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Dr Cruikshank

from the author

On the structure of the Intestinal Villi in Man and certain of the Mammalia, with some observations on Digestion, and the Absorption of Chyle. By JOHN GOODSIR, Esq., M.W.S. Surgeon, and Conservator of the Museum of the Roy. Coll. Surgeons, Edinburgh.

Mr Cruikshank, in treating of the orifices of the Lacteals and Lymphatics,* states that he and Dr William Hunter observed the openings by which the lacteals communicated with the cavity of the gut in portions of the intestine of a woman who died after eating a hearty supper. The two preparations of the intestine on which these celebrated anatomists made their observations came into the possession of the College of Surgeons in Edinburgh, as part of the collection of the late Sir Charles Bell. When employed lately in removing these interesting specimens into fresh spirits, I availed myself of the opportunity of examining into the nature of the appearances described and figured by Mr Cruikshank.†

I removed one of the villi from Mr Cruikshank's preparation,‡ placed it between two glass plates, and had no difficulty in recognising what had been described and figured by the original owner of the preparation. With a low power the extremity of the villus appeared bulbous and opaque. With a higher power I observed that this opacity was due to the existence, at the extremity of the villus, of a number of vesicles of different sizes. The larger vesicles were pretty uniform in size, and about twenty in number. The smaller were of different sizes and more numerous, and appeared gradually to pass into the granular looking tissue of the attached extremity of the villus. No blood-vessels could be detected, but along the neck of the villus distinct traces of two or more opaque lacteals were visible. The vesicles and the lacteals, when

* William Cruikshank. The Anatomy of the Absorbing Vessels of the Human Body, 2d Ed. 1790, page 56.

† Loc. Cit. Plate 11, figs. 2, 3.

‡ xiii. 4 N. 49, Bell Catalogue.

viewed by transmitted light, were of a light brown colour; but when examined as opaque objects, against a dark ground, they stood out of a dead white appearance, contrasting strongly with the semi-transparency of the surrounding tissue. Repeated examinations of these preparations satisfied me that Dr William Hunter and Mr Cruikshank were quite correct in describing and figuring radiating lacteals within the villi, but that they were led into error in describing those vessels as opening on the free surface of the gut, partly by imperfect instruments and methods of observation, partly by the general prejudice of the period in favour of absorbent orifices. I also satisfied myself of what appeared highly probable from the commencement of the observations, that the villi, when turgid with chyle, were destitute of their ordinary epithelial covering. This circumstance I could not avoid connecting with the fact of the stomach throwing off its epithelia during the process of digestion. I determined, therefore, to investigate the process of absorption of chyle in fresh subjects, as the facts exhibited in Mr Cruikshank's preparations indicated the probable existence of complicated processes going on in villi during digestion. The analogy of the vesicular bulbous extremity of the villus, to the spongiole of the vegetable, forced itself upon me; and the existence of milky chyle, within closed cells, led me to anticipate an explanation of some of the phenomena of digestion.

A dog was fed with oatmeal, milk, and butter. Three hours afterwards he was killed, and a cord thrown round the root of the mesentery. The lacteals became more turgid, and the gut, when opened, was found to be full of milky chyme, with an admixture of thin brownish fluid of a bilious appearance. The milky matter was situated principally towards the mucous membrane; the brown fluid occupied the cavity of the gut.

The white matter was found to consist of a transparent fluid, with a few oil globules, and numerous epithelia.

Some of the epithelia I recognised as those which cover the villi. They were pointed at their attached extremities, flat at the other. (Fig. 1, Pl. I.) Many of them were single, others were united in bundles, adhering principally by their flat or free extremities, as if a fine membrane passed over and connected

the edges of their extreme surfaces. (Fig. 2, Pl. I.) Occasionally these epithelia presented a distinct nucleus ; but generally, and whether single or in bundles, they exhibited in their interior a group or mass of oil-like globules, which, when viewed as opaque objects, had a peculiar semi-opaque or opalescent appearance.* (Fig. 3, Pl. I.) Others of the epithelia, contained in the chyme, were prismatic, single, or in columns. (Fig. 4, Pl. I.) They were the lining epithelia of the follicles of Lieberkühn, and presented the usual nuclei.

The mucous membrane displayed the villi turgid as if in a state of erection, and, as I had anticipated, naked or destitute of epithelia, except at their bases where a few still adhered. Each villus was covered by a very fine smooth membrane, which from its free bulbous extremity, passed on to its sides, and became continuous with what I have elsewhere denominated the primary membrane (Trans. Roy. Soc. Ed. 1842) of the follicles of Lieberkühn. (Fig. 8, Pl. I.) These villi when removed from the mucous membrane, and examined with $\frac{1}{3}$ inch magnifier, were semi-transparent, except at their free or bulbous extremities, which appeared both by direct or transmitted light white and opaque ; under higher powers they exhibited appearances represented in fig. 6, Pl. I. The summit of the villus, somewhat flattened, was crowded immediately under the membrane before mentioned, with a number of perfectly spherical vesicles. These vesicles varied in size from 1000 to less than 2000 of an inch. The matter in their interior had an opalescent milky appearance. Towards the body of the villus on the edges of the vesicular mass, minute granular or oily particles were situated in great numbers, and gradually passed into the granular texture of the substance of the villus.

The trunks of two lacteals could be easily traced up the centre of the villus, and as they approached the vesicular mass they subdivided and looped. In no instance could one of these lacteals be traced to any of the spherical vesicles, nor could any direct communication between the structures be detected. The bloodvessels and capillaries, with their columns of tawny

* Is this appearance due to a partial absorption of chyle by these protective epithelia ?

blood disks, could be seen passing in radiating lines and in loops across the villus, immediately under the fine membrane already mentioned. This membrane, perceptible on the body and neck of the villus only by the smooth surface it presented, was most distinctly traced at the free extremity of the villus, as it passed from the surface of one vesicle on to that of another. The vesicles pushing the membrane forward, and grouped together in masses on its attached surface, gave the extremity of the villus the appearance of a mulberry. When viewed on a dark ground as an opaque object, the point directed to the light, a villus in this condition is remarkably beautiful, the play of the light on the surface of the highly refractive semi-opaque and opalescent vesicles, giving them the appearance of a group of pearls.

In villi turgid with chyle, which have been kept for some time in spirits, the contents of the vesicles are opaque, the albumen having become coagulated.

The villi of the rabbit exhibit similar vesicles during digestion, and I am at present engaged in preparing drawings and descriptions of these formations in the different classes of the animal kingdom.

To understand the part which the vesicles of the villus play in digestion, it is necessary to be aware of certain of the functions of the cell, with which physiologists are yet unacquainted. Not only are these bodies the germs of all the tissues, as determined by the labours of Schleiden and Schwann, but as I have observed, they are the immediate agents of secretion. (Trans. Roy. Soc. Edin. 1842.) A primitive cell absorbs from the liquor sanguinis which surrounds it, and which is supplied by the capillaries, the matters necessary to enable it to form, in one set of instances, nerve, muscle, bone, if nutrition be its function; milk, bile, urine, in another set of instances, if secretion be the duty assigned to it. The only difference between the two functions being, that in the first, the cell dissolves nd disappears among the tissues, after having performedits part; in the other, it dissolves, disappears, and throws out its contents on a free surface. Now, it will be perceived that before a cell can perform its function as a nutritive cell,

or as a secreting cell, it must have acted as an absorbing cell.* This absorption, too, must necessarily be of a peculiar and specific nature. It is in virtue of it, that the nutritive cell selects and absorbs from the liquor sanguinis those parts of the latter necessary for building up the peculiar tissue of which the cell is the germ. It is in virtue of this peculiar force that the secreting cell not only selects and absorbs, but also in some instances elaborates, from the same common material, the particular secretion of which it is the immediate organ. And it is by the same force that the cell becomes the immediate agent of absorption in certain morbid processes.

The primitive cell, then, is primarily an organ of specific absorption, and secondarily of nutrition, growth, and secretion.

With these few introductory observations on subjects which

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* "Absorption," says Professor Müller, Baly's Translation, p. 301, "seems to depend on an attraction, the nature of which is at present unknown, but of which the very counterpart, as it were, takes place in secretion; the fluids altered by the secreting action being impelled towards the free surface only of the secreting membranes, and then pressed onwards by the successive portions of fluid secreted. In many organs, for instance in those invested with mucous membranes—absorption by the lymphatics and secretion by the secreting organs, are going on at the same time on the same surface." It appears, however, from what I have stated in the present paper, and in Trans. Roy. Soc. Edin. 1842, that Prof. Müller, and indeed all the physiologists hitherto have been in error in supposing the forces of secretion and absorption as of different and opposite tendencies,—the one attractive, the other repulsive. They are both attractive, absorption being but the first stage in the process of secretion. Secretion, in fact, differs from absorption, not physiologically, but morphologically.

What has been stated in the present paper explains also how, in the mucous membranes, "absorption by lymphatics and secretion by secreting organs are going on at the same time on the same surface." (Müller, *loc. cit.*) There is no physiological mystery in this. It depends on a morphological circumstance. The absorbing chyle cells are on the attached surface of the primary membrane—the secreting epithelia are on its free surface; the former are interstitial cells, the latter peripheral; the former cast their contents into the substance of the organism,—the latter into the surrounding medium. It may be here observed that absorption, as it occurs in the chyle vessels, takes place as in the absorption which occurs in all the secreting cells, through two structureless membranes, probably molecular in their constitution—the primary membrane and the membrane of the cell.

I shall consider more at length on another occasion, I may proceed to apply the laws of structure and function of the cell to the structure and function of the intestinal villi.

As the chyme begins to pass along the small intestine, an increased quantity of blood circulates in the capillaries of the gut. In consequence of this increased flow of blood, or from some other cause with which I am not yet acquainted, the internal surface of the gut throws off its epithelium, which is intermixed with the chyme in the cavity of the gut. The cast off epithelium is of two kinds,—that which covers the villi, and which, from the duty it performs, may be denominated the *protective* epithelium, and that which lines the follicles, and is endowed with secreting functions. The same action, then, which, in removing the epithelia from the villi, prepares the latter for their peculiar function of absorption, throws out the secreting epithelia from the follicles, and thus conduces towards the performance of the function of these follicles.

The villi, being now turgid with blood, erected, and naked, are covered or coated by the whitish-grey matter already described. This matter consists of chyme which has undergone the changes induced in it by the bile, of cast off epithelia of the villi, and of the secreting epithelia of the follicles. The function of the villi now commences. The minute vesicles which are interspersed among the terminal loops of the lacteals of the villus (fig. 6, Pl. I.), increase in size by drawing materials from the liquor sanguines, through the coats of the capillaries, which ramify at this spot in great abundance. While this increase in their capacity is in progress, the growing vesicles are continually exerting their absorbing function, and draw into their cavities that portion of the chyme in the gut necessary to supply materials for the chyle. When the vesicles respectively attain in succession their specific size, they burst or dissolve, their contents being cast into the tissue of the villus, as in the case of any other species of interstitial cell.

The looped network of lacteals, like the other lymphatics, continually exerting their peculiar function, take up the remains, and the contents of the dissolved chyle cells, as well as the other matters which have already subserved the nutrition of the villus. As long as the cavity of the gut contains

chyme, the vesicles of the terminal extremity of the villi continue to develope, to absorb chyle, and to burst, and their remains and contents to be removed by the interstitial absorbent action of the lacteals.

When the gut contains no more chyme, the flow of blood to the mucous membrane diminishes, the development of new vesicles ceases, the lacteals empty themselves, and the villi become flaccid.

The function of the villi now ceases till they are again roused into action by another flow of chyme along the gut.

During the intervals of absorption, it becomes necessary to protect the delicate villi from the matters contained in the bowel. They had thrown off their protective epithelium when required to perform their functions, just as the stomach had done to afford gastric juice, and the intestinal follicles to supply their peculiar secretions. In the intervals of digestion, the epithelium is rapidly reproduced. Repeated examinations have induced me to believe that this reproduction is accomplished in the following manner.

That peculiar diaphanous membrane which I have denominated (Trans. Roy. Soc. Ed., 1842) the primary membrane, and which, as I have stated, not only forms the outer membrane of the follicles, under the epithelia, but also the underlying membrane of the villi, contains in its substances nuclei of an oval form, situated at pretty regular distances. These nuclei have a dark spot in the centre, and are always visible when the epithelium is removed. The membrane consists of flattened cells, the nuclei of which continue active. Blood vessels, therefore, do not exist in this membrane, but ramify beneath it, as in glands. Serous membranes have a similar constitution.

These nuclei I have elsewhere shewn to be germinal spots or centres of reproduction and growth in the secreting glands (*loc. cit.*). More extended observation has convinced me that they are the centres from which all epithelium, whether secreting or protective, is formed. The process is similar to that described by Reichart and Dr M. Barry, as taking place in the ovum. Cells form in the centre of the spot. These cells increasing in size, and having other cells in their interior,

pass off in a radiating direction in the plane of the primary membrane, and gradually assuming the form and properties of the epithelium of the region, till they meet and form a continuous layer of nucleated particles which cover the primary membrane, from whose nuclei they sprung. These nuclei still remain as sources of future crops of epithelia.

During this process of development, the primary membrane would appear to split into two laminæ, the epithelia passing out from its nuclei between these. This would account for the epithelia, particularly the prismatic and conical, adhering by their free extremities.

Such are the processes which would appear to take place in the villi of the intestinal tube during digestion and absorption. When considered in relation to the functions of digestion and absorption of chyle, these processes are highly interesting.

The labours of the chemist have now so far simplified the theory of digestion, as to deprive the stomach of their vitalizing or organizing powers so long ascribed to it.

Every step in this chemico-physiological inquiry leads to the conclusion that the changes which the food undergoes while in the cavity of the gut are entirely of a chemical nature.

If we continue, then, to apply the term digestion to that series of processes by which the aliment is assimilated to the matter of which the body is composed, we must divide the series into two groups. The first group will include all those changes which take place *within* the digestive tube, but *exterior* to the organism. The second will include those which present themselves after the alimentary matter is taken up into the animal body, and becomes buried in its substance. The first group of processes are mechanical and chemical in their nature. They may be considered in a great measure as peculiar to the animal, although even vegetables throw out from their roots matter which, acting on some of the materials of the surrounding soil, prepare these for absorption.

The second group of processes is common to animals and vegetables. In these, for the first time, are alimentary substances taken into the tissues of the organism. In animals, as in plants, as I have already pointed out, these alimentary

substances are drawn by a peculiar force into the interior of cells, after escaping from which they are taken up by the absorbent system. The chemist has not yet informed us of the change which the matter has undergone during its passage from the cavity of the gut, or from the soil, into the afferent lacteals and the sap-vessels ; but if in vegetables, as in animals, this matter passes through the coats and is lodged in the cavities of the cells of the spongiole before it passes on to the sap-vessels, then it is highly probable that the organizing and vitalizing part of the function of digestion commences in the cells of the spongiole and of the extremity of the villus.

The extremity of the fibril of the root of a plant elongates by the cells added to its tissue by the germinating spongiole. The spongiole is, therefore, an active organ of growth as well as of absorption. It is to the fibril of the root what I have denominated in the animal tissues the germinal spot. I conceive it to be probable, therefore, although as to this I have made no observations, that absorption by, and elongation of, the fibril of the root vary inversely as one another. This supposition is founded on the assumption that the cells of the spongiole do not absorb by transmission but by growth and solution.

In the villi of the intestines of animals my own observations lead me to believe that absorption by growth and solution is the process which actually takes place.

The vesicular extremity, like the spongiole of the root fibril, is the primitive germinal spot of the villus. The villus originates in a cell, one of those which form the last deposit from the substance of the yelk. During the development of the villus, this spot or cell was employed only in procuring materials for the growth of the organ. In the perfect animal, the formative function of the spot ceases ; its action becomes periodical, active during digestion, at rest during the intervals of that process. The same function is performed, the same force is in action, and the same organ, the cell, is provided for absorption of alimentary matters in the embryo, and in the adult, in the plant, and in the animal. The spongioles of the root, the vesicles of the villus, the last layer of cells on the internal membrane of the included yelk, or the cells which cover the vasa lutea of the depende[illegible] yelk, and as I have satisfied myself, the cells which

cover the tufts of the placenta, are the parts of the organism in which the alimentary matters first form a part of that organism, and undergo the first steps of the organizing process.

Explanation of the Plate.

Fig. 1. Protective epithelium cells from a villus in the dog.

Fig. 2. A group of the same cells adhering by their distal extremities.

Fig. 3. Protective epithelium cells, cast off preparatory to absorption of chyle; instead of nuclei, they present, in their interior, groups of globules.

Fig. 4. Secreting cells thrown out of the follicles of Leiberkühn during digestion.

Fig. 5. Extremity of a villus immediately before absorption of chyle has commenced. It has cast off its protective epithelium, and displays, when compressed, a net-work of peripheral lacteals. The granular germs of the absorbing vesicles, as yet undeveloped, are seen under its primary membrane.

Fig. 6. Extremity of a villus, with its absorbent vesicles distended with chyle, and the trunks of its lacteals seen through its coats.

Fig. 7. Diagram of mucous membrane of jejunum when absorption is not going on. *a* Protective epithelium of a villus. Secreting epithelium of a follicle. *c c c* Primary membrane, with its germinal spots or nuclei, *d d*. *e* Germs of absorbent vesicles. *f* Vessels, and lacteals of villus.

Fig. 8. Diagram of mucous membrane during digestion and absorption of chyle. *a* A villus, turgid, erect; its protective epithelia cast off from its free extremity; its absorbent vesicles, its lacteals, and blood-vessels turgid. *b* A follicle discharging its secreting epithelia.

IDEAL SECTION OF THE ALPINE SYSTEM.

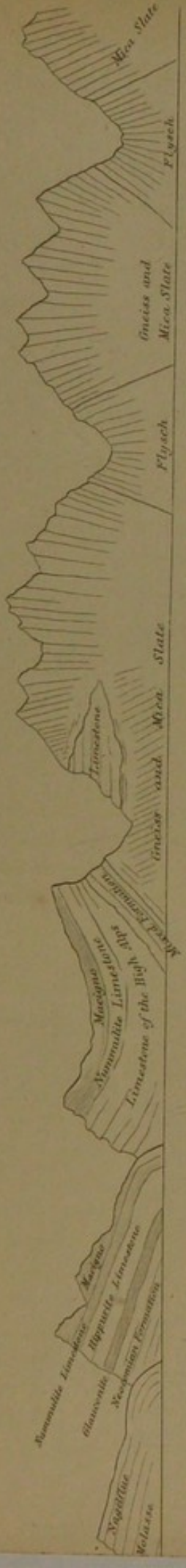

Fig. 1.

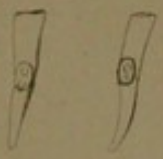

Fig. 2.

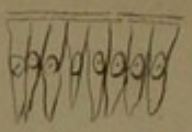

Fig. 3.

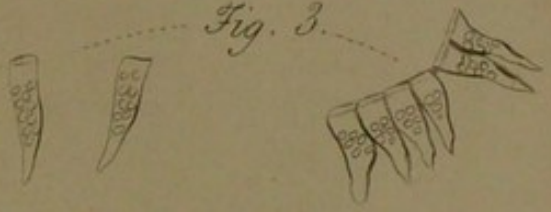

Fig. 4.

Fig. 5.

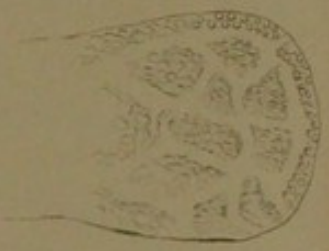

Fig. 6.

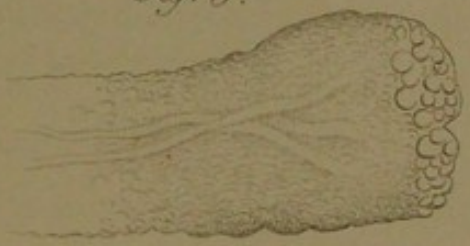

Fig. 7.

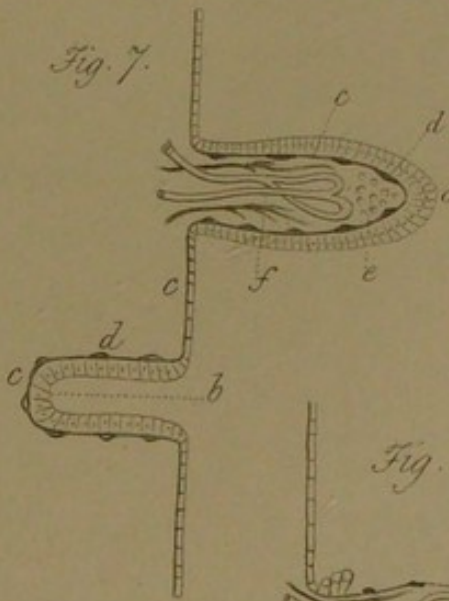

Fig. 8.