II. "On the Changes in Pepsin-forming Glands during Secretion." By J. N. LANGLEY, M.A., Fellow of Trinity College, Cambridge, and H. SEWALL, B.Sc., Fellow of the Johns Hopkins University, Baltimore, U.S.A. Communicated by Professor MICHAEL FOSTER, M.D., F.R.S. Received October 13, 1879.

The Œsophageal Glands of the Frog. (Rana temporaria.)

In a frog three to four days after food the acini of the œsophageal glands in the living state are granular throughout, and so thickly granular that the outlines of the alveoli are but faintly indicated, the outlines of the cells not at all seen, nor are there any indications of nuclei.

Shortly after food is given, the granules thin away at the peripheries of the alveoli and so render the alveolar outlines more obvious. This thinning proceeds so rapidly that in a few hours there is a well-marked clear zone in the outer part of each alveolus, the part nearest the basement membrane.

Later the clear zone becomes larger, the granular zone becoming smaller, but as the clear zone enlarges it ceases to form in section a ring, it dips down into the granular zone at intervals, or in other words, the cells in using up their stored granules do not all use them up at the same rate, some are more energetic than others, so that the granular zone takes in section a somewhat star shape. In addition to this, the star-form of the granular zone is aided by the granules along the margins being less readily used up than those in the interior of the cells.

Nuclei are as little seen in the digesting as in the resting gland. The glands having then as digestion goes on got rid of a large number of their granules, proceed to form others as digestion ceases. The clear spaces between the points of the star are filled up, and the clear zone forms granules from within outwards, until the granules once more extend to the basement membrane.

An indication of the changes taking place in the alveoli of the glands can be seen in the œsophagus itself with the unaided eye; in a hungry frog the œsophagus is an opaque white, in a digesting frog it is greyer and more transparent.

Frogs in an ill state of health do not show the full granular condition characteristic of the hungry frog, the granules are much less numerous, and often, indeed, do not extend to the basement membrane; with these, however, as with healthy frogs, the granules diminish during digestion.

The granules we have hitherto spoken of may be called "central"

granules, to distinguish them from others which occur immediately beneath the basement membrane. These "border" granules are smaller and more highly refractive; they occur usually in small clumps.

The points mentioned above as observable in the fresh tissue, can also in the main be observed in glands treated first with osmic acid and then with alcohol. There are one or two things to be noticed in sections of glands so treated. The border granules stain more deeply and readily than the central granules. The mucous cell granules have disappeared, the cells present the usual characters of a mucous cell in hardened specimens. In the resting gland the nuclei are generally hidden; in the digesting gland the nuclei are large, spherical, situated in the clear zone, with faint outlines; the nucleolus is deeply stained and prominent. In the digesting there are fewer obvious mucous cells than in the resting gland.

Nussbaum* has made some observations on the glands treated with osmic acid; it will be noticed that we differ from him in almost every respect.

Swieçicki† found the glands after treatment with alcohol, to be, in the digesting state as a rule, larger, more granular, and better staining. The greater granulation here obviously only means that in the digesting state there is a greater amount of substance precipitable by alcohol in the granular condition. The cells when alive are less granular during digestion.

Partsch,‡ working also with hardened specimens, found the glands to increase in size as they secreted, but only for the first 5—10 hours.

Whilst not prepared to deny that an increase of size may in the first stages take place, we have failed to observe it, and are inclined to think that as the granules are used up, there is a steady diminution in the size of the glands.

Comparing Grützner's§ observations on the amount of ferment present in the glands in hunger and digestion with our own on their varying granular state, we find that the ferment diminishes during digestion as do the granules. For this and other reasons we are inclined to consider the granules as stored up cell products which, on suffering molecular re-arrangement, give rise amongst other substances to the proteid ferment.

Nussbaum also holds this, ascribing however both to granules and ferment a different maximal time. We cannot agree with Nussbaum's view that the depth of staining with osmic acid tells the amount of ferment unless perhaps it is restricted much more than he is inclined

* Max Schültze. "Arch. f. Mik. Anat." Bd. xiii, p. 746, 1877.
† Pflüger. "Archiv f. d. Ges. Physiologie," Bd. xiii, p. 444, 1876.
‡ Max Schültze. "Arch. f. Mik. Anat." Bd. xiv, p. 179, 1877.
§ Pflüger. "Arch. f. d. Ges. Physiologie," Bd. xvi, p. 122, 1877.

to restrict it. On his view it appears to us the border rather than the central granules should be connected with the ferment.

The Gastric Glands of the Newt (Triton Tæniatus).

In the newt the glands were observed through the muscular coat of the stomach, with a rapid capillary circulation still going on.

Twenty-four hours after feeding, the glands of the fundus are thickly granular throughout; about three hours after feeding, the maximal change takes place; it corresponds in the main to that already described for the œsophageal glands of the frog. In the newt the lumina and cell outlines become more conspicuous, the clear zone is generally less sharply marked off from the granular zone; and the star arrangement of the granules is apparently only caused by the presence of granules along the lateral margin of the cells after those in the interior have disappeared.

The glands recover their granular appearance comparatively quickly; in six hours after feeding, the granules have usually again crept up to the periphery, they then increase in number throughout the cells up to about the twenty-fourth hour. Later than this they diminish somewhat, in six days the peripheries of the glands have become more sparsely populated. It is at this period that digestion changes are most readily observed.

The pyloric glands are clear, or very finely granular, changes in them would be much less conspicuous, in such observations as we have made; we have seen no difference in the hungry and digesting states.

In *Triton cristatus* the digestive changes are of the same nature, but much less pronounced.

The Gastric Glands of Stickleback (Gasteropodus trispinatus ?)

We chose the stickleback mainly for its voracity, there is seldom any difficulty in feeding it.

In the gastric glands of the hungry fish, the granules thin away somewhat from the centre to the periphery, the lumina are inconspicuous; three to five hours after feeding the lumina are much larger, the granules are aggregated about it leaving a peripheral clear rim, the glands are more unequal in size, some having lost more granules and diminished more in size than others.

The Gastric Glands of Mammals.

Examining in the fresh state, the glands of the fundus of the dog, cat, or rat, we find that the body of each gland is marked out sharply into two parts. A central part near the lumen, consisting of many rather large sharp granules, these granules form a central mass, which here

and there branches out to the periphery, no cell outline at all can be seen. A peripheral very finely granular almost homogeneous part.

The necks of the glands are finely granular, with scattered small dark granular patches. By treatment with 33 per cent. potash and other re-agents, it can be seen that the dark granules are contained in the chief-cells; the outer finely granular or clear portion of the glands being the border-cells. At the outer border, the outlines of the border-cells can be well seen; at the junctions of the cells, however, the outlines disappear. No nuclei are visible. The small dark granular patches in the necks of the glands are found to be also the chief-cells which are here and there scattered amongst the border-cells.

The pyloric glands in the fresh state are fairly transparent, finely granular to homogeneous. The lumina are usually distinct, and often stretch up between the cells; apart from this no cell outlines are visible. No nuclei are to be seen.

Heidenhain* described correctly the appearance of the fresh fundus glands; except that he mentions the nuclei of the border-cells as being normally just visible.

Ebstein,† I think, implies that the pyloric glands are normally not coarsely granular.

Yet Heidenhain, Ebstein, Grützner, and others, who advocate the identity of the chief-cells with the pyloric gland cells, do not seem to have noticed the difference existing between the two cells in the fresh state. The difference is, however, most marked.

The above description is of the chief-cells in the resting state. If the glands are observed a few hours after a hungry animal has been fed, the central granular mass in the body of the gland is found to have very much diminished. A transverse section instead of showing a thick mass of granules stretching here nearly, there quite to the periphery, show a narrow rim or star of granules.

During secretion then the granules of the chief-cells are used up.

The stomach of the rabbit deserves especial consideration. It may be divided into four portions, each in succession graduating into the next.

1. The *Fundus* or dilatation at the cardiac end of the stomach. This is to the eye of an opaque white colour. The body of each gland shows comparatively few border-cells, but consists mainly of a darkly granular mass of chief-cells.

2. The *Greater Curvature*. This is to the eye somewhat pink; in fresh specimens scarcely any dark granules are to be seen. In passing from the fundus to the greater curvature, the number of dark granules gradually diminishes, at first being confined more and more to the

* Max Schültze. "Arch. f. Mik. Anat." Bd. vi, p. 368, 1870.

† P. 515, 1870.

deeper parts of the glands than those also taking a thin rim or star arrangement.

3. The *Lesser Curvature*. The glands here have the character given above for pyloric glands.

4. The *Pylorus*. The glands are simply shallow depressions of the mucous membrane, and are still more transparent than the glands of the smaller curvature.

In hunger the opaque thickly granular region encroaches on the greater curvature.

In digestion the granules diminish, beginning at the opaque part near the greater curvature, so that the opaque thickly granular region is more and more limited to the extremity of the fundus.

As far as concerns the diminution of the coarse granules of the chief-cells during digestion, this is but a repetition of what we have already said of the dog, cat, and rat. The point of additional interest is this. Sections of alcohol-hardened fragments of the greater curvature show that here, as well as in the fundus, there are a large number of chief-cells. Probably no one examining such sections of the greater curvature would consider them as other than typical fundus glands with chief-cells and border-cells. Yet the former cells in the fresh state do not contain the coarse granules characteristic of chief-cells.

Deferring for a moment the consideration of this, we would mention some experiments we have made on the amount of ferment-content of the various parts of the rabbit's stomach.

Equal-sized pieces of the mucous membrane of a rabbit were taken and put in absolute alcohol. A. From the fundus. B. From the greater curvature. C. From the smaller curvature, including part of the pylorus. These were kindly tested for ferment by Mr. Sheridan Lea, of Trinity College, both by the ordinary digestive method and by Grützner's colorimetric method. The result was that A contained more ferment than either B or C; B and C contained a not very different amount, B rather more than C.

Now A contained border-cells and coarsely granular chief-cells; B contained more border-cells than A, but chief-cells with scarcely any coarse granules; C contained only pyloric cells, with possibly here and there a solitary border-cell.

Hence the part with the pre-eminently large number of border-cells offered hardly appreciably more pepsin than the part containing few, if any; the conclusion that the border-cells do not form pepsin appears to us unavoidable.

Moreover a comparatively very large amount of pepsin was contained in the part of the mucous membrane with a densely granular chief-cell. This, we think, is enough to connect the ferment with these granules; in this opinion we are confirmed by the result of the following experiment. Two rabbits of the same breed, and in all

respects as much as possible alike, were taken; one was killed hungry, *i.e.*, twenty-four hours after feeding, the other in full digestion some 5—6 hours after a plenteous meal. The gastric mucous membrane showed the usual difference to the unaided eye and to microscopical examination; equal-sized pieces were removed from as near as possible a corresponding position of the fundus of each animal. They were tested by Mr. Lea for ferment, the resting more granular piece was found to possess a not inconsiderably greater amount of ferment than the active less granular piece. We may recall that Grützner found the amount of ferment to diminish during digestion.

There is one other fact which leads us to connect the chief-cell granules with the ferment; in protracted hunger the chief-cell granules, instead of increasing diminish, as we have mentioned above, occurs in the newt; according to Grützner, in protracted hunger, the ferment-content of the gastric mucous membrane diminishes.

To return to the consideration of the meaning of the finely granular chief-cells of the greater curvature. These differ but little, histologically, from the pyloric gland cells. Both form pepsin. Such close similarity in form and function justify us in considering them to be fundamentally the same kind of cell. How, then, do they stand related to the coarsely granular chief-cells? The distinguishing features of the latter are their coarsely granular appearance and their large ferment-content; in an extreme digestive stage these features become much less conspicuous. We are led, then, to think that the coarsely granular chief-cells are but a more highly developed form of the cells found in the other parts of the stomach as the finely granular chief-cells and pyloric gland cells.

The greater curvature of the rabbit probably corresponds to the intermediary portion of the stomachs of dog, cat, and rat.

It will be noticed that in the main we advocate Heidenhain's views, objecting, however, to the statement that the chief-cells and the pyloric gland cells are *identical*, since their normal appearance is so strikingly different.

The investigations, of which the foregoing is a brief account, were carried on in the Physiological Laboratory, Cambridge.

III. "Report on Phyto-Palæontological Investigations of the Fossil Flora of Sheppey." By Dr. Constantin Baron Ettingshausen, Professor in the University of Graz, Austria. Communicated by Professor Huxley, Sec. R.S. Received November 3, 1879.

One of the most important, if not the most important, locality for the Eocene Flora of Great Britain, and perhaps of the tertiary forma-