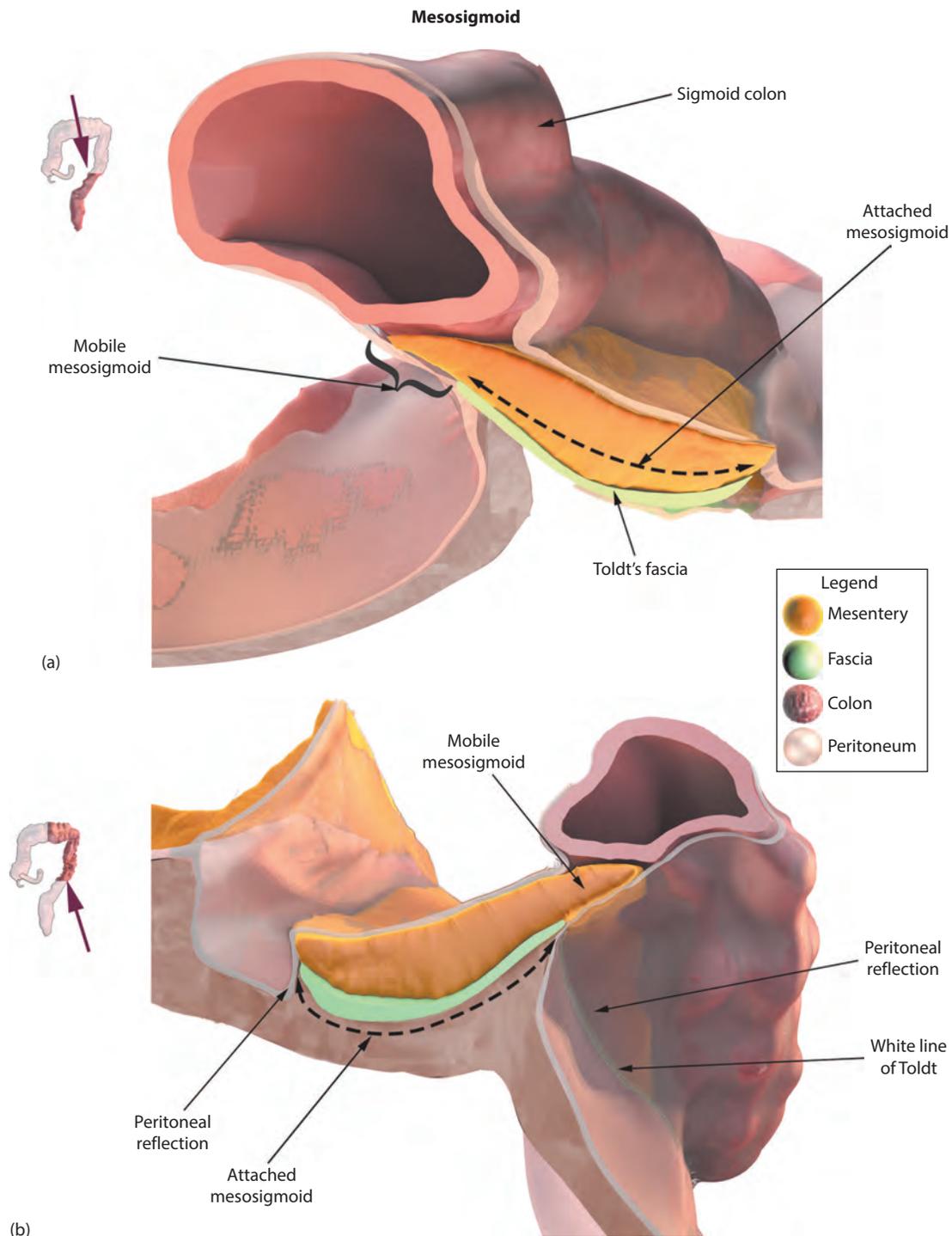


Figure 2.16 **(a)** (See also QR 5/1.) 2.5D snapshot of a 3D digital model demonstrating the mesosigmoid viewed from above down and demonstrating attached and mobile regions. Toldt's fascia is observed beneath the attached mesosigmoid, between it and the retroperitoneum. The fascia continues laterally as far as the peritoneal reflection where the attached region of mesosigmoid continues laterally as the mobile region. **(b)** (See also QR 6/1.) Same model as in **(a)** sectioned and viewed from below up to illustrate the same mesofascial relationships beneath the attached mesosigmoid. The fascia continues laterally until limited by the lateral peritoneal reflection.

Not for distribution - Property of Taylor & Francis Group

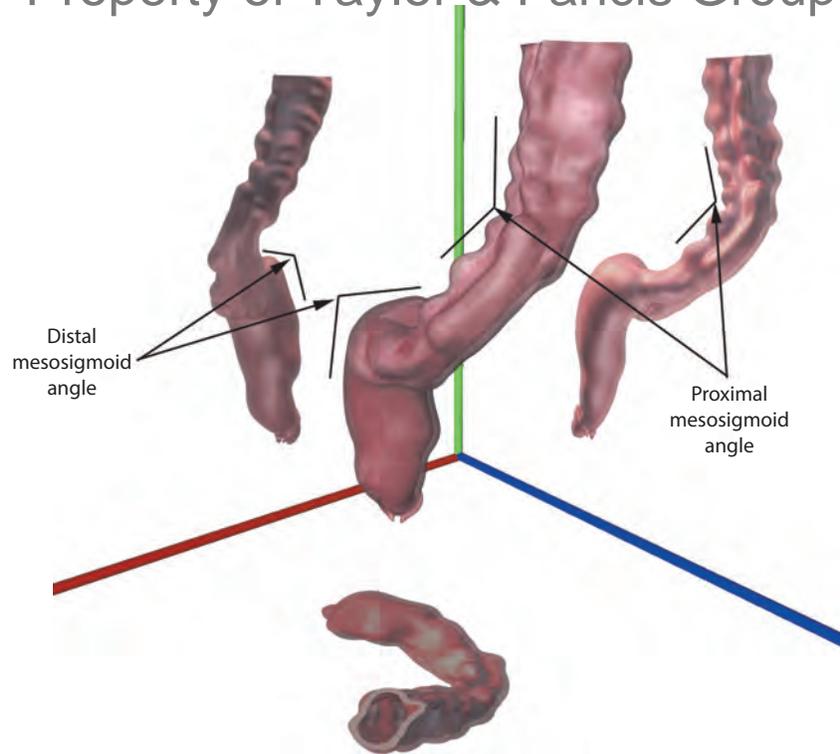


Figure 2.17 Panel of 2.5 D images presenting sigmoid and rectum from multiple viewpoints. These enable demonstration of the proximal and distal mesosigmoid angles. The proximal mesosigmoid angle occurs at the junction of the descending and sigmoid colon. The distal mesosigmoid angle occurs at the junction between the sigmoid and the rectum.

Mesorectum

The mesorectum is the distal continuation of the mesosigmoid (Figure 2.18a and b). It encases the upper rectum posteriorly and laterally. Distal to the anterior reflection the mesorectum continues around the anterior rectum to encase this also. Toldt's fascia occurs between the mesorectum and surrounding structures. This relationship holds *circumferentially at all levels* and is of considerable clinical relevance (Figure 2.18a and b). Anteriorly, the fascia is markedly attenuated between the rectum and prostate (in the case of males) and between the rectum and the vagina in females (Figure 2.18). Anteriorly, the complex of mesorectum and fascia is often referred to as Denonvillier's fascia. Deep in the pelvis, where the mesorectum tapers toward the anorectal junction, the fascia coalesces to become more distinct. Several terms are used interchangeably for the fascia in this region. They include *Waldeyer's fascia*, *the retrorectal or presacral fascia* (Figure 2.18c and d). In most individuals, the fascia occupies the interface between the distal (tapering) mesorectum and surrounding bony pelvis. However, in some individuals, the fascia is markedly attenuated in this region and an anatomic space arises [10,16,20,21].

THE PERITONEAL REFLECTION

An understanding of the anatomy of the mesentery is essential in comprehending the associated peritoneal reflection

(Figure 2.3). For descriptive purposes, the peritoneal reflection will be subdivided into regions, based on the associated region of mesentery, and these will be named accordingly. Although this system greatly aids in the conceptualization of the reflection, it is not meant to indicate that there are separate anatomic structures [17,20,21]. Rather, they are different regions of a single, continuous structure.

As mentioned earlier, a peritoneal reflection occurs where the small intestinal mesentery attaches to the posterior abdominal wall (*the small intestinal peritoneal reflection*) (Figure 2.19a through c). The peritoneal reflection in this location continues on the inferolateral aspect of the ileocecal mesenteric confluence (arbitrarily called the "ileocecal peritoneal reflection"), thus obscuring this confluence from direct visualization (Figure 2.20a and b). The reflection then continues on to the lateral aspect of the right colon as the *right peritoneal reflection* (Figure 2.21a and b). As with the ileocecal mesenteric confluence, the right peritoneal reflection obscures the plane formed between the right colon and Toldt's fascia. The right peritoneal reflection is often identifiable by the occurrence of a thin white trace, that is, the white line of Toldt [3,11,16,18].

At the hepatic flexure, the reflection continues around the cephalad aspect of the flexure, as the *hepatocolic reflection* (Figure 2.22a through c). When this reflection is surgically divided via peritonotomy, the interface between the colon and underlying fascia can be visualized. More medially, the greater omentum coalesces with the hepatocolic reflection

Not for distribution - Property of Taylor & Francis Group

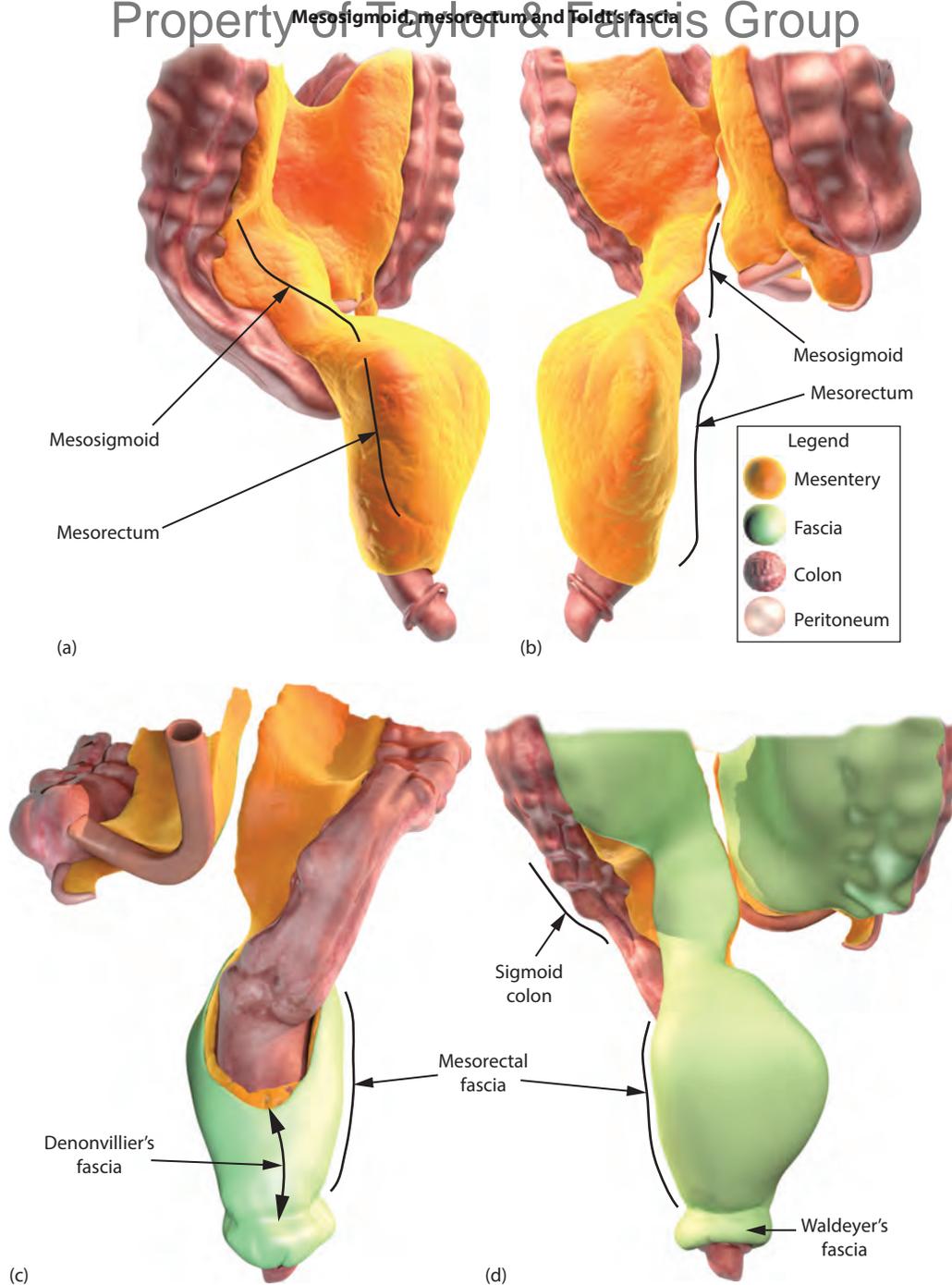


Figure 2.18 **(a)** (See also QR 7/1.) 2.5D snapshot of a 3D digital model demonstrating continuity between the mesosigmoid and mesorectum from a posterior and left-sided viewpoint. **(b)** (See also QR 7/2.) 2.5D snapshot of a 3D digital model demonstrating continuity between the mesosigmoid and mesorectum from a posterior and right-sided viewpoint. **(c)** 2.5D snapshot of a 3D digital model demonstrating continuity between the mesosigmoid and mesorectum with Toldt's fascia included. **(d)** 2.5D snapshot of a 3D digital model demonstrating continuity between the mesosigmoid and mesorectum and fascia included.

making the anatomic arrangement in this location difficult to define. A further reflection is always evident beneath the greater omentum bridging the space between this and the transverse mesocolon [10,11,16,20,21]. This has been arbitrarily called the omento-colic reflection.

The cephalad aspect of the splenic flexure is also obscured from view by the *splenocolic reflection*. Just as occurred for the hepatic flexure, coalescence of the greater omentum with the splenocolic reflection makes it difficult to differentiate anatomic structures at this location

Not for distribution -
Property of Taylor & Fancis Group

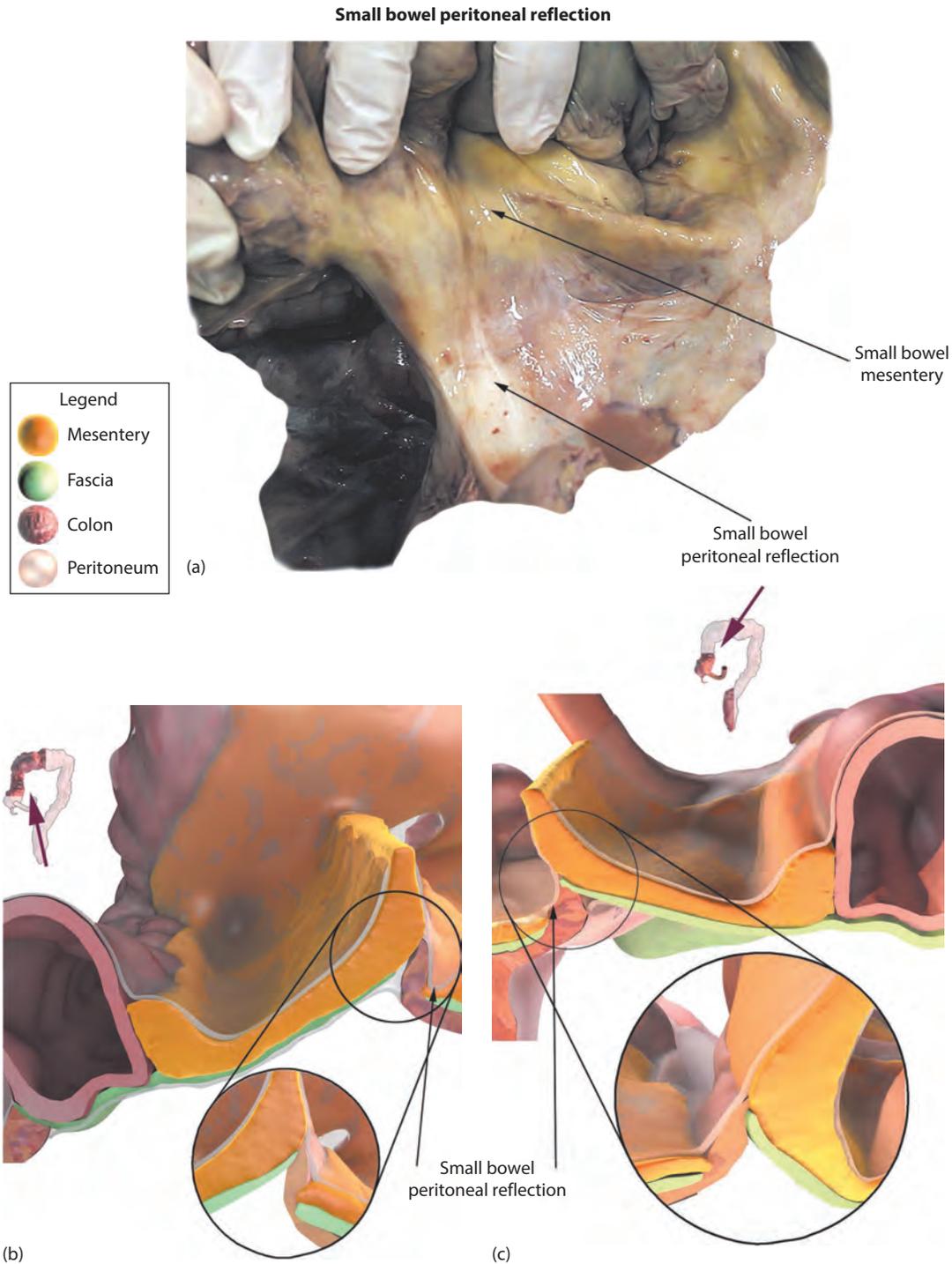


Figure 2.19 (a) Cadaveric view of the peritoneal reflection at the base of the mesentery and continuing around the ileocecal junction. (b) (See also QR 4/1.) 2.5D snapshot from 3D digital model that has been sectioned through the mesentery and right mesocolon. This enables demonstration of the peritoneal reflection at the base of the small intestinal mesentery. The view is from below up. (c) (See also QR 3/1.) Same model as in (b) but with view from above down. The small intestinal mesentery is continuous with the right mesocolon and at the base of the former, the peritoneal reflection is apparent.

Not for distribution -
Property of Taylor & Fancis Group

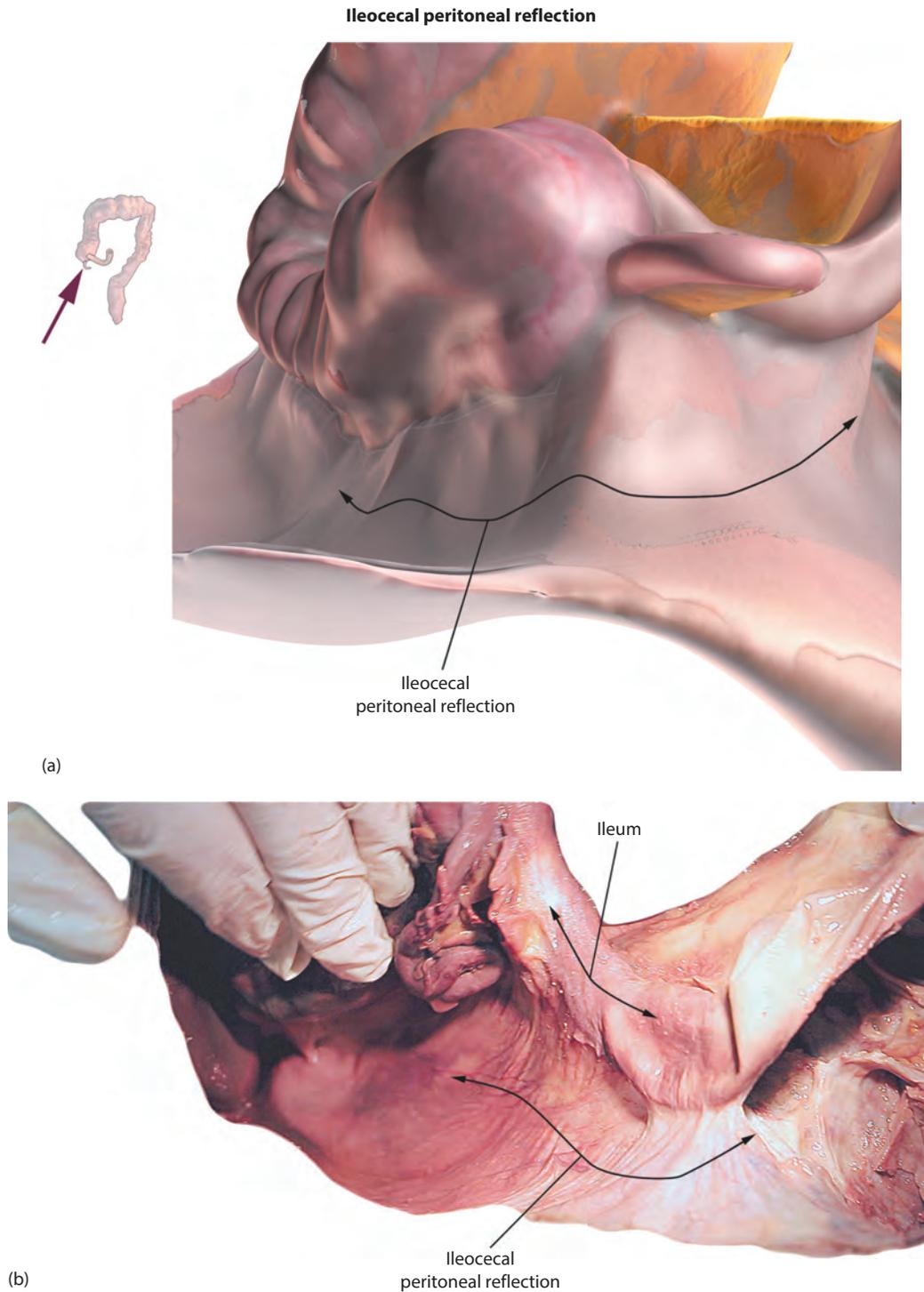


Figure 2.20 **(a)** (See also QR 2/2.) 2.5D snapshot of a 3D digital model demonstrating the peritoneal reflection at the ileocecal junction. This is a distal continuation of the reflection at the base of the small intestinal mesentery. **(b)** Cadaveric example of the peritoneal reflection at the ileocecal junction.

Not for distribution - Property of Taylor & Fancis Group

Right peritoneal reflection

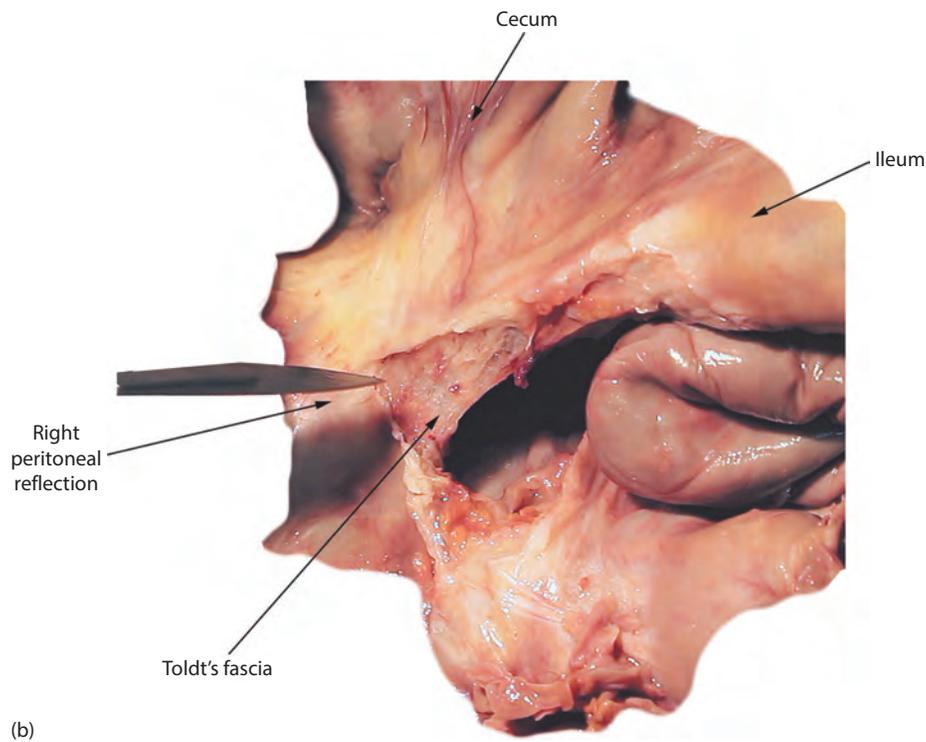
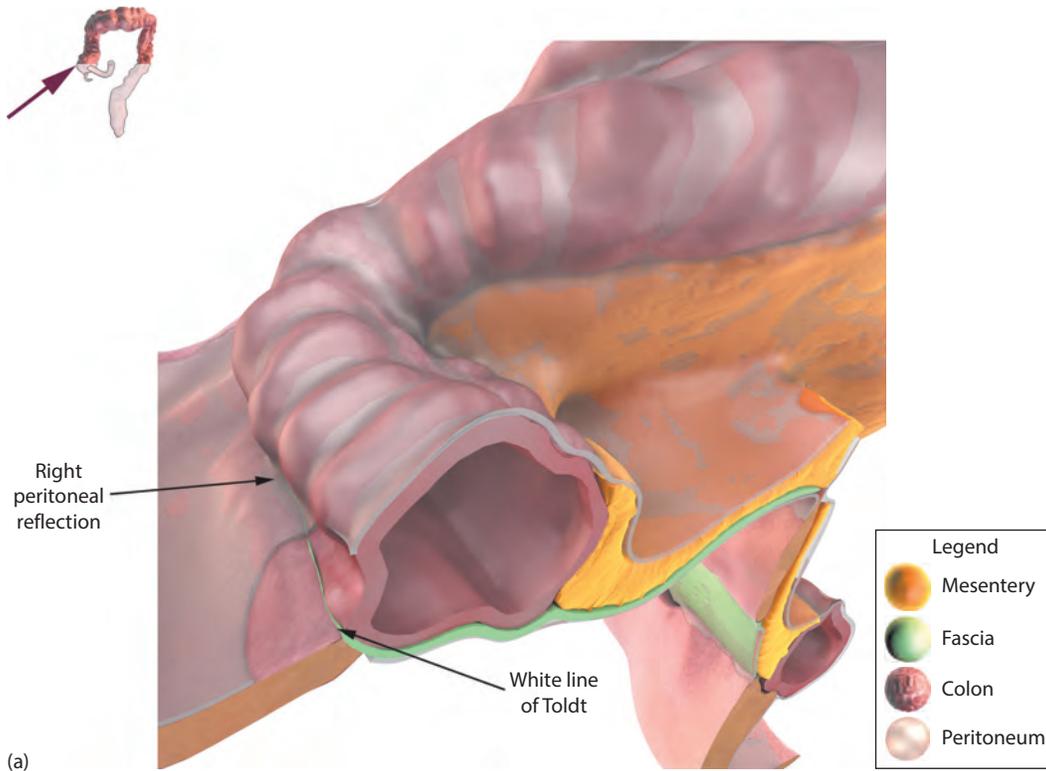


Figure 2.21 (a) (See also QR 2/3.) 2.5D snapshot of a 3D digital model demonstrating the right peritoneal reflection. This is a cephalad extension of the peritoneal reflection at the ileocecal junction. (b) Cadaveric example of the right peritoneal reflection. The reflection is being divided (i.e., peritonotomy) to expose the fascia of the colofascial plane beneath.

Not for distribution - Property of Taylor & Francis Group

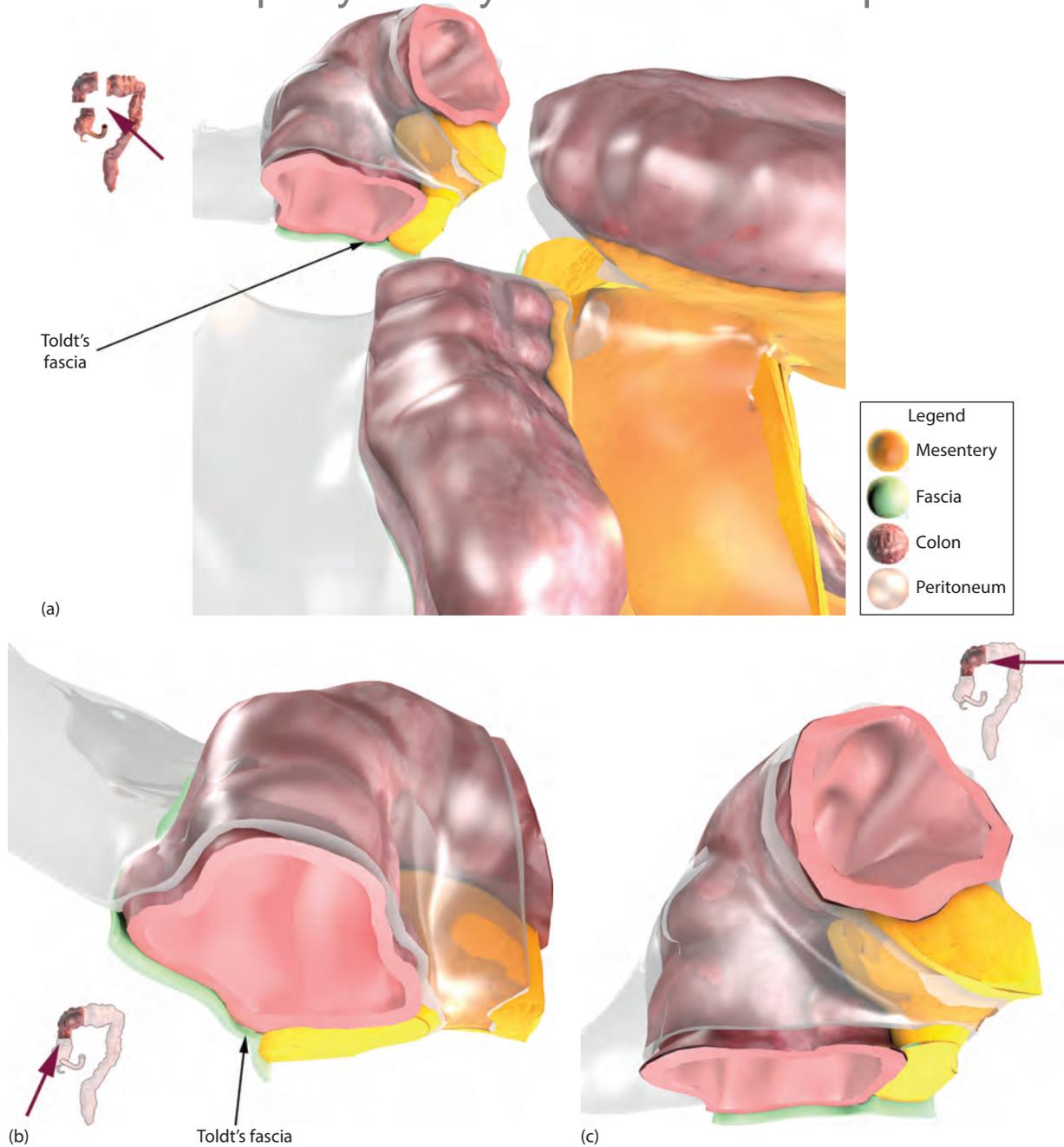


Figure 2.22 (a) (See also QR 11 and 12.) 2.5D snapshot of a 3D digital model demonstrating the hepatic flexure conceptually removed from continuity. (b) (See also QR 11 and 12.) Hepatocolic peritoneal reflection from lateral to medial and (c) from medial to lateral.

(Figure 2.23a and b). On the left side, the *left peritoneal reflection* occurs on the lateral aspect of the descending colon and covers the plane formed by this and the underlying fascia (Figure 2.24).

Just distal to the splenic flexure, the left peritoneal reflection forms a prominent transverse fold. At this fold, the colon subtly changes from nonattached to attached and

continues as the descending colon toward the left iliac fossa (Figure 2.24). A similar peritoneal fold occurs at the fourth part of the duodenum (generating the para-duodenal recess) where the duodenum detaches from the posterior abdominal wall and continues as the jejunum. These are peritoneal folds as opposed to reflections. They represent regions where the reflection folds back on itself to form

Not for distribution - Property of Taylor & Francis Group

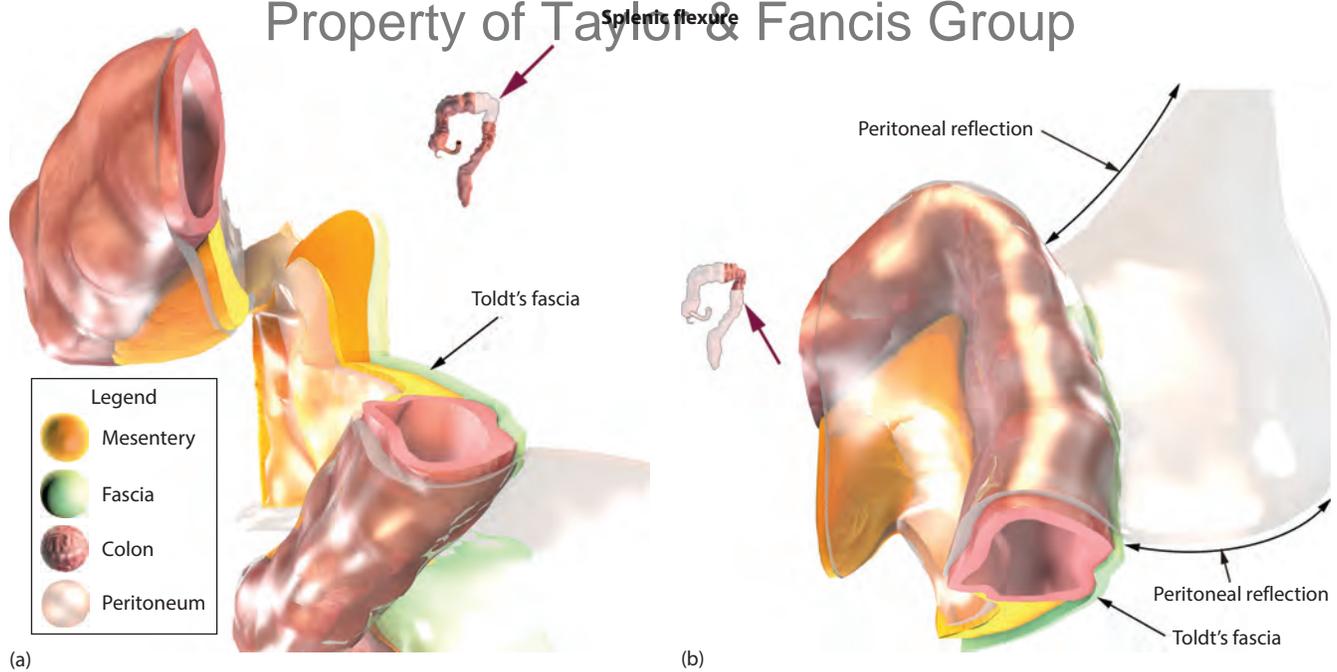


Figure 2.23 (a) (See also QR 9 and 10.) 2.5D snapshot of a 3D digital model demonstrating the splenic flexure conceptually removed from continuity. (b) (See also QR 9 and 10.) Peritoneal reflection associated with the splenic flexure.

a ridge of peritoneum. They may also be observed at the ileocecal junction and anterior reflection. They are not an anatomic constant being variable in number, extent, and distribution.

The *left peritoneal reflection* continues over the lateral aspect of the mesosigmoid and obscures the base of the mesosigmoid from direct visualization (i.e., *the mesosigmoidal reflection*) (Figure 2.25a and b). A further peritoneal reflection occurs on either side of the rectum and mesorectum (*the right and left pararectal reflections*) (Figure 2.26). These are continuous into the pelvis and anteriorly they merge at the anterior reflection. The latter is the true anatomic termination of the peritoneal cavity (Figure 2.26) [9,17,20,21].

FLEXURAL ANATOMY

Given the principles described earlier, the flexures can now be described. In so doing, it is important to recall mesenteric continuity, elongation of the intestinal margin of the mesentery, and the peritoneal reflection. A flexure occurs at any point where the intestinal tract changes from *attached* (to the posterior abdominal wall) to *mobile* (or vice versa). Thus, a flexure arises at the duodenojejunal junction, at the ileocecal junction, at hepatic and splenic levels, at the junction between the descending and sigmoid colon, and finally between the sigmoid colon and rectum. The anatomy at each flexure can be simplified in terms of four main components. These are the colonic, mesenteric, peritoneal, and fascial components [18].

Duodenojejunal and ileocecal flexures

At the duodenojejunal flexure, the jejunum separates from the posterior abdominal wall. The intestinal margin of the mesentery elongates extensively unlike the abdominal (i.e., attached) region of the mesentery. The duodenojejunal complex of intestine and mesentery is obscured from direct view by the small bowel mesenteric peritoneal reflection in this region. A paraduodenal peritoneal fold may occur here.

At the ileocecal junction, the terminal ileum approaches and attaches to the posterior abdominal wall, and the confluence between the small intestinal mesentery and right mesocolon tapers toward an apex (which is also attached). Thus, the reverse occurs to that observed at the duodenojejunal flexure. The ileocecal complex of intestine and mesentery is also obscured from direct visualization by the peritoneal reflection here [9,17,18,20,21].

Hepatic flexure

At the hepatic flexure, the colonic component of the flexure separates from the posterior abdominal wall and the right colon becomes the transverse colon. The mesenteric component of the flexure (i.e., the confluence between the right and transverse mesocolon) is attached to the posterior abdominal wall at its base, while the body of the confluence detaches and fans out to reach the mesenteric border of the intestinal tract. Although this series of conformational changes is complex, conceptualization is greatly aided by

Not for distribution - Property of Taylor & Fancis Group

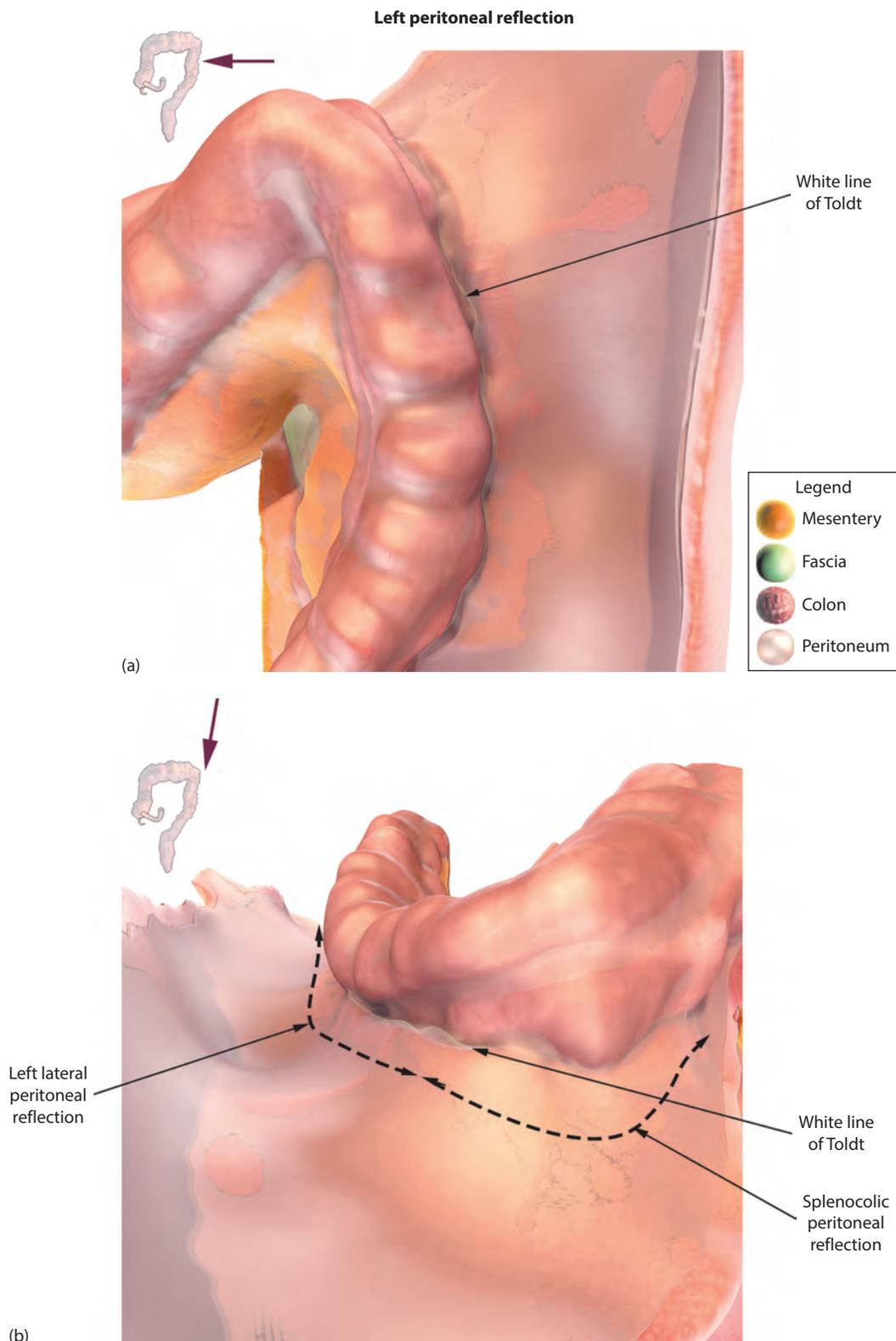


Figure 2.24 **(a)** (See also QR 2d/2.) 2.5D snapshot of a 3D digital model demonstrating the left peritoneal reflection looking from lateral to medial. **(b)** (See also QR 2d/2.) View of the left peritoneal reflection as it would be seen if looking from the splenic flexure distally.

Not for distribution -
Property of Taylor & Fancis Group

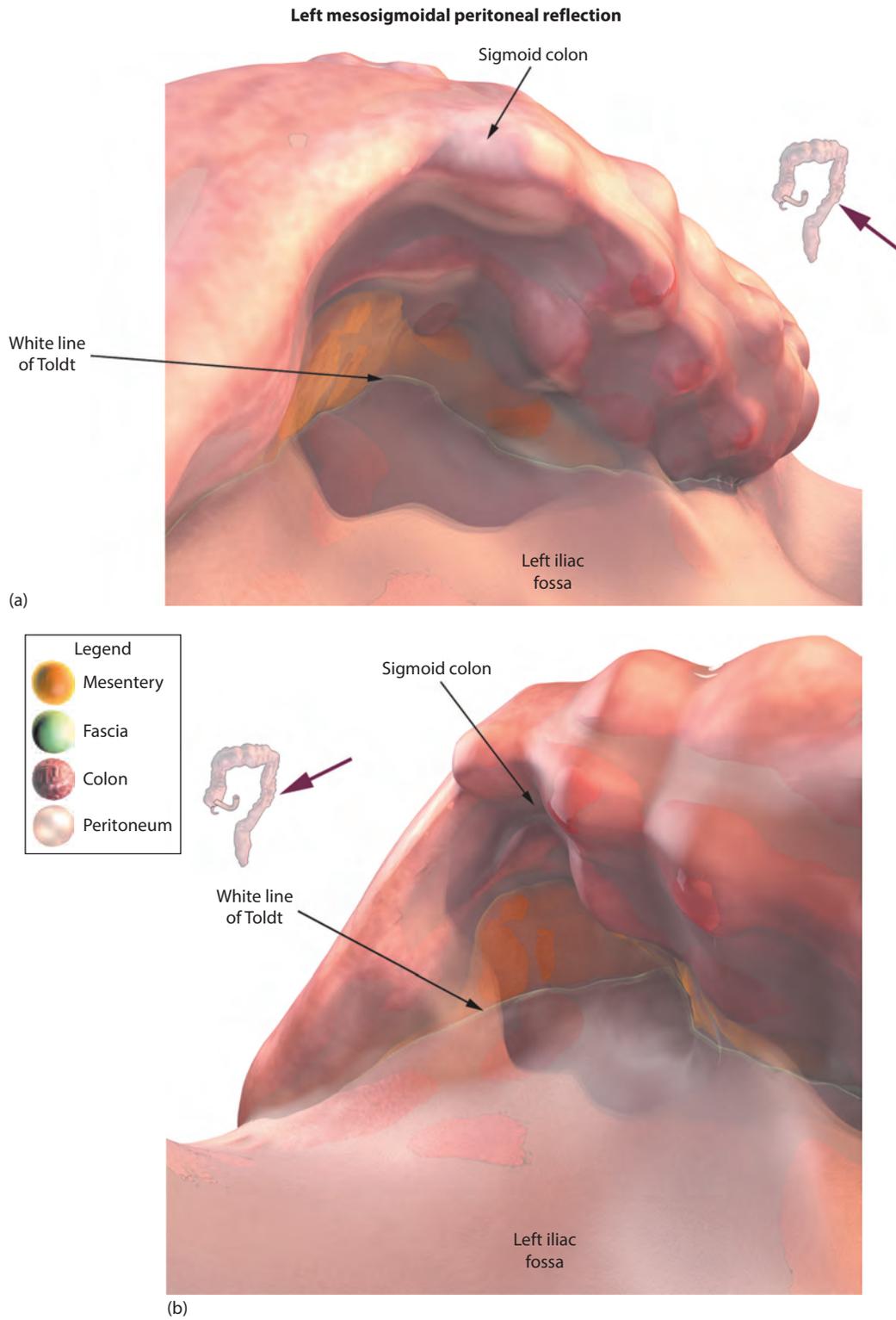


Figure 2.25 (a) (See also QR 2d/8 and 9.) 2.5D snapshot of a 3D digital model demonstrating the peritoneal reflection at the lateral aspect of the mesosigmoid, looking from below up. (b) (See also QR2d/8 and 9.) View of peritoneal reflection at the lateral aspect of the mesosigmoid, looking from above downward.

Not for distribution -
Property of Taylor & Fancis Group

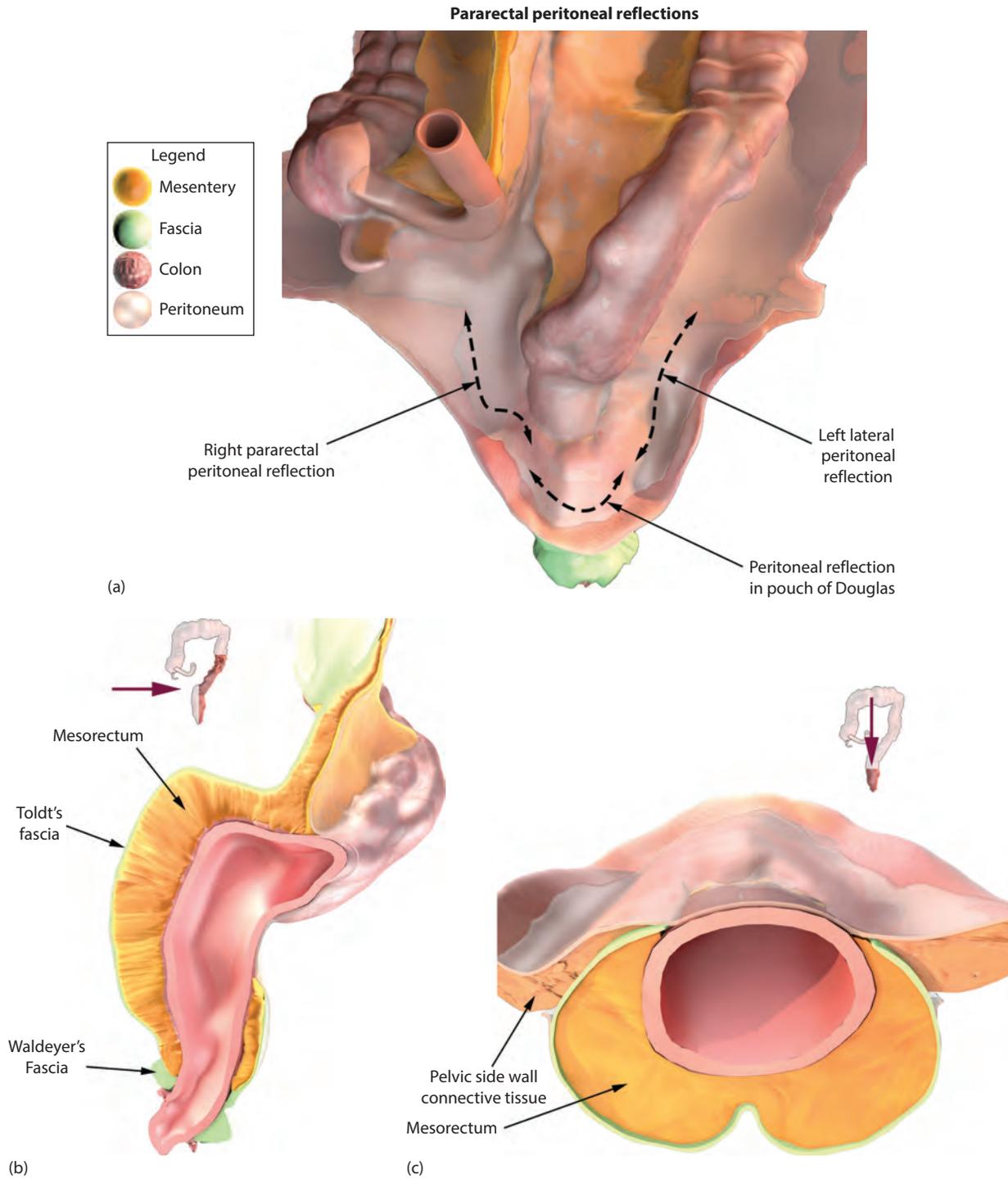


Figure 2.26 **(a)** (See also QR 2/8 and QR 3/2.) 2.5D snapshot of 3D digital model demonstrating the rectum, associated peritoneal reflections, mesorectum, and fascia. **(b)** 2.5D snapshot demonstrating the same model as in **(a)** but sectioned in the sagittal plane to demonstrate anatomic relationships. **(c)** (See also QR 2/8 and QR 3/2.) 2.5D snapshot demonstrating the same model as in **(a)** but sectioned in the transverse plane to demonstrate anatomic relationships.

bearing continuity in mind. At the intestinal margin of the confluence, the intestinal tract is seen to round the flexure, centered on the mesentery [10,16,20,21]. This complex of anatomic structures and pattern of attachment is again obscured from direct visualization by the right peritoneal and hepatocolic regions of the peritoneal reflection.

Splenic flexure

The reverse occurs at the splenic flexure where the colon changes from being mobile (transverse colon) to *attached* (descending colon) to the posterior abdominal wall. The mesenteric component of the confluence changes from having a mobile component at the mesenteric border of the intestinal tract to fully attaching to the posterior abdominal wall across the transverse extent of the left mesocolon. This anatomic arrangement is obscured from direct view by the splenocolic and left peritoneal regions of the peritoneal reflection.

Colosigmoid and rectosigmoid flexures

At the junction between the descending and sigmoid colon, the intestinal margin of the mesentery separates from the posterior abdominal wall and elongates considerably in tandem with the colon itself. At the flexure between the rectum and sigmoid, the reverse occurs as the intestinal margin of the mesentery tapers distally, becomes adherent, and continues caudally as the mesorectum.

MESENTERIC CONFORMATION IN GENERAL

All anatomic structures have limits (i.e., a beginning and an end). The mesentery distal to the duodenum emerges from the superior mesenteric root region. The anatomic end, or termination, occurs at the distal end of the mesorectum. In between these, the mesentery is best understood as fanning out and adopting a spiral conformation. In addition, it undergoes an extensive elongation at the intestinal margin. This combination, in conjunction with plication, ensures that despite extensive elongation at the intestinal margin, the entire gastromesenteric complex can be neatly packaged into a limited intraperitoneal space.

FUTURE DIRECTIONS

An improved understanding of mesenteric and peritoneal anatomy enables one to propose areas for future research, of which there are many. To the surgeon involved in excising the rectum, it remains unclear as to how, structurally, vessels and nerves interface with the mesorectum. Some propose the presence of lateral ligaments or the “zone of adhesion,” while others demonstrate that the mesorectum remains separate from surrounding structures, throughout its full circumference.

Splanchnic nerves supply postganglionic parasympathetic and sympathetic nerve fibers to the intestinal tract.

Although the distribution of these nerves is of enormous clinical relevance, little is known regarding their trajectory within the mesenteric organ [21]. Most descriptions mention three ganglia from which postganglionic fibers arise, but none accurately delineate the course of these, once they leave the ganglia. It is not unreasonable to suggest that the mesentery provides a crucial platform in this regard and that the lack of comprehensive descriptions of enteric neuroanatomy stems from the inaccurate appraisals of mesenteric anatomy in the first instance. It will be important to redress this in future studies and accurately determine the course of postganglionic nerves once these have left the celiac, superior or inferior mesenteric ganglia.

SUMMARY

The mesenteric organ, distal to the duodenojejunal flexure, fans out from its origin at the superior mesenteric artery to span the intestinal tract from DJ flexure to anorectal junction [2]. It is continuous, as are the associated intestinal tract and peritoneal reflections. Anatomic continuity has implications for all related basic and clinical disciplines. Clarification of mesenteric, peritoneal and fascial anatomy now enables a systematic (i.e., scientific) study of each [21].

REFERENCES

1. Treves, F., Lectures on the anatomy of the intestinal canal and peritoneum in man. *Br Med J*, 1885. 1(1264): 580–583.
2. Standring, S., *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. Elsevier Health Sciences, London, U.K., 2015, pp. 1098–1111, 1124–1160.
3. Blackburn, S.C. and M.P. Stanton, Anatomy and physiology of the peritoneum. *Semin Pediatr Surg*, 2014. 23(6): 326–330.
4. Sinnatamby, C.S., *Last's Anatomy: Regional and Applied*. Elsevier Health Sciences, London, U.K., 2011, pp. 234–238, 247–259.
5. Snell, R.S., *Clinical Anatomy by Regions*. Lippincott Williams & Wilkins, 2008, pp. 216, 226, 228, 233, 237, 240.
6. Schoenwolf, G.C. et al., *Larsen's Human Embryology*. Elsevier Health Sciences, Philadelphia, PA, 2014, pp. 341–375.
7. Cochard, L.R., *Netter's Atlas of Human Embryology: Updated Edition*. Elsevier Health Sciences, London, U.K., 2012, pp. 133–134.
8. Sadler, T.W., *Langman's Medical Embryology*. Wolters Kluwer Health, Philadelphia, PA, 2011, pp. 208–232.
9. Sehgal, R. and J.C. Coffey, The development of consensus for complete mesocolic excision (CME) should commence with standardisation of anatomy and related terminology. *Int J Colorectal Dis*, 2014. 29(6): 763–764.

Not for distribution -

Property of Taylor & Francis Group

10. Culligan, K. et al., The mesocolon: A prospective observational study. *Colorectal Dis*, 2012. **14**(4): 421–428; discussion 428–430.
11. Coffey, J.C., Surgical anatomy and anatomic surgery—Clinical and scientific mutualism. *Surgeon*, 2013. **11**(4): 177–182.
12. Treves, F., Discussion on the subsequent course and later history of cases of appendicitis after operation. *Med Chir Trans*, 1905. **88**: 429–610.
13. Standring, S., *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. Churchill Livingstone/Elsevier, Edinburgh, Scotland, 2008, pp. 1069–1083, 1099–1111, 1125–1163.
14. Moore, K.L., A.F. Dalley, and A.M.R. Agur, *Clinically Oriented Anatomy*. Wolters Kluwer Health, Philadelphia, PA, 2013, pp. 219–221, 239–263.
15. McConnell, A.A. and T.H. Garratt, Abnormalities of fixation of the ascending colon: The relation of symptoms to anatomical findings. *Br J Surg*, 1923. **10**: 532–557.
16. Culligan, K. et al., The mesocolon: A histological and electron microscopic characterization of the mesenteric attachment of the colon prior to and after surgical mobilization. *Ann Surg*, 2014. **260**(6): 1048–1056.
17. Coffey, J.C. et al., An appraisal of the computed axial tomographic appearance of the human mesentery based on mesenteric contiguity from the duodenojejunal flexure to the mesorectal level. *Eur Radiol*, 2016. **26**(3): 714–721.
18. Coffey, J.C. et al., Mesenteric-based surgery exploits gastrointestinal, peritoneal, mesenteric and fascial continuity from duodenojejunal flexure to the anorectal junction—A review. *Dig Surg*, 2015. **32**(4): 291–300.
19. Culligan, K. et al., Review of nomenclature in colonic surgery—Proposal of a standardised nomenclature based on mesocolic anatomy. *Surgeon*, 2013. **11**(1): 1–5.
20. Coffey, J.C. et al., Terminology and nomenclature in colonic surgery: Universal application of a rule-based approach derived from updates on mesenteric anatomy. *Tech Coloproctol*, 2014. **18**(9): 789–794.
21. Coffey, J.C. and D.P. O'Leary, The mesentery: structure, function, and role in disease. *Lancet Gastroenterol Hepatol*, 2016. **1**(3): 238–247.