Journal of Anatomy and Physiology.

A CONTRIBUTION TO THE MINUTE ANATOMY OF THE HUMAN RETINA.

By R. Marcus Gunn, M.A., M.B. (Edin.). (Plate XII.)

[From the *Physiological Laboratory, University College, London.*]

(See Note and Explanation of Plate, p. 516.)

The object of the present paper is to describe an apparently direct connection between the cones of the retina and certain of the corpuscles of the inner nuclear (granule) layer. It will be useful to preface the description by giving a short explanation of some of the terms employed.

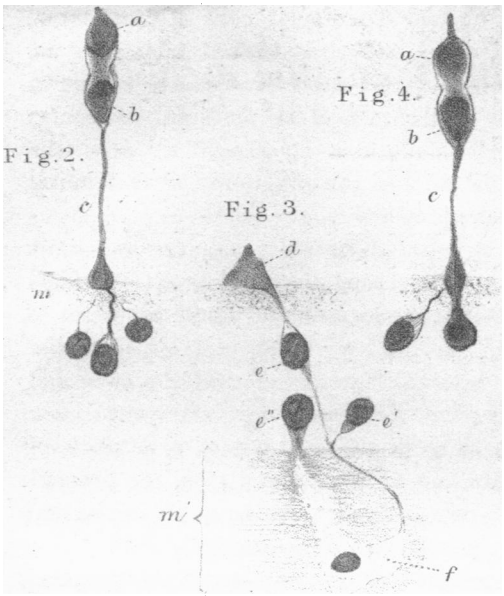
The rods and cones, seated on the *limitans externa*, are each prolonged by a straight fibre—finer in the case of the rods than in that of the cones—which passes directly through the external nuclear ("granule") layer (one of the granules of which is interpolated in the course) as far as the external molecular (intergranular) layer. Having attained the outer surface of this layer each fibre ends in a well-marked enlargement, which may be termed the rod-fibre enlargement, or the cone-fibre enlargement, as the case may be; or, more shortly, the bulb of the rod- or cone-fibre. The bulbs of the rod-fibres seem like exaggerations of the minute varicosities these fibres exhibit at intervals along their course, and they have a rounded or oval shape. The bulbs of the cone-fibres, on the other hand, are larger and much better characterized. Their shape is pyramidal with the base resting on the external molecular layer; and from the basal margin various observers have described fine fibres extending a short distance into and becoming lost in that layer.

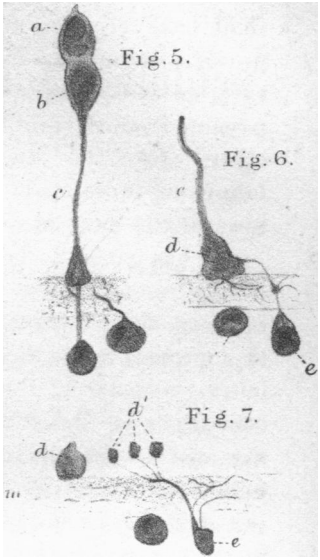
Of the elements to be found in the internal nuclear (granule) layer at least three or four distinct kinds have been described.

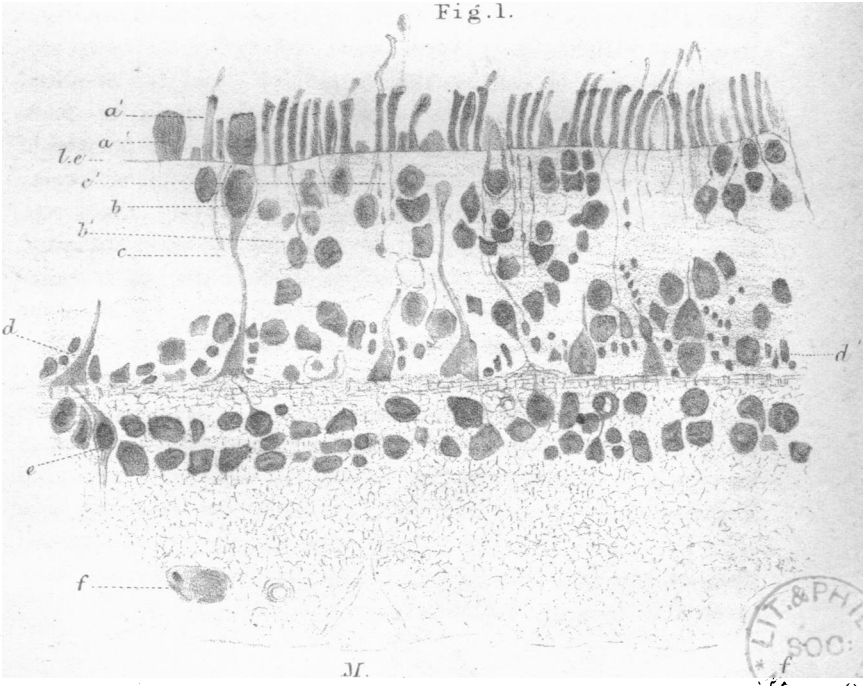
Those which are the most numerous, and of which alone we shall have occasion to speak, are bipolar cells with the one process—the outer—extending outwards towards and into the external molecular layer, and the other process—the inner—passing inwards into the substance of the internal molecular layer. Into the internal molecular layer extend also the branching processes of the cells of the ganglionic layer, tending towards the internal nuclear layer.

It has generally been believed, by Max Schultze and most of the recent writers on the retina, that a connection exists between the ganglion-cell-processes and the inner processes of the internal "granules" on the one hand, and between the outer processes of the internal "granules" and the rod- and cone-fibres on the other; but this connection has always been assumed to take place through the medium of a network of numerous and exquisitely fine fibrils, derived from the branching of the fibres and cell-processes above referred to, and seated in the outer and inner molecular layers respectively.

From the study of sections of the human retina prepared with osmic acid, and subsequently hardened in alcohol, I have been able to convince myself that a far more direct connection than that hitherto conjectured, subsists between the outer processes of some of the internal "granules" and the terminal enlargements or bulbs of the cone-fibres. It has in fact been possible, in numerous instances, to trace the outer process of one of the granules in question through the external molecular layer immediately into the bulb of a cone-fibre (Plate XII. Figs. 2—6). The connecting fibre, which is often tapering, generally passes to one of the edges of the bulb. It is sometimes comparatively broad and ill-defined (Fig. 4), at other times finer but much more distinct, and may then take a somewhat wavy course (Fig. 2), and have a more oblique direction; but it is possible that these differences of appearance depend upon the aspect from which the connecting fibre happens to be viewed. Occasionally, but rarely, the bulb of a cone-fibre has seemed to receive two such processes, one at either side (*Stu*, Fig. 4), and it is not unlikely that this may be the normal state of the case in all, the second connection having been severed in making the sections.







R.M. Gunn. del. T.P. Collings.

In some instances (perhaps in every case) the outer process of the inner "granule" bifurcates close to or within the substance of the external molecular layer[1], and it has occasionally been possible to follow one at least of the resulting branches into the bulb of a cone-fibre in the manner above described. Whether the other branch ends in the bulb of another cone-fibre I have been unable to determine. In one case at least it appeared to divide again into two or three very fine branches, and these seemed rather to tend towards the bulbs of adjacent rod-fibres, but a connection with them could not be distinctly perceived: if it exists at all it must be of excessive delicacy.

Lastly, I would mention that in a solitary instance I observed what appeared to be a direct continuation of a branch of one of the ganglion-cells of the ganglionic layer into the inner end of one of the internal "granules" (Fig. 3); this, on the other hand, by its outer process was in connection with the bulb (*d*) of a cone-fibre, in the manner above described. At the same time I am not prepared to lay too much stress on this observation. For in the first place it is, as just mentioned, solitary; and secondly, by the method of preparation adopted, the ganglion-cells and their processes exhibit nearly the same, or, if anything, a rather less amount of staining than the substance of the internal molecular layer in which they are embedded; and this fact renders the course of their branches very much more difficult to trace.

It was found possible to obtain sections of retina of the extreme thinness requisite for such an investigation as the present only by the employment of the cacao-butter method of embedding[2]. The chief difficulty otherwise experienced was in making the plane of section exactly vertical to the surfaces and corresponding with the direction of inclination of the fibres in the retina. The connections described were investigated with the highest obtainable power[3].

[1] Occasionally, as Mr Hulke has shown, instead of a single bifurcating outer process two separate fibres are observed to pass in an outward direction from one of the inner granules.

[2] See Mr Schäfer's description in this *Journal*, Vol. x. p. 775.

[3] The no. 12 immersion of Hartnack was the objective mostly used for this purpose.

NOTE TO MR GUNN'S PAPER. P. 357.

The above observations were completed last June, and the paper was sent in (in August) for publication in the October number of this Journal. But from accidental causes the publication has unfortunately been deferred until now. In the interval, Prof. Fr. Merkel, of Rostock, has published, in the *Archiv. für Ophthalmologie*, observations which strikingly corroborate those made by Dr Gunn. This independent corroboration is of value, not only on account of Prof. Merkel's high reputation as a histologist, especially on the subject of the eye, but also from the fact that he has arrived at a similar conclusion by a different method of working—Dr Gunn's results having been obtained from the study of sections, Prof. Merkel's mainly from observation of the separated retinal elements.

E. A. SCHÄFER.

UNIVERSITY COLLEGE,
March, 1877.

EXPLANATION OF PLATE XII.

Fig. 1. Vertical section through Human Retina, *a.* cone, *b.* cone-nucleus, *c.* cone-fibre, *d.* cone-fibre enlargement or cone-bulb, *e.* bipolar inner "granule," its outer process extending to *d*, its inner becoming lost abruptly in the inner molecular layer, *f.* ganglion-cell, *a'.* rod, *b'.* rod-nucleus, *c'.* rod-fibre shewing minute varicosities, *d'.* rod-fibre enlargement or rod-bulb, *l. e.* membrana limitans externa; *M.* base of Müllerian fibre.

Fig. 2. Cone, cone-nucleus, cone-fibre and cone-bulb: to the latter an inner granule is seen to send a well-defined wavy process, while two neighbouring inner granules send processes towards, but not traceable into, the same cone-bulb.
m. external molecular layer.

Fig. 3. An apparent direct continuation of a branch of a ganglion cell (*f*) with the inner process of an internal granule (*e*): the outer process of this granule is prolonged into a cone-bulb (*d*): *e'.* an inner granule attached to an off-shoot of the same branch of the ganglion cell; another branch of the ganglion cell seems to go directly to an inner granule *e''*.

Fig. 4. Cone-bulb showing a connection with two inner granules: the process of one is short, broad and straight; that of the other, longer, narrow and wavy.

Fig. 5. Like the last, but the second wavy process is not traceable into the cone-bulb.

Fig. 6. The outer process of this inner granule (*e*) exhibits an enlargement about the middle of its course through the intergranular layer, from which proceed several minute branches, one entering the cone-bulb (*d*).

Fig. 7. The outer process of the inner granule (*e*) bifurcates in the substance of the intergranular layer. From one branch three very delicate twigs proceed directly towards three rod-bulbs (*d'*).