Ward's Intestinal Wall Model

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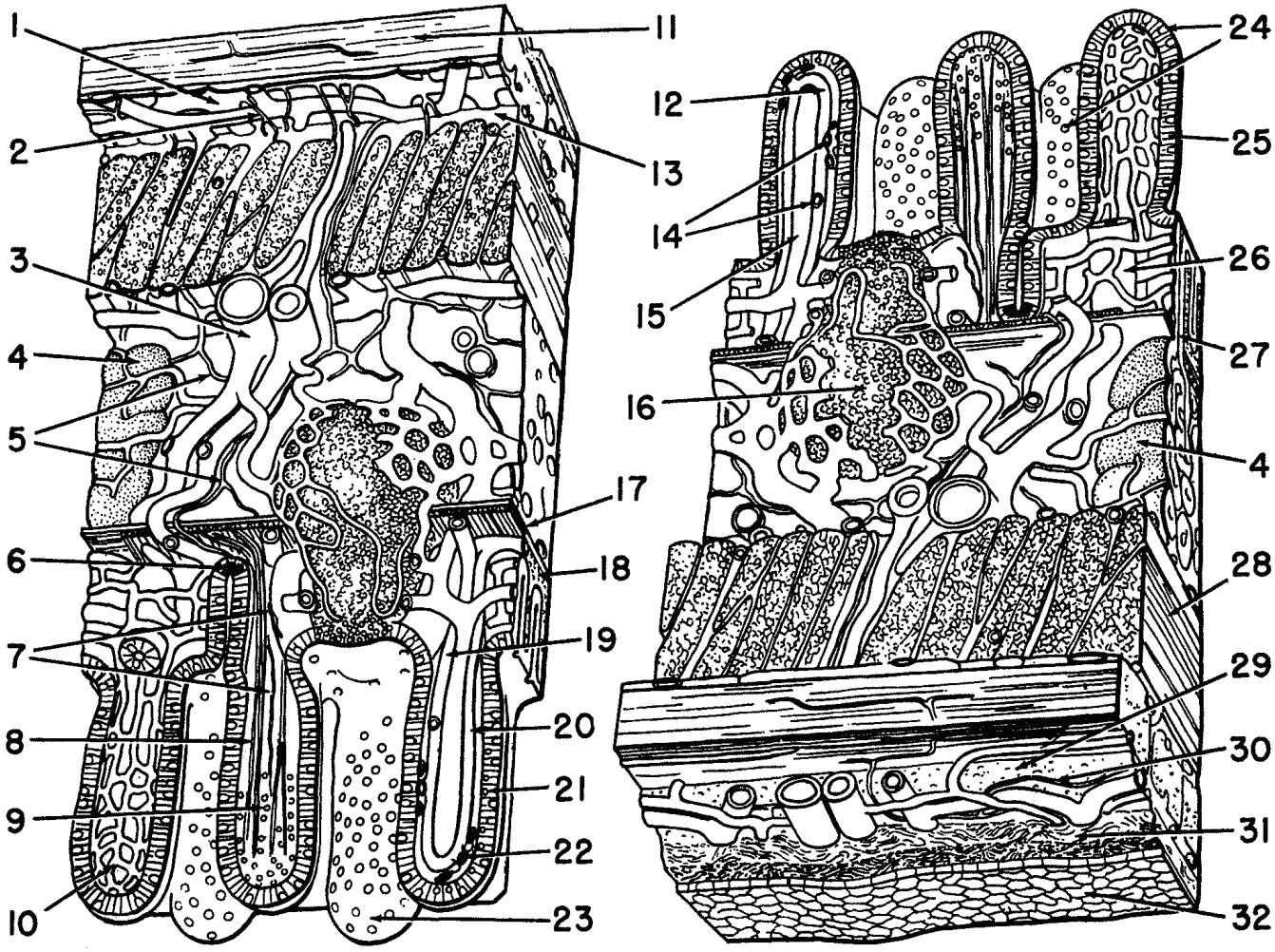

1. Myenteric plexus of Auerbach
2. Myenteric plexus of Auerbach
3. Large distributing vessels
4. Brunner's gland
5. Submucous plexus of Meissner
6. Paneth cells
7. Nerves of villi and glands
8. Muscle cells of villus
9. Wandering cells in stroma of villus
10. Capillary net of villus
11. Longitudinal muscle layer
12. Arterio-venous anastomosis
13. Lamina intermuscularis
14. Connections of villus capillaries with vein
15. Central lacteal of villus
16. Lymph follicle
17. Muscularis mucosae
18. Cell-rich zone of lamina propria
19. Efferent vein of villus
20. Afferent artery of villus
21. Lymphocytes in epithelium
22. Connection of artery and capillary net of villus
23. Villus
24. Goblet or mucous cells
25. Columnar epithelium of mucosa
26. Glands (crypts) of Lieberkuehn
27. Opening of Brunner's gland into crypt
28. Circular muscle
29. Subserous connective tissue, loose layer
30. Subserous nerve plexus
31. Subserous connective tissue, dense layer
32. Squamous epithelium of serosa

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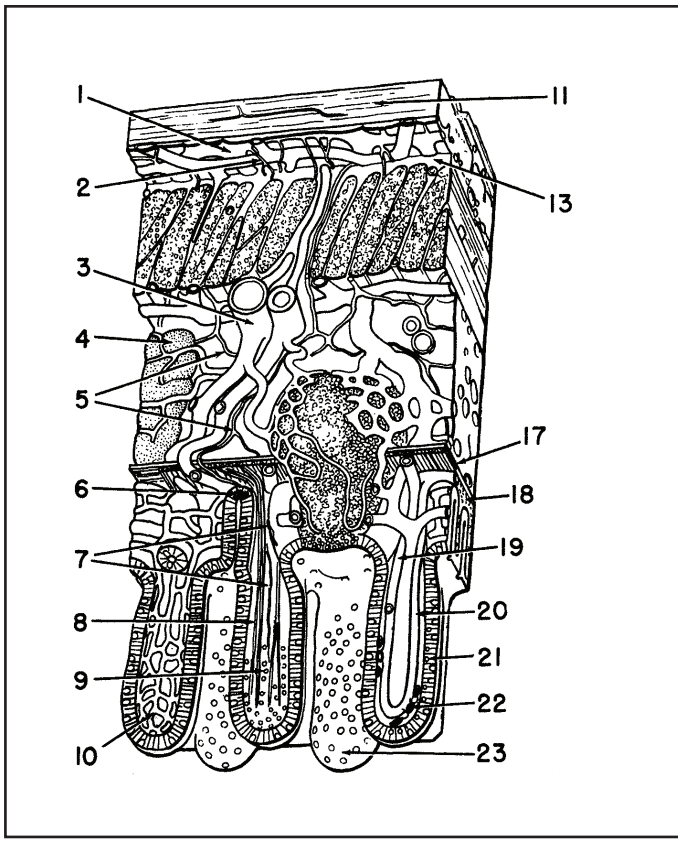
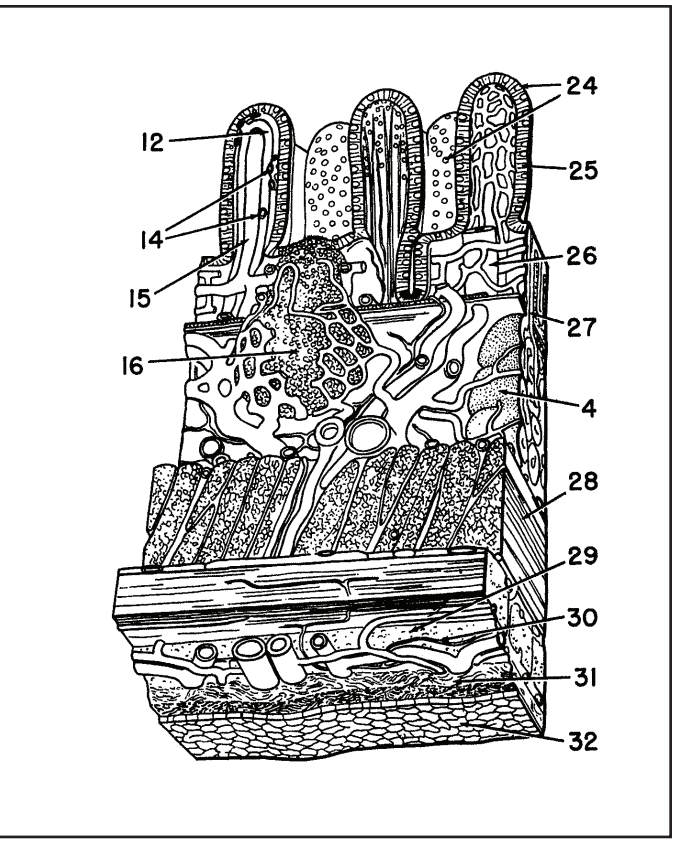
The intestinal wall of different mammals varies considerably in relative development and thickness of different layers, and in the finer pattern of circulation. The model represents a microscopic portion of the wall of the small intestine of man, magnified approximately 180X. The villi (23) constitute the inner, the serosa (32) the outer surface of the gut. The longitudinal axis is transverse in the model. The wall of the gut is divisible into several layers from within outward: (a) the **mucosa**, outwardly bordered by the **muscularis mucosae** (17); (b) the **submucosa**; (c) the **muscularis propria,** consisting of internal and external coats; and (d) the **serosa** embracing the outer coverings. The relative thickness of these coats varies in different regions and with the state of contraction. The model is composite in that it shows a Brunner's gland, characteristic of the duodenum, and a large lymph follicle, of the type occurring in the ileum. All muscle of the intestine is smooth muscle. The model shows three breakdowns of the villi to different levels. The cylindrical villi shown are more characteristic of the ileum. Those of the duodenum are tongue or leaf-like, set transversely. The mucosa of the small intestine is thrown into transverse circular or semicircular folds, the so-called **Kerckring's valves** or **plicae circulares**. But a model of gross anatomy would be required to show these, as well as the course of the major blood vessels.



The blood and lymph vessels enter the wall of the intestine along the mesenterial border, penetrate and encircle the gut at various levels in the wall, chiefly in the subserosa, muscularis, and submucosa. These larger vessels are connected with each other by anastomoses (one of which is shown in the model), particularly near the mesenterial border. The small arteries and veins supplying the mucosa break through the muscularis mucosae independently. The arteries form a net on the floor of the mucosa, from which small branches arise to form the capillary bed surrounding the crypts and wider vessels ringing their mouths. Other larger stems ascend independently into the villi. The smaller villi have only a single supply artery. The larger leaf-like villi of the duodenum have several. In any case, near the tip of the villus (22) the artery divides to supply the capillary network on the one hand, and on the other passes over as an arterio-venous anastomosis into the efferent vein. The capillary network of the villus consists of small irregular meshes near the summit and long rectangular meshes near the base. It is everywhere superficial, being intimately bound to the basement membrane of the epithelium.

The vein drains the capillary network at one or more points near the middle of the villus (14). The A-V anastomosis (12) provides a shunt enabling blood to by-pass the capillary circulation of the villus during periods of fasting. The capillary bed of the crypts does not connect directly with the veins, but only through the capillary beds of the villi, with which it is confluent. The efferent veins of the villi may join with others before penetrating the muscularis mucosae.



Each villus, depending upon its form, contains one or more blindly ending lymphatic vessels, the central lacteals (15), which vary widely in diameter with the state of digestion. Toward the villus base the lacteal narrows, divides, and joins the lymphatic net of the mucosa, which forms wide meshes enclosing groups of crypts. Other stems descend from this net, penetrate the muscularis mucosae, and join the lymphatic plexus of the submucosa. Here the lymphatics form a plexus around, but do not penetrate, the lymph follicles, as do the blood capillaries. Other larger vessels pass toward the muscularis propria and give rise to a plexus on its inner surface. This plexus is in turn connected with the interlaminar net lying between the two muscle layers, and this in turn is joined through the longitudinal muscle with a plexus of smaller vessels lying in the subserosa. The larger lymph channels are provided with valves. Rhythmic contractions of the villi, set up by their intrinsic muscle cells (8) force the lymph out of the lacteals into the deeper vessels, where it is propelled by the alternate contractions of the muscular coats, aided by the action of the valves, and finally leaves the intestine along the mesenterial border.

The lymph follicles vary from solitary follicles lying entirely in the mucosa, to large follicles of the type shown, which in the ileum compose the Peyer's patches. Lymphocytes invade the epithelium, particularly above the follicles, but also elsewhere (21), and many pass into the lumen of the intestine. The lamina propria, or connective tissue forming the core of the villi, contains numerous wandering cells of different types: lymphocytes, plasma cells, mast cells, eosinophiles, and neutrophiles. A particularly cell-rich zone occurs between the crypts (18). In fact the entire stroma of the mucosa is marked by the abundance of these leukocytic elements, and for this reason it is often regarded as constituting a special type of connective tissue. For purposes of clarity, the cells of this cell-rich zone have been indicated only on the sides of the model. According to one school of thought, the wandering cells of the mucosa constitute the body's first line of defense against the bacteria of the intestinal lumen. According to another school of thought, they assist in the absorption of fats and possibly other substances from the intestinal contents. The question must be regarded as unsettled.

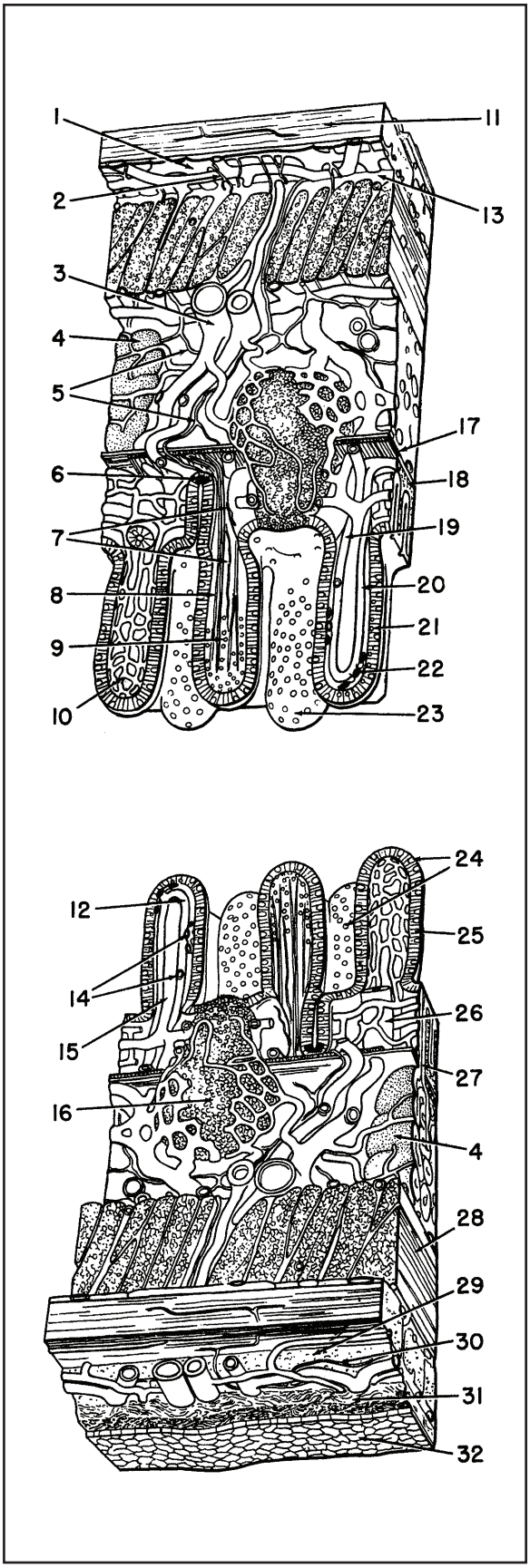
The epithelium of the entire mucosa is regenerated in the crypts, and moves outward over the surface of the villi, where the individual cells are finally shed into the intestinal contents, along with large quantities of mucus. Certain special types of cells appear in this epithelium, the Paneth cells (6), and the goblet cells (24) being particularly conspicuous. The basic cell type is columnar epithelium with a striated border, but Paneth cells may transform into goblet cells, and probably all the cells arise from a common stem cell.

The muscularis mucosae consists of two layers, as shown. The cells of this coat curve around blood vessels, or they may be completely interrupted by large obstacles like the lymph follicles. The fibers are quite irregular in course, but in general are circular in the inner, and longitudinal in the outer layer. The muscle strands of the villi are also anchored in this layer. The cells of the muscularis propria (11, 28) are gathered together in bundles, separated by lamellae of connective tissue. The circular muscle is always much more developed than the longitudinal.

The myenteric plexus of Auerbach consists of a coarse primary net of trunks and ganglia (1) from which finer branches (2) arise, forming a secondary plexus. Fibers from the primary plexus pass to both muscle layers, but the secondary plexus innervates the circular muscles exclusively. The fine subserous plexus (30) sends fibers to the longitudinal muscles. In the submucosa lies the rather delicate plexus of Meissner (5). Branches of this plexus penetrate the muscularis mucosae, and terminate on the glands, muscle fibers and vessels of the villi, on the fibers of the muscularis mucosae, and on Brunner's glands, etc. All plexuses of the intestinal wall are interconnected with each other, and centrally with the vagus and sympathetic systems.

The serous coat of the intestine consists of a squamous epithelium, underlain by a layer of interwoven elastic and collagenous fibers, which blends into the loose subserous connective tissue that serves as a pathway for blood vessels and nerves. These layers pass over onto the surface of the mesentery.

The connective tissue of the submucosa is very loose and poor in cells. It forms a highly elastic cushion for the delicate mucosa, and also serves as the space in which the much-coiled nerves and blood vessels distribute themselves evenly in order to supply all parts of the mucosa.



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