THE ASTROGLIA OF THE HUMAN OPTIC NERVE, CHIASMA AND TRACT

A STUDY WITH SILVER-CARBONATE

LEOPOLD LISS[1]

Laboratory of Neuropathology and Neuro-ophthalmology, Neuropsychiatric Institute, University of Michigan Hospital, Ann Arbor, Michigan

FOURTEEN FIGURES

The present knowledge concerning the astroglia of the optic nerve is very limited. We found in the literature only the investigations of Marchesani ('26), Cone-Macmillan ('32) and Kolmer ('36). According to Marchesani ('26) the astroglia are supporting elements which build a regular network, with the processes of the cells placed at right angles to the nerve fibers. Kolmer ('36) studied the astrocytes with the gold-sublimate method of Cajal; he described large plasmatic elements and came to conclusions similar to those of Marchesani.[2]

MATERIAL AND METHODS

With the silver-carbonate technique of del Río Hortega the astroglia of the optic nerve and optic chiasma can be impregnated without difficulty and their complicated pattern and relationships to nerve fibers studied. Human tissue has been used exclusively for this study. The age of the individuals ranged from 8 months to 80 years.

The optic nerve, chiasma and tract were cut on a freezing microtome at 10–15 μ. The blocks containing optic nerve,

[1] Grant-in-aid from the U.S. Department of Public Health and Welfare.

[2] The structures of the intra-ocular portion of the optic nerve were studied by J. R. Wolter (to be published).

chiasma and tract were fixed in brom-formalin. The sections were impregnated by different variants of the silver-carbonate method for (1) astroglia, (2) unreduced, for nerve fibers, (3) triple impregnation without alcohol, (4) triple impregnation with alcohol, and (5) silver-carbonate with alcohol, unreduced. Horizontal and cross sections were examined. The horizontal specimens measured 20–25 mm in length. Microphotographs were prepared from the areas indicated in scheme 1. Several modifications of the silver-carbonate technique of del Río Hortega were adjusted to the requirements of the problem.

The first three methods were described in detail by Scharenberg and Zeman ('52) and we shall not discuss them again. Method 4 is a variation of the triple technique (1) fix sections of brom-formalin, (2) wash for two–three minutes in 50 c^3 of distilled water to which were added 20–30 drops of concentrated ammonia, (3) wash one-two minutes in distilled water, (4) transfer sections into 50 cm^3 solution of 2% silver nitrate with 20 drops of pyridine and 40 drops of 96% alcohol; leave sections at room temperature and protected from light for 24–72 hours. Sections will turn yellowish-brown, then (5) transfer into 50 cm^3 of weak silver-carbonate solution to which 20 drops of pyridine and 40 drops of 96% alcohol are added for 2–4 days, (6) transfer the sections (one at a time!) without washing into 50 cm^3 of 2% silver-nitrate ammonia with 40 drops of 96% alcohol for 30–60 seconds, (7) reduce in 1% formaline with pyridine for 30 seconds (2.5 cm^3 of 36–38% neutral formaldehyde + 247.5 cm^3 of distilled water + 10 drops of pyridine), (8) wash in distilled water for 30 seconds, (9) transfer into 0.2% gold chloride solution for 20 minutes at room temperature, (10) wash in distilled water for 30 seconds, (11) transfer into 5% thiosulfate solution for 5 minutes, (12) wash in distilled water, (13) clear and mount. The sections are tranfered from one silver solution into another without washing. Method 5: (1) sections are preserved in brom-formalin, (2) wash sections for two-three minutes in 50 cm^3 of distilled water + 20–30 drops of concentrated ammonia, (3) wash one–two minutes in distilled water, (4) transfer sections into weak silver-carbonate solution with 20–50 drops of pyridine and 40–100 drops of 96% alcohol, and leave them in room temperature protected from light for 2–6 days, (5) wash the sections for 30 seconds in distilled water, (6) gold in 0.2% gold chloride, (7) wash, fix in thiosulfate, (8) wash, clear and mount.

To prepare silver-carbonate stock solution: add 100 cm^3 of 10% silver-nitrate to 300 cm^3 of 5% sodium carbonate solution;

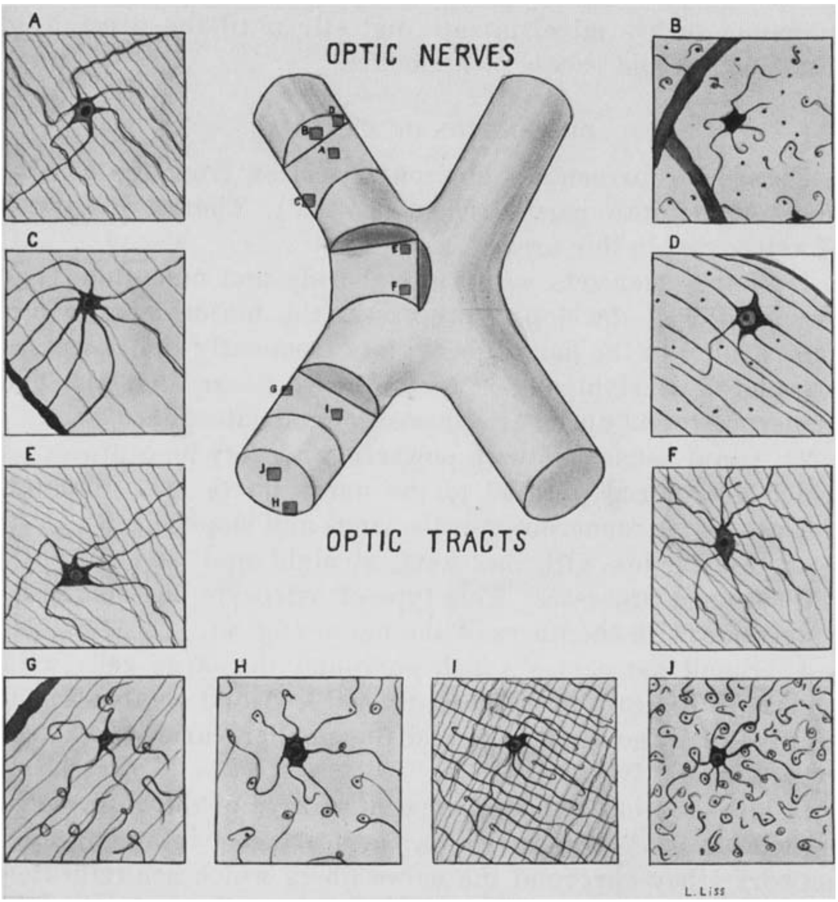


Fig. 1 Scheme showing the different areas which were photographed and the typical pattern of glial fibers in each area.

add concentrated ammonia until the precipitate dissolves (avoid excess of ammonia). Keep in dark brown bottle; this solution is good for 6–8 weeks. Use only clear solution.

This stock solution is used in three concentrations:

weak:	stock solution	100 cm^3
	distilled water	275 cm^3
medium:	stock solution	100 cm^3
	distilled water	100 cm^3
strong:	stock solution	100 cm^3
	distilled water	25 cm^3

To prepare 2% silver-nitrate ammonia, add concentrated ammonia to 2% silver-nitrate and stir until the precipitate dissolves. Avoid excess of ammonia.

DESCRIPTION OF MATERIAL

Figure 2 represents a horizontal section from the central fibers of the optic nerve (scheme 1 "A"). There are 4 types of astrocytes in this area:

1. Large elements with an oval body and numerous very long and well developed processes, the majority of which run parallel to the nerve fibers; less frequently the processes are placed at right angles to the nerve fibers (fig. 2). The numerous round nuclei are those of oligodendroglia.

2. Giant astrocytes with powerful and very long processes which are placed parallel to the nerve fibers and surround the latter with numerous spirals, rings and loops (fig. 3).

3. Astrocytes with one long, straight and several wavy "V" shaped processes. This type of astrocyte has no visible connection with the fibers of the nerve (fig. 4).

4. Small astrocytes which surround the large cells with a maze of delicate processes (fig. 4 "A") and establish contact between the giant cells and the smaller variety of astrocytes (fig. 4 "B" and "C").

In cross sections through the central area of the optic nerve (scheme 1 "B") the astroglia form a dense interconnected network; they surround the nerve fibers which are indicated as dark points (fig. 5). No definite pattern of the glia could be discerned. Horizontal sections from the lateral fibers of the optic nerve (scheme 1 "C") show star shaped, large astrocytes with the majority of their processes placed at right angles to the nerve fibers (fig. 6). In cross sections through the lateral portion of the optic nerve (scheme 1 "D") there are numerous coarse nerve fibers which have longitudinal arrangement and stand out prominently because of their caliber. They are surrounded by numerous large astrocytes with processes running at almost right angles to the nerve fibers (fig. 7).

In horizontal sections of the anterior portion of the chiasma (scheme 1 "E") the astrocytes are characterized by an oval body with a long, powerful, wavy process and two smaller processes placed at the opposite poles of the cell body (fig. 8). The long process runs perpendicular to the nerves and the short processes run parallel. The pattern of the glia is determined by that of the nerve fibers, which in this area cross at almost right angles. In horizontal sections of the posterior part of the chiasma (scheme 1 "F") the astroglia forms a dense network without any definite pattern but follow the interlacing course of the nerve fibers (fig. 9).

In horizontal sections from the lateral part of the optic tract (scheme 1 "G") the astroglia are of a different type and pattern. The body of the astroglia cell is round or oval, the processes (usually 3 or 4) are thin, long, wavy and end with large and distinct terminal loops and rings which surround the nerve fibers. The pattern of the astroglia is that of a loose network (fig. 10). In cross section the corresponding area of the optic tract (scheme 1 "H") shows identical structure and pattern to that seen in horizontal planes. The processes have numerous and well developed loops and surround the nerve fibers, which, in cross sections, appear as small dark points (fig. 11). In horizontal sections of the central part of the optic tract (scheme 1 "I") the fibers of the astroglia form a dense network and are placed both perpendicular and parallel to the nerve fibers (fig. 12). Cross sections of the central part of the optic tract (scheme 1 "J") show a complicated arrangement of nerve fibers, appearing as multiple hooks and spirals (fig. 13). The corresponding pattern of the astroglia is shown in figure 14; here the astrocytes are clearly visible as dark or round bodies with numerous long, thin processes which are placed perpendicularly to the nerve fibers and form a dense but delicate network (fig. 14).

DISCUSSION AND SUMMARY

As mentioned before, the knowledge of the astroglia of the optic nerve has been limited to that of a single type of fibrillary astrocyte described by Marchesani and Kolmer. In reality there are numerous types of astroglia which form complicated patterns peculiar to various parts of the nerve. In the central and lateral portions of the optic nerve there are 4 morphologically different astrocytes: 1. Fibrillar astrocytes of Marchesani-Kolmer (figs. 2 and 6); (2) giant astrocytes with numerous long and powerful processes (fig. 3); (3) elements with one long and several "V" shaped processes (fig. 4); (4) very small cells with numerous, thin, radiating processes which form a dense network and are in close contact with type 3 (fig. 4).

Our investigation shows that the pattern of the astroglia is adjusted to the course of the nerve fibers. According to Cajal the majority of the latter are straight and are placed parallel, but others bifurcate and some cross the parallel fibers of the nerve at almost right angles. In our preparations some of the latter variety were encountered as far frontally as the foramen opticum; this explains the presence of longitudinal fibers in the cross sections of that area (fig. 7). In areas in which the parallel nerve fibers predominate, the majority of the astroglia and their processes are placed parallel to the nerve fibers. A smaller number lie at right angles. This accounts for a very regular pattern of the glia in the central part of the optic nerve (fig. 2). Cross sections through the same area show mainly processes of the astroglia which are perpendicular to the nerve fibers and which form a dense interconnected network. This indicates that the number of the astroglia processes which are at right angles to the nerve in that area is not smaller than that of the processes parallel to the nerve fibers. This arrangement accounts for the density of the glia network in general.

In the posterior part of the chiasma the astroglia are of a very special type: the body of the cell is oval and the processes are thin and radiating. They form a dense network without definite pattern which corresponds to the interlacing course of the nerve fibers (fig. 9).

There are two types of astroglia in the optic tract: one is similar to that in the nerve (fig. 3), the other has long and thin processes ending with distinct loops and rings which surround the nerve fibers (fig. 10).

In the central part of the optic tract (horizontal sections) there is a dense glia network and the processes of the astroglia are placed as both parallel and horizontal (fig. 12). This pattern is very distinct. In cross sections through the central part of the optic tract the processes are predominantly perpendicular and the network is very dense (fig. 13 and 14).

LITERATURE CITED

CAJAL, S. RAMÓN Y 1911 Histologie du système nerveux de l'homme et des vertébrés. Masson et Cie, Paris. (Cited from p. 368).

CONE, W., AND J. A. MACMILLAN 1932 The optic nerve and papilla. Chapter 17, vol. 2 of Cytology and cellular pathology of the nervous system. W. Penfield, ed., New York, Paul B. Hoeber Inc., 839–901.

KOLMER 1936 Quoted from Lauber.

LAUBER, W. 1936 Handbuch der mikroskopischen Anatomie des Menschen. W. von Möllendorf, ed., Berlin, Springer, *3:* part 2, 468–493.

MARCHESANI, O. 1926 Die Morphologie der Glia im Nervus Opticus und in der Retina, dargestellt noch den neusten Untersuchungsmethoden und Untersuchungsergebnissen. Graefes Archiv., *117:* 575–605.

SCHARENBERG, K., AND W. ZEMAN 1952 Zur Leistungsfähigkeit und zur Technik der Hortegaschen Silberkarbonatmethoden. Arch. f. Psychiat. u. Zschr. Neurol., *188:* 430–439.

PLATE 1

EXPLANATION OF FIGURES

2 Fibrillary astrocyte. Horizontal section, central part of the optic nerve. Method 4.

3 Astrocyte of type 2 from the optic nerve. Horizontal section, central part. Method 4.

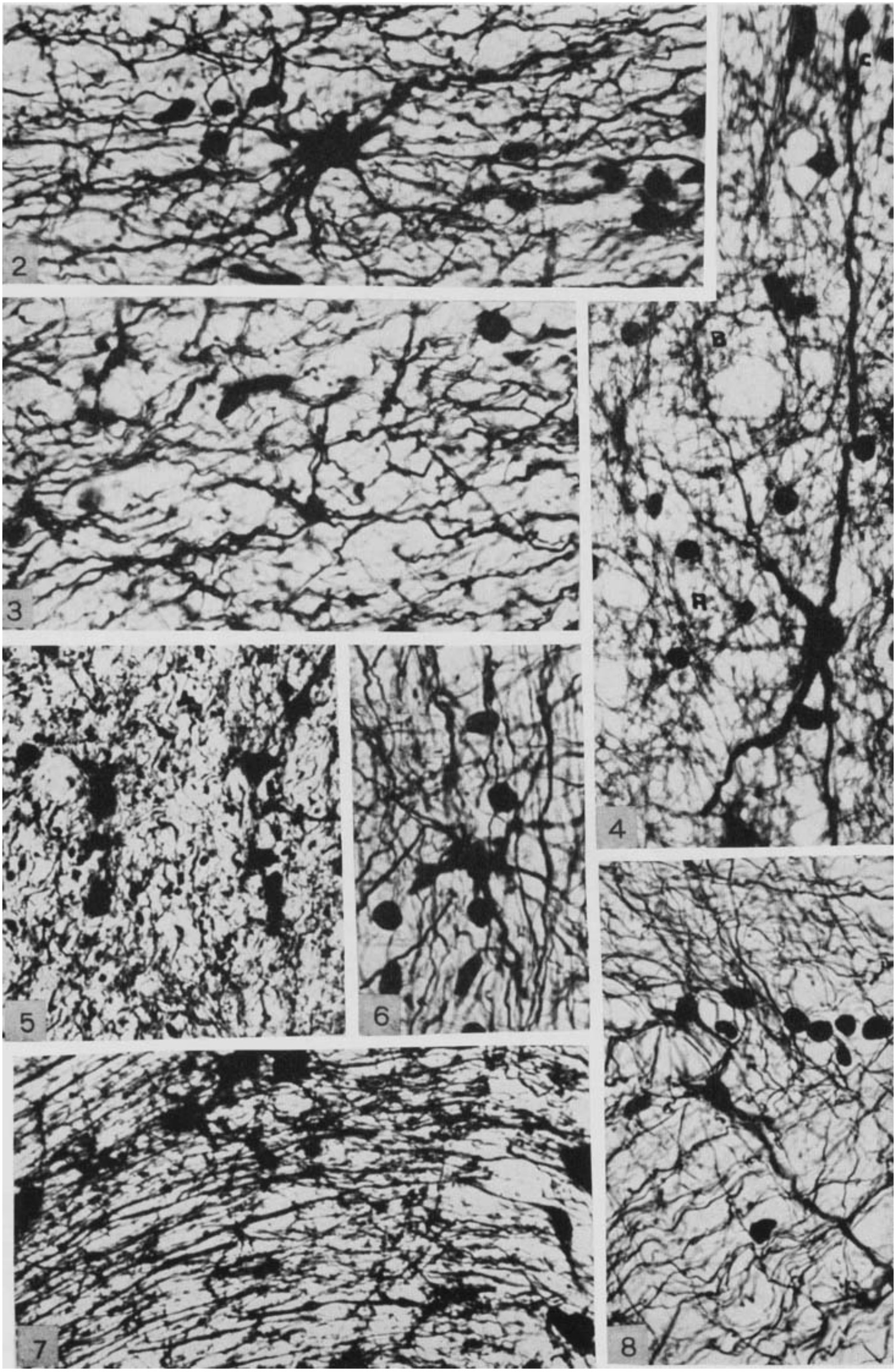
4 Horizontal section of the optic nerve, central part. Astrocyte of type 3. Note the "V" branched processes.
   (a) astrocyte of type 4.
   (b) connection between the astrocytes of the type 4 and the processes of the big cell.
   (c) connection between the processes of the big astrocyte with process of the large cell.
   Alcohol-weak-unreduced method.

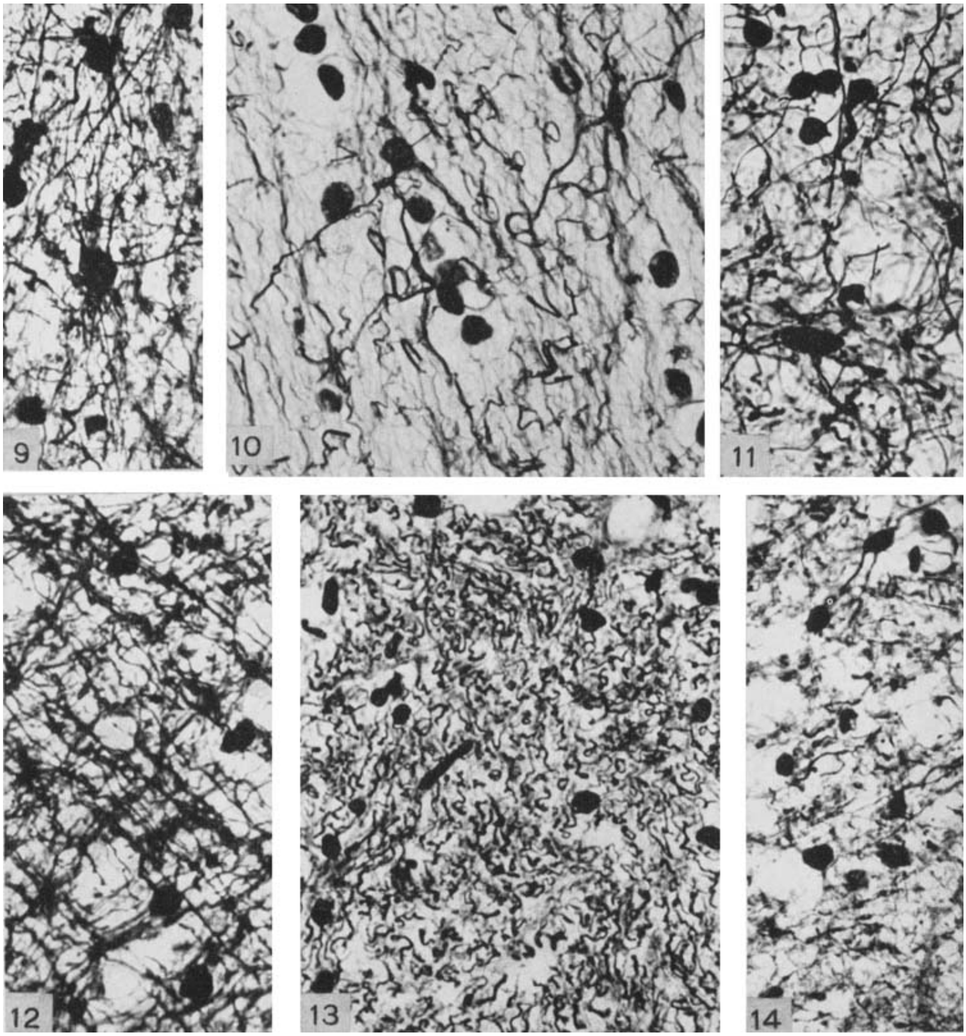
5 Astrocytes with their processes and nerve fibers on cross section of the optic nerve (central part).
   Method 3.

6 Astrocytes and oligodendroglia from the lateral part of the optic nerve (horizontal section).
   Method 4.

7 Cross section through the optic nerve (lateral portion). The majority of the nerve fibers and astroglia processes are placed perpendicular to the axis of the nerve.
   Method 3.

8 Astroglia cell with three processes from the anterior part of the chiasma (horizontal section).
   Method 5.


2
3
4
B
R
5
6
7
8



9 Astrocyte with many radiating processes from the posterior part of the chiasma (horizontal section).
Method 5.

10 Astroglia cell from the lateral portion of the optic tract (horizontal section).
Method 5.

11 Astroglia from the lateral part of the optic tract (cross section).
Method 5.

12 Horizontal section of the optic tract (central portion). Note the pattern of the network.
Method 3.

13 Cross section of the optic (central portion). The dense network is created by glial processes and nerve fibers.
Method 2.

14 Cross section of the optic tract (central portion). Astroglia processes surround the nerve fibers.
Method 2.