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Glial Cells in the Lizard *Gallotia galloti* Subpallial Nuclei During Ontogeny: An Ultrastructural Study

C. YANES,[1]* M. MONZÓN-MAYOR,[2] G. GOMBOS,[3]
J. RENAU PIQUERAS,[4] AND R.R. STURROCK[5]
[1]*Departamento de Biología Celular, Facultad de Biología, Universidad de La Laguna, Tenerife, Canary Islands, Spain*
[2]*Departamento de Morfología, Facultad de Ciencias de La Salud, Universidad de Las Palmas de G. C., Spain*
[3]*Laboratoire de Neurobiologie Cellulaire, UPR 9009 CNRS, Strasbourg, France*
[4]*Centro de Investigaciones, Hospital la Fé, Valencia, Spain*
[5]*Department of Anatomy and Physiology, University of Dundee, Dundee DD1 4HN, Scotland*

ABSTRACT A study was made of the maturation of glial precursors in the subpallial nuclei during the development of the central nervous system of the lizard *Gallotia galloti*. At the ultrastructural level these cells resemble developing glial cells previously described in mammals. Early glioblasts, light and dark glioblasts, astroblasts, oligodendroblasts, and active oligodendrocytes predominate during the prenatal period. Immature and satellite astrocytes as well as light and medium oligodendrocytes are the main cells observed between hatching and the early postnatal period. The early postnatal period is characterized by the presence of medium and satellite oligodendrocytes, most of which become dark oligodendrocytes in the adult. The thickness of myelin sheaths increases between hatching and adult age. Gliofilament-rich mature astrocytes similar to those seen in the midbrain of these animals were never found, not even in adults. The paucity of gliofilaments in immature astrocytes explains why we could not detect perikarya containing glial fibrillary acidic protein in the telencephalon of *Gallotia galloti* (Yanes et al., [1990] J. Comp. Neurol. *295:*559–568). The presence of glioblasts and immature astrocytes in the subpallial nuclei of lizards suggests that these animals could serve as particularly valuable models in studies of glial regeneration in the central nervous system. J Morphol *233:*1–13, 1997.

Different ultrastructural features in a variety of animal species and in different parts of the central nervous system (CNS) of the same species have been reported in studies of glial cell development. During mammalian ontogeny, the precursor cells of oligodendrocytes, the myelin-forming cells, change in size and in cytoplasmic electron density (Kruger and Maxwell, '66; '67; Mori and Leblond, '70; Parnavelas et al., '83; Lord and Duncan, '87). Some of these changes possibly depend also on the diameter of the axon being myelinated (Blakemore, '82). Oligodendrocyte precursors rapidly increase in number during the early phases of myelination (Vaughn, '69; Skoff et al., '76b; Lord and Duncan, '87). Astrocytes, the other macroglial cells, have been implicated in neuron-supporting activities, such as the uptake, recycling, and metabolism of neurotransmitters, and in neuromodulatory activity (Hertz et al., '78; Huszti et al., '90). They also serve as the major constitutive element of the blood-brain barrier (Bradbury, '84).

Most ultrastructural studies of glial cells have been carried out in mammals (Vaughn, '69; Vaughn and Peters, '67; Skoff et al., '76a,b; Sturrock, '74, '75, '80; Parnavelas et al., '83). The major ultrastructural feature of mature mammalian astrocytes is the presence of specific intermediate filaments or gliofilaments (Schultz, '64; Vaughn and Peters, '67; Mori and Leblond, '69). Fibrous

*Correspondence to: Carmen Yanes Méndez, Departamento de M. y Biología Celular, Facultad de Biología, Universidad de La Laguna, La Laguna, c.p. 38071, Tenerife, Spain.

astrocytes contain a large number of gliofilaments, protoplasmic astrocytes contain few gliofilaments, and intermediate cell types between these two extremes are also found (Sturrock, '86; Wilkin et al., '90). The quantity of intermediate filaments also varies among species (Vaughn and Peters, '71; Sturrock, '86). Morphological heterogenity represents one aspect of the response of astrocytes to different microenvironments (Privat and Rataboul, '86). Thus, the morphology of these cells may depend on location and may also reflect their biochemical interrelationships with neurons of different types and with neighboring astrocytes (Wilkin et al., '90).

Many ultrastructural studies have performed describing glial cell precursors in the mammalian CNS (Vaughn, '69; Privat and Leblond, '72; Blunt et al., '72; Philips, '73; Sturrock, '74, '75, '78, '80, '82; Skoff et al., '76a,b; Parnavelas et al., '83) and the corresponding histochemical changes during gliogenesis (Antanitus et al., '76; Dixon and Eng, '81; Bignami et al., '82; Ghandour et al., '83; Choi, '88, Noble et al., '89; Cameron and Rakic, '91; Skoff and Knapp, '91; Luskin et al., '93). Less interest has been paid to the same phenomena in lower vertebrates. Few studies dealt with the oligodendrocyte development in the CNS of amphibians (Stensaas and Stensaas, '68; Schonbach, '69; Stensaas, '77), teleosts, or reptiles (Kruger and Maxwell, '67; Monzón-Mayor et al., '90d). Concerning the astrocytes of *Gallotia galloti*, we have shown by using an antiserum that recognizes the monomere of gliofilaments (i.e., the glial fibrillary acidic protein [GFAP]) that two types of GFAP-positive astrocytes are present in the midbrain of the lizard in addition to GFAP-positive radial glia, which is maintained in the adult CNS (Monzón-Mayor et al., '90b). Ultrastructural studies carried out in the midbrain confirmed the immunohistochemical results (Monzón-Mayor et al., '90c). In telencephalon our immunohistochemical studies indicated no GFAP-positive perikarya besides radial glia and cells in the ventricular wall. However, supallial nuclei (SPN) (i.e., the anterior ventricular ridge, the striatum ventralis, the septal nuclei, and the amigdala central and lateral nuclei) of *Gallotia galloti* are particularly rich in GFAP-positive glial fibers (Yanes et al., '90). This finding suggests the possible presence of astrocytes with little GFAP in the perikarya and abundant GFAP in the processes. Moreover, in comparison with other nerve centers in lizards, subpalliali nuclei show remarkable filogenetic development at the structural level.

In order to complete our previous studies on lizard glial cell development and to determine if astrocytes are present or absent in the telencephalon of *Gallotia galloti*, we examined the ultrastructure of the perikarya present in areas in which GFAP-rich cell processes are abundant (i.e., subpallial nuclei). In addition, we documented the ultrastructural modifications of glial cell precursors that occur during ontogeny.

MATERIALS AND METHODS

Animals

Eight adult lizards of the species *Gallotia galloti*, ten animals at early and mature postnatal stages of development, and 25 embryos were used in the present study. Pregnant females were caught in the wild during May and June, and, after anaesthesia with sodium pentobarbitone, early embryos were removed from them by Caesarean section. Older embryos were obtained during July, August, and September from eggs buried underground. The stages of embryo development were defined according to the tables of equivalence between the development of *Gallotia galloti* (Ramos, '80) and *Lacerta vivapara* (Dufaure and Hubert, '61). Postnatal classification was based on measurements of head-to-tail length. Only the developmental stages at which most prominent morphological changes occurred are reported here: E33, E34, E37, E40, at hatching, and adults.

Electron microscopy

The embryos were fixed by immersion in 2.3% glutaraldehyde in 0.1 M sodium phosphate buffer at pH 7.2. Postnatal and adult lizards were anaesthetized with sodium pentobarbitone and killed by perfusion fixation via the ascending aorta with the same fixative. Upon completion of perfusion, the brains were removed and immersed in the fixative for 3 h. After this, brains were postfixed in 2% osmium tetroxide in Millonig buffer (2.28% sodium dihydrogen phophate monohydrate buffer adjusted to pH 7.3 with NaOH and containing 5.4% glucose) at 4°C for 2 h, dehydrated in graded acetone, and embedded in Araldite. Semithin coronal sections through different levels of the telencephalon were stained with 1% toluidine blue, and ultrathin sections were stained with lead

citrate and uranyl acetate. The ultrathin sections were observed with an EM 420 Philips electron microscope.

Differential counts of glioblasts, oligodendrocytes, and astrocytes were carried out from E39 to adult. The ultrathin sections were examined at ×3,000–4,000, and after identification each individual oligodendrocyte and astrocyte was examined at ×9,000–10,000 to ensure accurate identification. Thirty to forty samples were collected from the telencephalon at each developmental stage and examined in order to count the different cell types (200–300 cells). The porcentual distribution of each cell type is roughly proporcional to the thickness of the lines (Table 1).

RESULTS

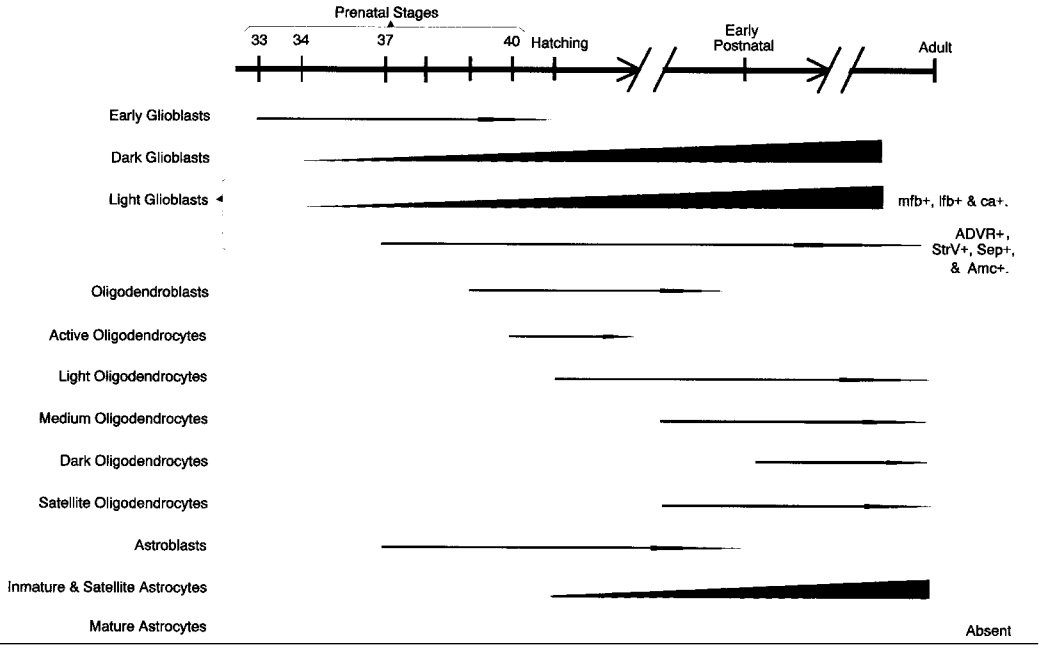
During *Gallotia galloti* ontogeny, at least nine different nonneuronal cell types were found in the subpallial nuclei of this lizard. Furthermore, the quantities of each type vary in each stage of development (Table 1).

Prenatal period

One cell type found at the earliest developmental stage examined usually exhibits an elongated nucleus with fine and homogeneous euchromatin. Its scanty cytoplasm (Fig. 1A) is very pale and much less electron dense than the surrounding neuropil on the cytoplasm of other cell types. The cytoplasm is arranged in a narrow rim surrounding the nucleus and contains scattered rosettes of free ribosomes and a few mitochondria. The features of this cell type are those of the so-called "early glioblast" described in mouse brain by Sturrock ('74). In *Gallotia galloti* subpallial nuclei, this cell type is detected from embryonic stage 33 (E33) to hatching.

Another cell type exhibits a cytoplasm that is more electron dense than the surrounding neuropil and contains mitochondria, short cisternae of rough endoplasmic reticulum (RER), numerous rosettes of ribosomes, and small dense bodies. The shape of the nucleus is irregular. Part of the chromatin is distrib-

TABLE 1. Diagram showing the temporal sequence of the presence/absence of glial cells at different stages of maturation in the subpallial nuclei of the lizard Gallotia galloti *(the thickness of each line is proportional to the percent distribution of each cell type)*



Symbols: ADVR, anterior dorsal ventricular ridge; Amc, Amigdala central; ca, commissura anterior; lfb, lateral forebrain bundle; mfb, medial forebrain bundle; Sept, nucleos septales; StrV, striatum ventralis.

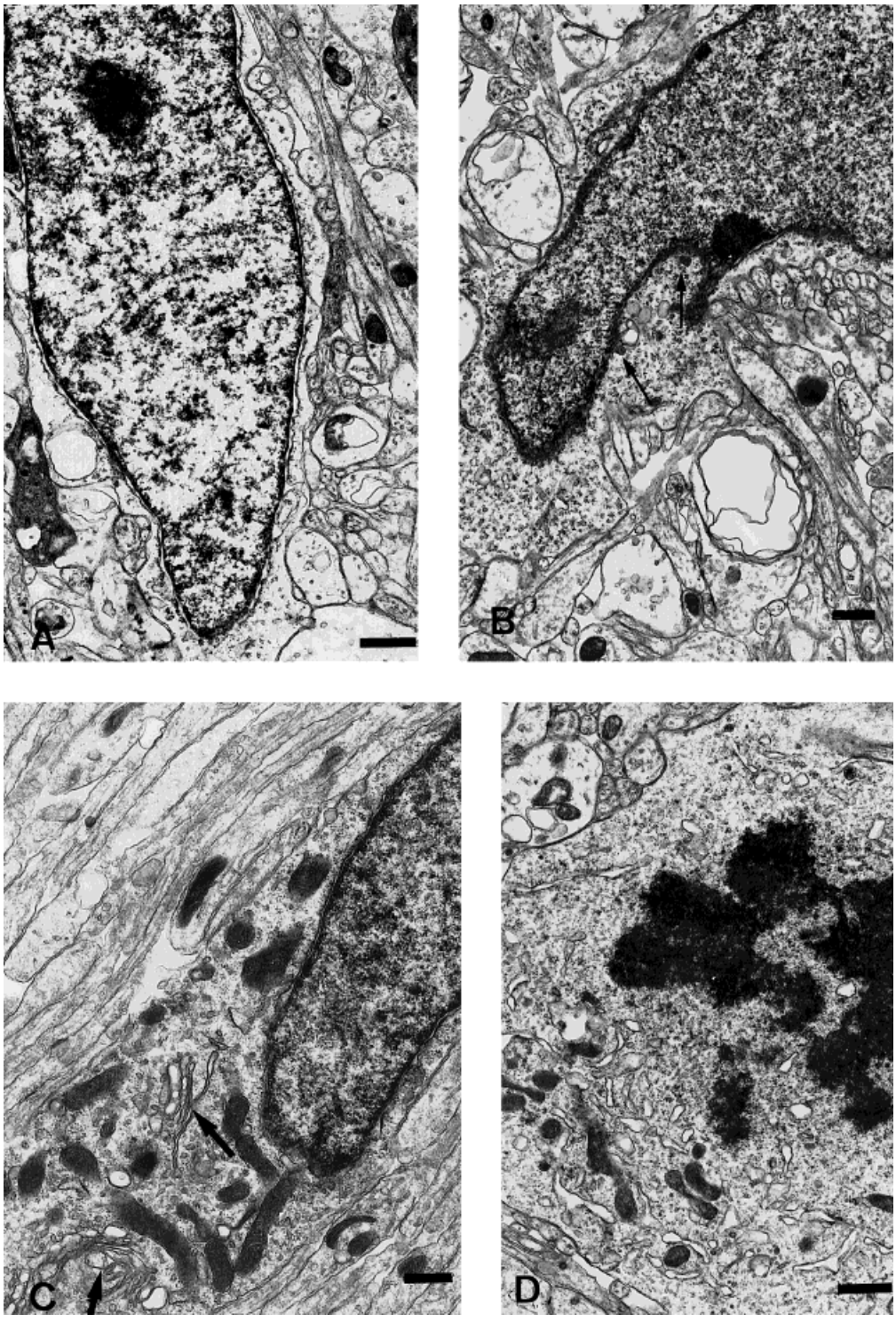


Figure 1

uted as a rim underneath the nuclear envelope, while the remainder is dispersed throughout the nucleus, forming clumps that are larger than those of early glioblasts (Fig. 1B). The features of this cell type are those of the so-called "dark glioblast" described in the mouse commissura anterior by Sturrock ('74). In *Gallotia galloti,* dark glioblasts are found from E34 to adult age especially in the lateral forebrain bundle and in the commissura anterior.

A third cell type exhibits a cytoplasm that is as electron dense as, or less dense than, the surrounding neuropil, and it contains more organelles than the two cell types described above (Fig. 1C). Euchromatin is finely dispersed throughout the nucleus. The features of this cell type are those of the so-called light glioblast described in the mouse commissura anterior by Sturrock ('74). In *Gallotia galloti* this cell type is detected from E34 to adult age. At E34, light glioblasts are observed, especially in the medial forebrain bundle, the lateral forebrain bundle, and the commissura anterior. At E37 they are also found in the subpallial nuclei: anterior dorsal ventricular ridge, the striatum ventralis, the septal nuclei, and the amigdala central and lateral nuclei (Table 1).

Light and dark glioblasts appear fairly during development (E34–E35), and they are numerous at E40. A small number of them could be formed in the adult. At E38 and E39, mitotic light glioblasts were observed in the neuropile close to the lateral forebrain (Fig. 1D).

Starting at E37 a more mature cell type similar to the glioblasts appears. It resembles the astroblasts (Fig. 2A) described during mammalian development (Sturrock, '74) and can be differentiated from the light glioblasts by the following characteristics (Sturrock, '74): the presence of dilated RER cisternae filled with a flocculent material (Fig. 2B), the presence of rosettes of ribosomes, numerous mitochondria, and scarse microtubules. In addition, some astroblasts have lipid droplets and dense cell bodies in their cytoplasm which raises the interesting possibility that these cells could be phagocytic (Fig. 2C).

At E39 another cell type similar to the "oligodendroblast" described in the mouse encephalon commissura anterior (Sturrock, '74) appears. These oligodendroblasts can also be detected in postnatal *Gallotia galloti* telencephalon. They differ from astroblasts by being much richer in polyribosomes, microtubules, and mitochondria. The RER cisternae are short and do not contain the electro-dense material that is typical of cells of the astrocyte line (Fig. 4A).

Starting from E40 and continuing until eclosion, a cell type displaying the same features as the active oliodendrocyte described by Sturrock ('74) in the mouse commissura anterior is present. This cell differs from the light oligodendrocyte by showing an electron-dense cytoplasm, a well-developed Golgi apparatus, and cisternae of endoplasmic reticulum appearing as piled-up bags (Fig. 4C). The cell nucleus is irregular with a central nucleolus, and the chromatin forms a ring under the nuclear membrane (Fig. 4B).

Hatching and postnatal period

At hatching, some immature astrocytes are first found in the subpallial nuclei. At later ages they are numerous (Table 1). Their characteristic feature is the presence of a few gliofilaments, while the other typical feature of mouse astrocytes (i.e., the presence of cytoplasmic glycogen granules) is not evident (Figs. 2D, 3A,B). Satellite (i.e., perineuronal) astrocytes are also first found at hatching. They resemble immature astrocytes by containing only a few gliofilaments. They are numerous in the anterior dorsal ventricular ridge and striatum ventralis (Fig. 3B). The typical gliofilament-rich, mature astrocytes similar to those seen in the midbrain of *Gallotia galloti* are not seen, not even in adult lizards.

From hatching to adult age we observed oligodendrocytes exhibiting the morphology of the three oligodendrocyte types described by Mori and Leblond ('69) in mice and reported to be present in mouse cortex by Parnavelas et al. ('83). One group consists of oligodendrocytes similar to mouse light oligo-

Fig. 1. *Gallotia galloti.* Scale bars = 1 μm. **A:** The elongated nucleus and the narrow rim of clear cytoplasm indicate that this cell is an early glioblast at E39. **B:** The irregular nucleus and the abundance of free polyribosomes in the electron-dense cytoplasm indicate that this cell is a dark glioblast at E40. Note also the small dense bodies (arrows) in the cytoplasm. **C:** The clear cytoplasm containing numerous mitochondria and a voluminous Golgi complex (arrows) indicate that this cell is a light glioblast at E40. **D:** At E40, a mitotic glioblast with cytoplasmic electron density similar to that of a light glioblast (see C). Note the abundant cisternae of the smooth endoplasmic reticulum and the mitochondria in the cytoplasm.

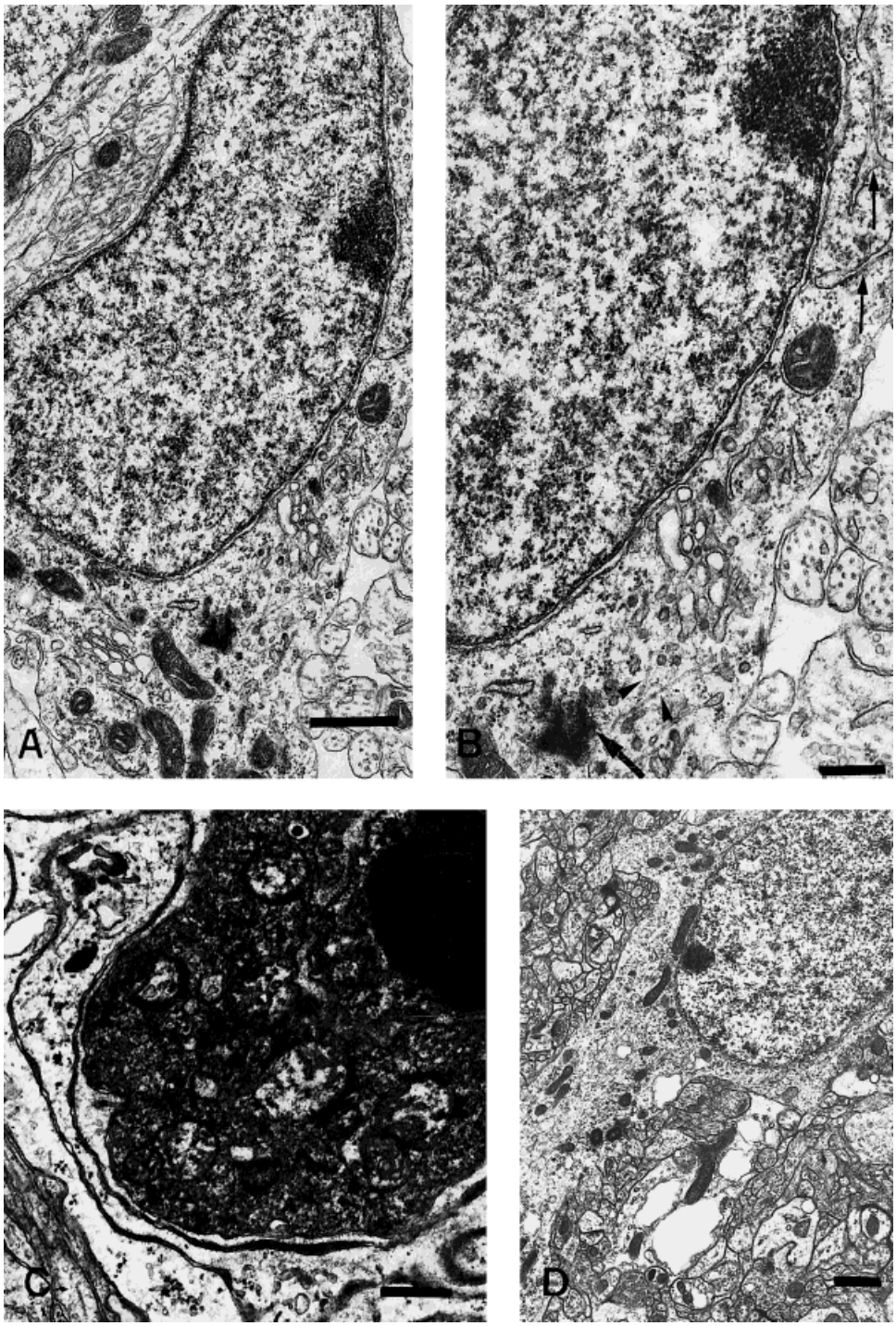


Fig. 2. *Gallotia galloti*. **A:** At E37, a cell identified as an astroblast exhibiting a cytoplasm rich in organelles: dilated RER cisternae and microtubules. Scale bar = 1 µm. **B:** View at higher magnification of the astroblast in A showing the centriole (thick arrow), microtubules (arrowheads), and cisternae of rough reticulum containing flocculent material (thin arrows). Scale bar = 0.5 µm. **C:** At E37, note an astroblast containing phagocytized debris. Scale bar = 1 µm. **D:** Early postnatal age, a cell identified as an immature astrocyte because of its nuclear morphology and content of gliofilaments (visible in Fig. 3A). Note the pale cytoplasmic matrix. Scale bar = 1 µm.

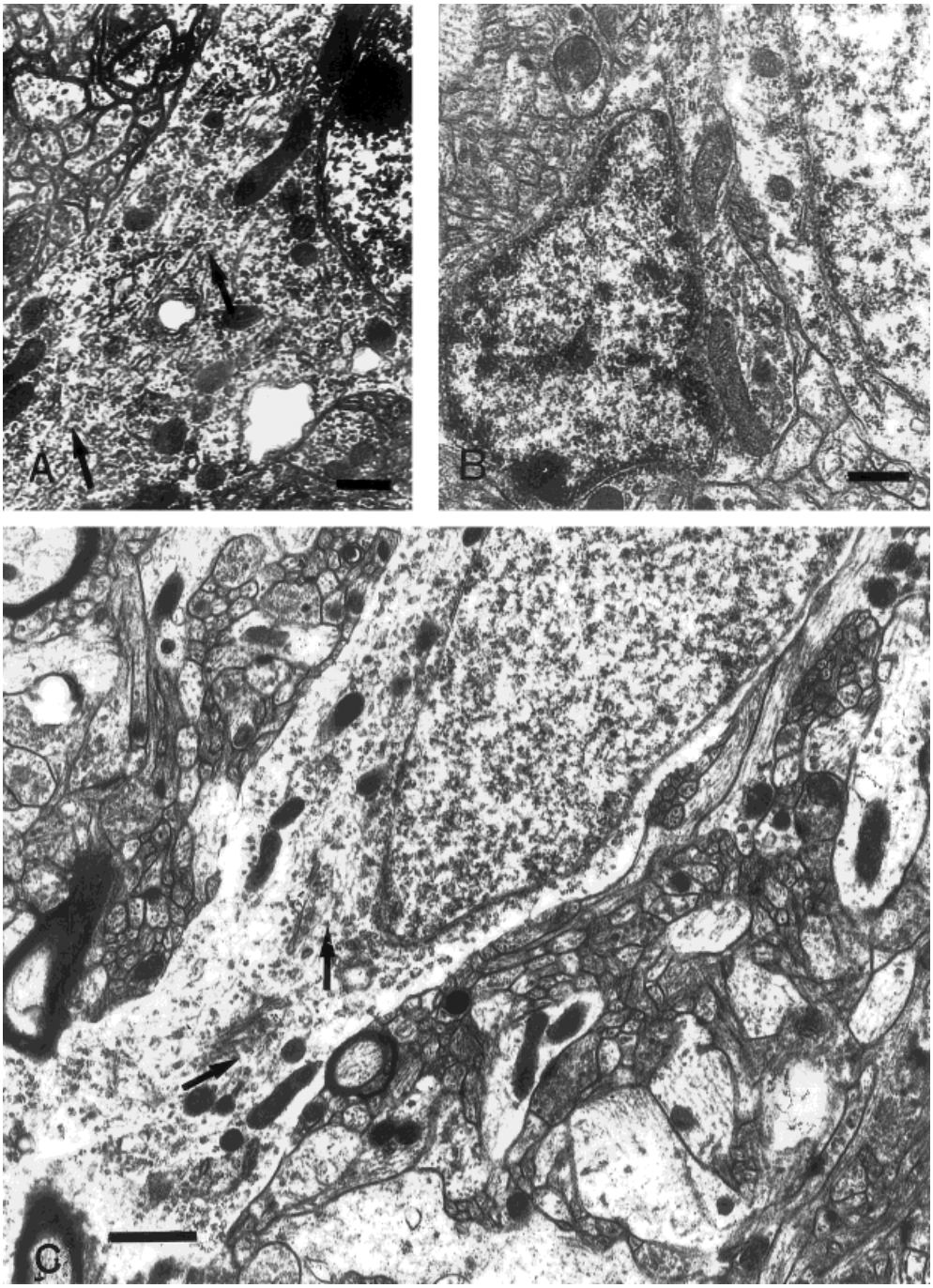


Fig. 3. *Gallotia galloti*. A: View at greater magnification of the immature astrocyte in Fig. 2D. Notice the few gliofilaments (arrows). Scale bar = 0.5 µm. **B:** Satellite (perineuronal) astrocyte in the anterior ventricular ridge of an adult lizard. Scale bar = 0.1 µm. **C:** Immature astrocyte with few intermediate filaments (arrows) in the cytoplasm. Adult lizard. Scale bar = 0.1 µm.

dendrocytes. This cell displays a pale, indented nucleus with dispersed chromatin clumps, pale cytoplasm containing numerous organelles including free ribosomes, mitochondria, abundant microtubules, and, occasionally, a centriole (Fig. 4D). The endoplasmic reticulum cisternae are abundant but are not piled up as in active oligodendrocytes (Fig. 4F). The Golgi apparatus is not greatly developed. At the hatching stage, light oligodendrocytes were observed in different nerve bundles, such as the medial forebrain bundle, lateral forebrain bundle, and the alveus, all of which reach the subpallial nuclei. At early postnatal ages, oligodendrocytes are present in the neuropile of the subpallial nuclei.

Medium oligodendrocytes, first seen at early postnatal ages and later in the adult, are more electron dense than the surrounding neuropile. Compared to light oligodendrocytes, the cytoplasm of medium oligodendrocytes is denser and the Golgi apparatus is less developed (Fig. 5A). The cell processes are very thin and contain numerous packed microtubules, all oriented in the same direction. At more mature ages dark oligodendrocytes appear. Their cytoplasm is much more electron dense, and microtubules are not all oriented in the same direction (Fig. 5D).

Starting from early postnatal ages, satellite (perineuronal) oligodendrocytes are present, particularly in the striatum ventralis and the anterior dorsal ventricular ridge. These oligodendrocytes are mainly of the light and medium types at early postnatal ages. In the adult, dark, light, and medium oligodendrocytes are still present, but most oligodendrocytes are of the dark type (Fig. 5B).

At hatching, we observed oligodendrocytes in the lateral forebrain bundle and medial forebrain bundle in contact with one or two axons. The myelin sheath in these axons is thin (0.03–0.05 mm), while the myelin sheath of the one or two axons in contact with active oligodendrocytes is thicker (0.05–0.5 mm) (Fig. 4B). In young lizards, the medium oligodendrocytes make contact with three or four axons, and the corresponding myelin sheath thickness is from intermediate to thick (0.5–1 mm) (Fig. 5A). At the same age, light oligodendrocytes make contact with one or two axons having myelin sheaths of intermediate thickness (Fig. 4D).

In the adult, medium oligodendrocytes exhibit the same characteristics as those observed at younger ages, while dark oligodendrocytes are in contact with thick axons covered by thick myelin sheaths (Fig. 5D).

DISCUSSION

In the rat optic nerve (Vaughn, '69; Skoff et al., '76a) and in the mouse commissura anterior (Sturrock, '74), the whole sequence of mammalian glial cell maturation has been followed by describing the ultrastructural differences between glial cells at each major stage of maturation. Such differences are based on the above described electron density of the nucleus and cytoplasm and on the characteristics of organelles in the cytoplasm. In the telencephalon of *Gallotia galloti* at different stages of development, we have found cells with the same features as those of mammalian cells; thus, there is reason to believe that glial cells exhibiting the same ultrastructural features in the various animal species are at similar stages of maturation and that the gliogenesis sequence in the lizard is the same as in mammals. Indeed, as shown in Table 1, the different cell types appear in the lizard telencephalon in the same sequences as they do in mammals: both light and dark glioblasts originate from early glioblasts, the light glioblasts mature into oligodendroblasts (as described in mouse by Sturrock ['74]), and the dark glioblasts mature into astroblasts. At E39 numerous light oligodendroblasts are present in the subpallial nuclei. These cells are replaced by immature oligodendrocytes at early postnatal ages. At E40 myelinization begins in the telencephalon, and the oligodendrocytes assume the ultrastructural features of cells in a phase of intense protein synthesis. These are the active oligodendrocytes. After hatching, more mature oligodendrocytes appear in the telencephalic nuclei, while in the midbrain they had already appeared at E40 (Monzón-Mayor et al., '90d). This indicates that, as in the mam-

Fig. 4. *Gallotia galloti*. Scale bars = 1 μm. A: Hatching stage. The pale cytoplasm, the large Golgi apparatus, and the presence of microtubules indicate that the cell shown here in the lateral forebrain bundle is an oligodendroblast. **B:** Hatching stage. The electron-dense cytoplasm and associated myelin ring (arrows) indicate that the cell is an active oligodendrocyte. **C:** Hatching stage. Note the parallel RER cisternae in an active oligodendrocyte. **D:** Pale oligodendrocyte. Note pale cytoplasm with small Golgi complexes (arrowheads). **F:** Another light oligodendrocyte with pale cytoplasm and an indented nucleus containing clumped chromatin in an adult lizard.

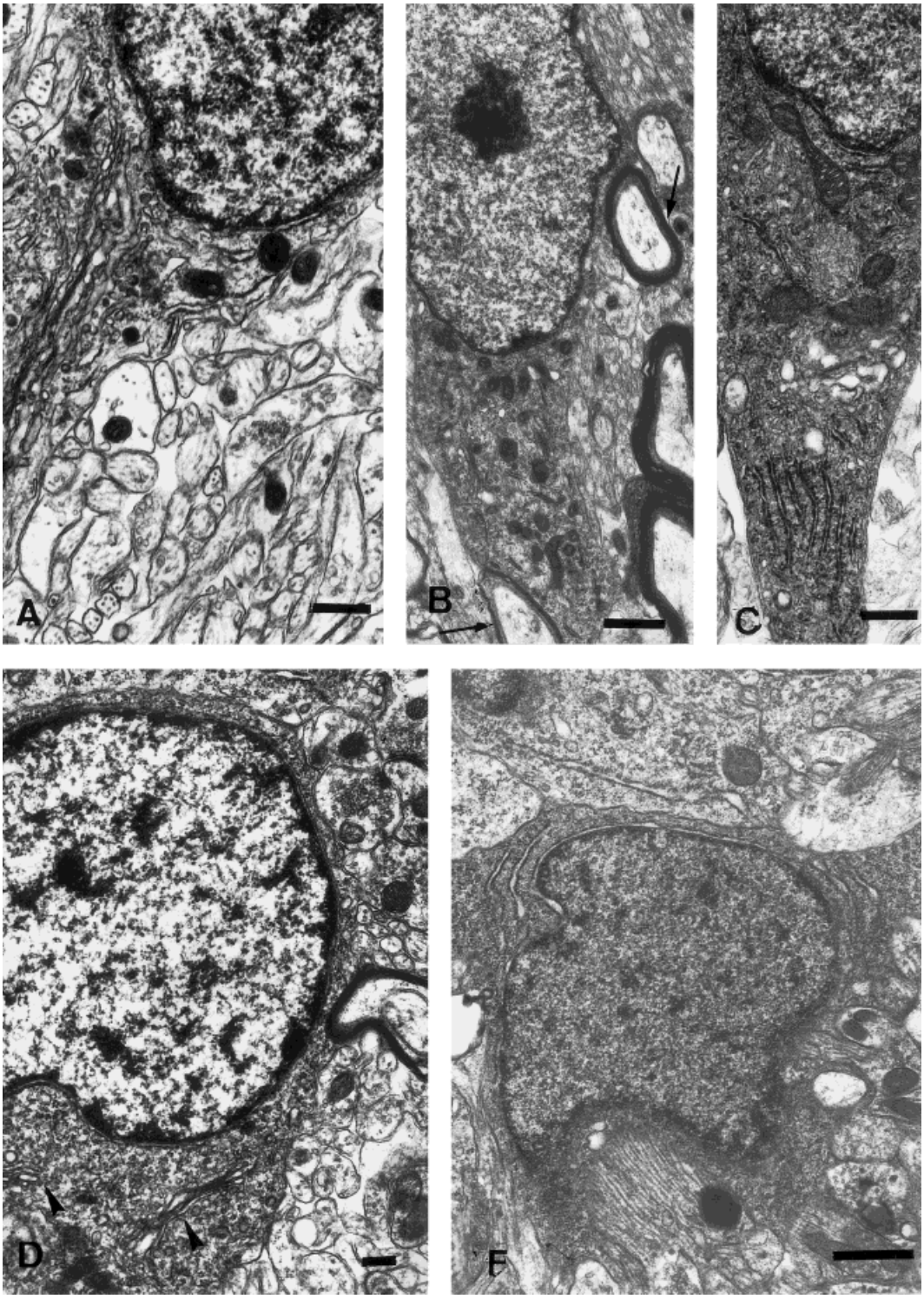


Figure 4

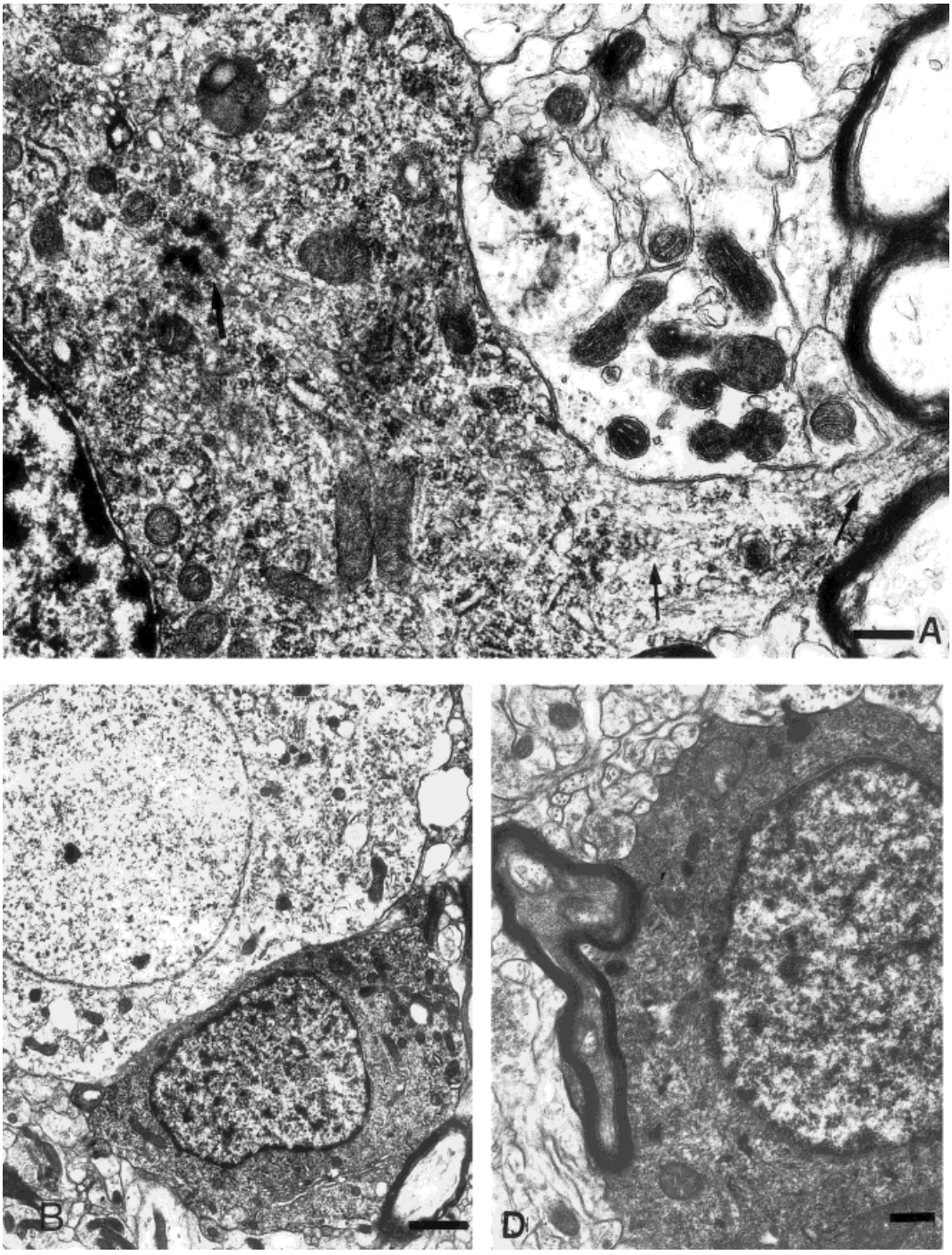


Fig. 5. *Gallotia galloti*. **A:** Mature postnatal period. In the medial forebrain bundle a medium oligodendrocyte, containing an electron-dense cytoplasm associated with myelin rings, a centriole (thick arrow), and tightly packed microtubules (thin arrow) are evident. Scale bar = 1 µm. **B:** Striatum ventralis of the adult. Cell in the lower half of micrograph is a satellite dark oligodendrocyte. Scale bar = 0.5 µm. **D:** Lateral forebrain bundle of the adult. Dark oligodendrocyte associated with a thick myelin ring. Scale bar = 1 µm.

malian CNS, oligodendrocytes in the lizard mature in a caudo-rostral sequence. As in mammals (Mori and Leblond, '69; Ling et al., '73; Vaughan, '84) and in the midbrain of *Gallotia galloti*, oligodendrocytes exhibit different electron densities and thus can be classified as light, medium, and dark. With age the dark oligodendrocytes increase in number, while light oligodendrocytes decrease. This is similar to what happens in mammals and suggests that dark oligodendrocytes develop from light oligodendrocytes. A strong correlation between oligodendrocyte type and thickness of the myelin sheath is evident: dark oligodendrocytes are connected to thick myelin sheaths on thick axons, while light oligodendrocytes are connected to thin myelin on thin axons. We suppose that the oligodendrocytes making myelin for thick axons evolve from the light to the dark type as they deposit more and more myelin lamellae.

According to Stensaas and Stensaas ('68), perineuronal oligodendrocytes are not present in amphibians. They are present in *Gallotia galloti*, suggesting that these cells might appear first along the phylogenetic scale in lizards and possibly in other reptiles. The dark glioblasts are the precursors of the astroblasts, which, as in the case of mammalian cells (Vaughn, '69; Vaughn and Peters, '67; Blunt et al., '72; Sturrock, '74, '75, '80, '86; Skoff et al., '76a,b), are characterized by the presence of flocculent material in dilated endoplasmic reticulum (ER) cisternae and the absence of gliofilaments. These cells appear in the subpallial nuclei of *Gallotia galloti* at E37, while in the midbrain they are present already at E35 (Monzón-Mayor et al., '90c).

Radial glia is maintained in lizards, even in the adult (Yanes et al., '90; Monzón-Mayor et al., '90a), while it disappears and is probably transformed in astrocytes in mammals (Levitt and Rakic, '80; Rakic, '84). It appears then that all or most astroblasts in the lizard derive from glioblasts.

Astrocytes, characterized by the presence of abundant gliofilaments in the cell body, were never found in the *Gallotia galloti* telencephalon, but immature astrocytes exhibiting a few gliofilaments are already detectable at E37 in the subpallial nuclei, while they appear at E35 in the midbrain (Monzón-Mayor et al., '90c). Also, glycogen granules that are present in mammalian astrocyte precursors and immature astrocytes (Sturrock, '86) are also present in mesencephalic astrocytes of *G. galloti* (Monzón-Mayor et al., '90c) and are abundant in other lower vertebrates (Kruger and Maxwell, '67; Schonbach, '69; Roots, '86). Glycogen granules generally are not observed in telencephalic astrocytes in *G. galloti*, although small amounts can be formed in some of these cells during ontogeny. It seems particularly noteworthy that these immature astrocytes exhibit signs of phagocytotic activity.

The results described above suggest that the absence of GFAP-positive cells in the *Gallotia galloti* telencephalon is not due to the absence of astrocytes in this CNS region but to the permanent immaturity of these cells that express very little GFAP. The permanently immature features of astrocytes in the adult lizard telencephalon might be related to the primitive character of this telencephalon. Astrocyte immaturity, together with the permanent presence of glioblasts, could be an indication of the regenerative capacity of the glial cell population, which persists throughout life in these animals. It is possible that some of these immature cells constantly migrate from the proliferative zones in the sulci (Yanes et al., '88), which apparently remain active even in the adult, but in any case we also have observed mitotic glioblasts in the subpallial nuclei.

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LITERATURE CITED

Antanitus, D.S., B.H. Choi, and L.W. Laphan (1976) The demonstration of the glial fibrillary acidic protein in the cerebrum of the human fetus by indirect immunofluorescence. Brain Res. *103*:613–616.

Bignami, A., T. Rasu, and D. Dhal (1982) Localization of vimentin, the non-specific intermediate filament protein, in embryonal glia and early differentiating neurons. Dev. Biol. *91*:286–295.

Blakemore, W. (1982) Myelinization, demyelinization and remyelinization in the CNS. In N.T. Smith and J.B. Caznavanagh (eds): Recent Advances in Neuropathology, Vol. 1. Edinburg, London, Melbourne, and New York: Churchill Livingstone, pp. 53–81.

Blunt, M.J., F. Baldwin, and C. P. Wendel-Smith (1972) Gliogenesis and myelination in kitten optic nerve. Z. Zell. Mikrosk. Anat. *124*:293–310.

Bradbury, M.W.B. (1984) The structure and function of the blood brain barrier. Fed. Proc. *43*:186–190.

Cameron, R.S., and P. Rakic (1991) Glial cell lineage in

the cerebral cortex: A review and synthesis. Glia *4:*124–137.

Choi, B.H. (1988) Prenatal gliogenesis in the developing cerebrum of the mouse. Glia *1:*308–316.

Dixon, R.G., and L.F. Eng (1981) Glial fibrillary acidic protein in the retina of the developing albino rat: An immunoperoxidase study of paraffin embedded tissue. J. Comp. Neurol. *195:*305–321.

Dufaure, J.P., and J. Hubert (1961) Table de développment du lézard vivipare (*Lacerta vivipara* Jacquim). Arch. Anat. Microsc. Morphol. Exp. *50:*309–327.

Ghandour, M.S., O.K. Langley, and J. Clos (1983) Immunochemical and biochemical approaches to the development of neuroglia in the CNS, with special reference to cerebellum. Int. J. Dev. Neurosci. *1:*411–425.

Hertz, L., P.H. Wu, and A. Schousboe (1978) Evidence for net uptake of gaba into mouse astrocytes in primary cultures: Its sodium dependence and potassium independence. Neurochem. Res. *31:*313–323.

Huszti, S., A. Rinanczy, A. Juhasz, and K. Magyar (1990) Uptake, metabolism and release of (3H)-histamine by glial cells in primary cultures of chicken cerebral hemispheres. Glia *3:*159–168.

Kruger, L., and D.S. Maxwell (1966) Electron microscopy of oliogodendrocytes in normal rat cerebrum. Am. J. Anat. *118:*411–436.

Kruger, L., and D.S. Maxwell (1967) Comparative fine structure of vertebrate neuroglia: Teleosts and reptiles. J. Comp. Neurol. *129:*115–142.

Levitt, P., and P. Rakic (1980) Immunoperoxidase localization of glial fibrillary acidic protein in radial glial cells and astrocytes of developing *Rhesus* monkey brain. J. Comp. Neurol. *193:*815–840.

Ling, E.A., J.A. Paterson, A. Privat, S. Mori, and C.P. Leblond (1973) Investigation of glial cells in the brain of young rats. J. Comp. Neurol. *149:*43–72.

Lord, K.E., and I.D. Duncan (1987) Early postnatal development of glial cells in the canine cervical spinal cord. J. Comp. Neurol. *265:*34–46.

Luskin, M.B., J.G. Parnavelas, and S.A. Barbifield (1993) Neurons astrocytes and oligodendrocytes of the rat cerebral cortex originate from separate progenitor cells: An ultrastructural analysis of clonally related cells. J. Neurosci. *13:*1730–1750.

Monzón-Mayor, M., C. Yanes, M.S. Ghandour, J. de Barry, and G. Gombos (1990a) Glial fibrillary acidic protein and vimentin immunohistochemistry in the developing and adult midbrain of the lizard *Gallotia galloti.* J. Comp. Neurol. *255:*569–579.

Monzón-Mayor, M., C. Yanes, G. Tholey, J. de Barry, and G. Gombos (1990b) Immunohistochemical localization of glutamine synthetase in mesencephalon and telencephalon of the lizard *Gallotia galloti* during ontogeny. Glia *3:*81–97.

Monzón-Mayor, M., C. Yanes, J.L. James, and R.R. Sturrock (1990c) An ultrastructural study of the development of astrocytes in the midbrain of the lizard. J. Anat. *170:*33–41.

Monzón-Mayor, M., C. Yanes, J.L. James, and R.R. Sturrock (1990d) An ultrastructural study of the development of oligodendrocytes in the midbrain of the lizard. J. Anat. *170:*43–49.

Mori, S., and C.P. Leblond (1969) Electron microscopic features and proliferation of astrocytes in the corpus callosum of the rat. J. Comp. Neurol. *137:*197–226.

Mori, S., and C.P. Leblond (1970) Electron microscopic identification of three classes of oligodendrocytes and a preliminary study of their proliferative activity in the corpus callosum of young rats. J. Comp. Neurol. *139:*1–30.

Noble, M., G. Wolswijk, and D. Wren (1989) The complex relationship between cell division and the control of differentiation in oligodendrocyte type-2 astrocyte progenitor cells isolated from perinatal and adult rat optic nerves. Prog. Growth Factor Res. *1:*179–194.

Parnavelas, J.G., R. Luder, S.G. Pollard, K. Sullivan, and A.R. Lieberman (1983) A qualitative and quantitative ultrastructural study of glial cells in the developing visual of the rat. Philos. Trans. R. Soc. Lond. [Biol.] *301:*55–84.

Philips, D.E. (1973) An electron microscopy study of macroglia and microglia in the lateral funiculus of the developing spinal cord in the foetal monkey. Z. Zell. Mikrosk. Anat. *140:*145–167.

Privat, A., and C.P. Leblond (1972) The subependymal layer and neighbouring region in the brain of the young rat. J. Comp. Neurol. *146:*277–302.

Privat, A., and P. Rataboul (1986) Fibrous and protoplasmic astrocytes. In S. Fedoroff and A. Vernadakis (eds): Astrocytes, Vol. 1. New York: Academic Press, pp. 105–129.

Rakic, P. (1984) Emergence of neuronal and glial cell lineages in primate brain. In I.B. Black (ed): Cellular and Molecular Biology of Neuronal Development. New York: Plenum Press, pp. 29–50.

Ramos, A. (1980) Tabla de de desarrollo embrionario de Lacerta *Gallotia galloti* (periodo de embriogeénesis) y aspectos de su reproducción. Memoria de Licenciatura. Univ. La Laguna. Canary Island, Spain.

Roots, B.I. (1986) Phylogenetic development of astrocytes. In S. Fedorroff and A. Vernadakis (eds): Astrocytes. Vol. 1. New York: Academic Press, pp. 29–50.

Schonbach, C. (1969) The neuroglie in the spinal cord of the newt *Triturus viridescens.* J. Comp. Neurol. *135:* 93–120.

Schultz, R.C. (1964) Macroglial identification in electron micrographs. J. Comp. Neurol. *122:*281–295.

Skoff, R.P., and P.E. Knapp (1991) Division of astroblast and oligodendroblast in postnatal rodent brain: Evidence of separate astrocyte and oligodendrocyte lineages. Glia *4:*165–174.

Skoff, R.P., D.L. Price, and A. Stocks (1976a) Electron microscopic autoradiographic studies of gliogenesis in rat optic nerve I: Cell proliferation. J. Comp. Neurol. *169:*291–312.

Skoff, R.P., D.L. Price, and A. Stocks (1976b) Electron microscopic studies of gliogenesis in rat optic nerve II. Time of origin. J. Comp. Neurol. *169:*313–334.

Stensaas, L.J. (1977) The ultrastructure of astrocytes, oligodendrocytes and microglia in the optic nerve of urodele amphibians (*A. punctatum, T. pyrrhogaster, T. viridescens*). J. Neurocytol. *6:*269–268.

Stensaas, L.J., and S.S. Stensaas (1968) Astrocytic neuroglial cells, oligodendrocytes and microgliacytes in the spinal cord of the toad. II. Electron Microscopy. Z. Zell. Mikrosk. Anat. *86:*184–312.

Sturrock, R.R. (1974) Histogenesis of the anterior limb of the anterior commissure of the mouse brain III. An electron microscopic study of gliogenesis. J. Anat. *117:* 37–53.

Sturrock, R.R. (1975) A light and electron microscopic study of proliferation and maturation of fibrous astrocytes in the human embryo. J. Anat. *119:*223–234.

Sturrock, R.R. (1978) Development of the indusium griseum II. A semithin light microscopic and electron microscopic study. J. Anat. *125:*433–445.

Sturrock, R.R. (1980) A developmental study of the mouse neostriatum. J. Anat. *130:*243–261.

Sturrock, R.R. (1982) Gliogenesis in the prenatal rabbit spinal cord. J. Anat. *134:*771–793.

Sturrock, R.R. (1986) Postnatal ontogenesis of astrocytes. In S. Fedoroff and A. Vernadakis (eds): Astrocytes, Vol. 1. New York: Academic Press, pp. 75–96.

Vaughan, D.V. (1984) The structure of neuroglial cells. In E.G. Jones and A. Peters (eds): Cerebral Cortex, Vol. 2: Functional Properties of Cortical Cells. New York, London: Plenum Press, pp. 285–329.

Vaughn, J.E. (1969) An electron microscopic analysis of gliogenesis in rat optic nerve. Z. Zell. Microsk. Anat. *94:*293–324.

Vaughn, J.E., and A. Peters (1967) Electron microscopy of early postnatal development of fibrous astrocytes. Am. J. Anat. *121:*131–152.

Vaughn, J.E., and A. Peters (1971) The morphology and development of neuroglial cells. In D. Pease (ed.): Cellular Aspects of Neuronal Growth and Differentiation. Los Angeles: University of California Press, pp. 103–140.

Wilkin, G.P., D.R. Marriott, and A.J. Cholewnki (1990) Astrocyte heterogeneity. Trends Neurosci. *13:*43–46.

Yanes, C., J.M. Martin Trujillo, M.A. Perez Batista, M. Monzón-Mayor, and A. Marrero (1988) Ependymogenesis of the lizard basal areas. II. Sulcus. Z. Zell. Mikrosk. Anat. *102*:573–589.

Yanes, C., M. Monzón-Mayor, M.S. Ghandour, J. de Barry, and G. Gombos (1990) Radial glia and astrocytes in developing and adult telencephalon of the lizard *Gallotia galloti* as revealed by immunohistochemistry with anti-GFAP and antivimentin antibodies. J. Comp. Neurol. *295:*559–568.