THE POSTNATAL DEVELOPMENT OF THE HUMAN CEREBRAL CORTEX

BY

J. LeROY CONEL

Research Associate in Pathology, The Children's Medical Center, Boston
Professor of Anatomy, Emeritus, Boston University School of Medicine

VOLUME V

THE CORTEX OF THE FIFTEEN-MONTH INFANT

HARVARD UNIVERSITY PRESS
CAMBRIDGE, MASSACHUSETTS
1955

DISTRIBUTED IN GREAT BRITAIN BY
GEOFFREY CUMBERLEGE
OXFORD UNIVERSITY PRESS
LONDON

LIBRARY OF CONGRESS CATALOG CARD NUMBER 39-3394
PRINTED IN THE UNITED STATES OF AMERICA

ACKNOWLEDGMENTS

THE INVESTIGATION of the state of development of the cerebral cortex in the infant at the age of fifteen months has been conducted in the Department of Pathology of The Children's Medical Center in Boston. The investigation was supported (in part) by a research grant from the National Institute of Mental Health, of the National Institutes of Health, Public Health Service. I shall always be grateful to Dr. S. Burt Wolbach, Director, Division of Nutritional Research, The Children's Medical Center, and Shattuck Professor of Pathological Anatomy, Emeritus, Harvard Medical School, for his encouragement in my starting and continuing this project.

I wish to acknowledge the generous support given in many ways to this investigation by Dr. Sidney Farber, Pathologist-in-Chief and Chairman, Division of Laboratories and Research, The Children's Medical Center.

The technical assistance for this study is furnished by Mr. Salvatore Lunetta and Miss Sandra Burstein. The careful drawings of the neurons in the Golgi-Cox sections are made by Miss Etta Piotti and Miss Mary Ellen Delaney.

J. LEROY CONEL, PH.D.
BOSTON, MASSACHUSETTS

CONTENTS

Volume V

The Cortex of the Fifteen-Month Infant

INTRODUCTION

THE STATE of development of the cerebral cortex at the age of fifteen months is described in the text in Volume V. The description is based upon the study of brains 38–149, 51–80, and 52–167. During the investigation, however, brains of the ages of twelve, thirteen, fourteen, and eighteen months have also been studied for the purposes of comparison. The methods used in preparing the tissue for study are described in Volume I of this series of monographs. All the brains are obtained at autopsies performed in the Department of Pathology in the Children's Medical Center in Boston. The following data are taken from the protocols.

No. 49–279. Age eighteen months. A poorly developed, poorly nourished, generally cyanotic, white, male infant. The body measures 74.5 cm. in length. The musculature is poorly developed. Diagnosis: Congenital heart disease; transposition of the great vessels; patent foramen ovale. The brain weighs 700 grams (normal 944 grams). Autopsy was performed 4 hours postmortem.

No. 38–149. Age fifteen months. A well-developed, obese, white, female infant. The body measures 80 cm. in length. Muscular development is normal. Diagnosis: Pharyngo-tracheo bronchitis; interstitial pneumonia. The brain weighs 1008 grams. Autopsy was performed 5 hours postmortem.

No. 51–80. Age fifteen months. A well-developed, well-nourished, white, male infant. The body is 80 cm. in length. The infant was well at the time of death. Was found dead in bed. Diagnosis: Pharyngeal obstruction by a foreign body (a plastic teddy-bear eye). Brain weighs 1050 grams.

No. 52–167. Age fifteen months. A well-developed, well-nourished, white, male infant. The body measures 80 cm. in length. The musculature is well developed. Diagnosis: Acute leukemia. The brain weighs 1050 grams. Autopsy was performed 3 hours postmortem.

No. 48–234. Age fourteen months. A poorly developed, poorly nourished, white, male infant. The body measures 61.5 cm. in length. The brain is normal in gross appearance. Diagnosis: Malnutrition, chronic interstitial pneumonia, multiple congenital anomalies. The autopsy was performed 14 hours postmortem.

No. 50–111. Age fourteen months. A small, poorly developed, poorly nourished, white, male infant. The body measures 76.74 cm. in length. The musculature is poorly developed. Diagnosis: Rhabdomyo-sarcoma, metastatic, involving lymph nodes, omentum, right lung, mediastinum, and pancreas. The brain weighs 944 grams. The autopsy was performed 8 hours postmortem.

No. 42–54. Age thirteen months. A well-developed, well-nourished, white, female infant. The body measures 71 cm. in length. The musculature is well developed. Diagnosis: Acute bilateral interstitial pneumonia; overwhelming sepsis. The brain weighs 964 grams.

No. 46–61. Age thirteen months. A well-developed, obese, white, female infant. The musculature is normal in development. Diagnosis: Acute interstitial and bronchopneumonia. The brain weighs 990 grams. The autopsy was performed 5½ hours postmortem.

No. 39–35. Age twelve months. A well-developed, well-nourished, white, male infant. The body measures 74 cm. in length. The musculature is normally developed. Diagnosis: Acute and chronic tracheo-bronchitis. The brain weighs 900 grams. The autopsy was performed 2 hours postmortem.

LOBUS FRONTALIS

GYRUS CENTRALIS ANTERIOR

AREA PRECENTRALIS GIGANTO-PYRAMIDALIS, FAγ

THE BOUNDARIES of this area of cortex are the same in the fifteen-month infant as in the adult as described by Economo and Koskinas. The area is characterized by the presence of the giant pyramidal cells of Betz. The largest of these cells are larger than any other cells in the entire cerebral cortex, but the smallest Betz cells in the fifteen-month cortex are actually smaller than the largest pyramidal cells in layers V and III in some other areas. The boundary between area FAγ and the adjacent areas FA and FB is indistinct. The Betz cells are usually more darkly stained, however, than their homologues, the extra-large pyramidal cells, and the large pyramidal cells in layer III in areas FA and FB.

REGION OF THE LOWER EXTREMITY

The functional area for the lower extremity is regarded to be the same in the fifteen-month cortex as in the cortex of the six-month infant. The cortex in the crown of gyrus centralis and in the paracentral lobule is described separately. The appearance of the cortex in the cresyl violet, Cajal, and Golgi-Cox sections in the region of the lower extremity is illustrated in Figures 5, 6, 7, and 8 on Plates III and IV.

CROWN OF THE SUPERIOR ONE-FOURTH OF GYRUS CENTRALIS ANTERIOR

In this location the cortex measures 2.515 mm. in breadth.

CELL-BODIES

Layer I. The molecular layer measures 0.220 mm. in width, and contains 14 neurons to the unit in the mid-region of the layer. The cells are more numerous near layer II. The small cells are much more faintly stained than the large ones. The nerve cells resemble those in layer II in appearance and in range of size. No horizontal cells of Cajal have been observed.

Layer II. The external border of the outer granular layer is fairly sharply defined, but the internal border is indistinct. The layer measures 0.150 mm. in width. The neurons are distributed irregularly throughout the breadth and length of the layer in the crown of the gyrus. They number 133 to the unit and range in size from 9/5 μ to 14/7 μ.

Layer III. This layer measures 0.740 mm. in width. The neurons are irregularly distributed throughout the length and breadth of the layer. The cells of layer II and lamina IIIa mingle freely along the boundary between layers II and III. The neurons in lamina IIIa range in size from 10/6 μ to 18/11 μ. In the mid-region of the lamina they number 44 to the unit. In lamina IIIb the nerve cells number 41 to the unit and measure 10/6–23/12 μ. The neurons in lamina IIIc range in size from 10/6 μ to 24/15 μ and number 37 to the unit in the mid-region of the lamina.

Layer IV. An inner granular layer is clearly visible and consists of a band of small cells between layers III and V. The external and internal boundaries of layer IV are indistinct because the layer is invaded by the large cells of laminae IIIc and Va. Layer IV measures 0.110 mm. in breadth, and contains 75 cells to the unit. The cells range in size from 9/6 μ to 14/10 μ.

Layer V. This layer measures 0.260 mm. in width. The neurons are small and large ordinary and special cells and extra-large pyramidal cells. The extra-large pyramidal cells throughout area FAγ are the giant pyramidal cells of Betz. The giant cells are frequently arranged in vertical rows of three or four cells, but also occur singly. They are chiefly located in lamina Vb, but are also present in lamina Va. The Betz cells average about 2 to the unit and range in size from 23/14 μ to 36/27 μ. The small and large ordinary and special cells are scattered irregularly throughout the breadth and length of layer V in this location. The small cells range in size from 10/6 μ to 14/10 μ and number 27 to the unit in Va and 24 in Vb. The large cells measure 16/9–20/13 μ and number 13 to the unit in Va and 15 in Vb.

Layer VI. This layer measures 1.035 mm. in width in the crown of gyrus centralis anterior. The neurons number 45 to the unit in lamina VIa and 26 in lamina VIb. The pyramidal cells range in size from 11/6 μ to 23/15 μ, and the spindle cells measure 18/7–27/9 μ.

Lobulus Paracentralis

The cortex in area FAγ in the paracentral lobule has the same features and general appearance as that in the crown of gyrus centralis anterior. In the paracentral lobule the cortex measures 1.775 mm. in breadth.

CELL-BODIES

Layer I. The molecular layer measures 0.445 mm. in width and contains 16 cells to the unit.

Layer II. This layer measures 0.150 mm. in breadth and contains 156 cells to the unit. The cells range in size from 7/5 μ to 15/11 μ.

Layer III. The outer pyramidal layer measures 0.665 mm. in width. In lamina IIIa the neurons number 80 to the unit and measure 10/6–23/13 μ. In lamina IIIb the nerve cells number 61 to the unit and range in size from 10/6 μ to 27/14 μ. Lamina IIIc contains 59 cells to the unit, and they measure 10/6–32/15 μ.

Layer IV. This layer measures 0.110 mm. in width. The small neurons which constitute the inner granular layer number 110 to the unit and range in size from 9/5 μ to 15/11 μ.

Layer V. The inner pyramidal layer measures 0.185 mm. in width. The giant pyramidal cells of Betz are distributed in the same manner as they are in the crown of gyrus centralis anterior, but are not as widely separated. They number 3 to the unit and range in size from 22/14 μ to 36/24 μ. The small neurons measure 11/6–15/9 μ, and number 38 to the unit in lamina Va and 35 in Vb. The large ordinary and special neurons number 21 to the unit in Va and 19 in lamina Vb, and range in size from 16/10 μ to 20/13 μ.

Layer VI. The layer of polymorph cells is much narrower than in the crown of gyrus centralis anterior, measuring only 0.220 mm. in breadth. The neurons number 63 to the unit in lamina VIa and 42 in VIb. The pyramidal cells range in size from 11/7 μ to 21/16 μ, and the spindle cells measure 16/6–27/11 μ.

In the cresyl-violet sections the giant pyramidal cells of Betz are stained more darkly than any other cells in this area. These cells contain more chromophil substance than any other cells, and this substance is more advanced in differentiation than in any other cells in this area. The chromophil substance is greater in quantity and more advanced in differentiation than in the giant pyramidal cells of Betz in this area of the cortex of the six-month infant. Differentiation of the chromophil substance is more advanced in the large giant cells than in the small ones. In addition to flakes and well-formed Nissl bodies, a few fine granules and several clumps of chromophil substance are present in the large giant cells, but both granules and clumps are less numerous than in the large giant cells in this area in the six-month cortex. Well-formed Nissl bodies are more numerous in all the giant cells than in giant cells of comparable size in this area in the six-month cortex. The Nissl bodies and granules extend into the apical and basal dendrites in greater quantity and for a greater distance than in the six-month cortex. Collateral branches of the apical dendrites are not stained, but the sites of origin of some of the proximal ones are indicated by a small, darkly stained clump of chromophil substance at the periphery of the dendrite. Branches of the basal dendrite are as rare and in about the same condition as in the six-month cortex. The nuclear membrane is thick and darkly stained, and has on its external surface a few small clumps of chromophil substance. A darkly stained cone of chromophil substance rests on the nuclear membrane immediately below the origin of the apical dendrite in almost every giant pyramidal cell.

The axon hillock is more clearly defined in the giant pyramidal cells than in the six-month cortex. The hillock is free of chromophil substance. The axon is stained for only a short distance.

The large ordinary and special pyramidal and spindle cells in layers V and VI come next after the giant pyramidal cells in the degree of differentiation of the chromophil substance. Nissl bodies are less numerous in these cells and small clumps of chromophil substance are more numerous than in the giant pyramidal cells. Nissl bodies are more numerous than in corresponding cells in this area in the six-month cortex.

The large pyramidal cells in lamina IIIc are next in degree of differentiation of the chromophil substance. Small clumps of chromophil substance are more numerous and Nissl bodies are less numerous and more flakelike than in the large ordinary and special pyramidal and spindle cells in layers V and VI. The cone of chromophil substance which rests upon the nuclear membrane immediately subjacent to the origin of the apical dendrite is more darkly stained than in the large ordinary and special pyramidal and spindle cells in layers V and VI, and the chromophil substance does not extend as far into the apical and basal dendrites as in the latter cells. The large pyramidal cells in laminae IIIb and IIIa contain more chromophil substance and are more darkly stained than corresponding cells in this area in the six-month cortex. For this reason the large pyramidal cells in lamina IIIc do not stand out as conspicuously as they do in the six-month cortex. Differentiation of the chromophil substance is less advanced in the large cells in lamina IIIb than in the large cells in IIIc, and it is still less advanced in the large cells in lamina IIIa. Clumps of chromophil substance are more numerous and Nissl flakes are less numerous in the large cells in IIIb than in the large cells in IIIc. No well-formed Nissl bodies are present. The chromophil substance is less in quantity in the large cells in lamina IIIa than in the large cells in IIIb, and it is in the form of granules, and small and large clumps; no Nissl bodies or flakes are present. Differentiation of the chromophil substance is more advanced in all cells in layer III than in corresponding cells in this area in the six-month cortex.

The larger of the cells belonging to layer IV stand next to the large cells in lamina IIIa as to the degree of differentiation of the chromophil substance. The substance is in the form of granules and clumps, and it is slightly greater in quantity than in these cells in this area in the six-month cortex.

The cells in layer II are the least advanced in the differentiation of the chromophil substance. The substance is in the form of a thin layer of granules and clumps clinging to the external surface of the nuclear membrane and it is greater in quantity than in this area in the six-month cortex. In almost every cell in layer II a cone of darkly stained chromophil substance rests upon the nuclear membrane immediately subjacent to the base of the apical dendrite. The apical dendrite is stained for only a very short distance, but for a greater distance than in the six-month cortex. The basal dendrites are stained for a much shorter distance than the apical dendrites, but they are more prominent than in corresponding cells in this area in the cortex of the six-month infant.

Horizontal cells of Cajal are seen occasionally in layer I, and most of them are faintly stained. The other neurons in this layer resemble the pyramidal and granular cells of layer II.

An inverted pyramidal cell is seen but rarely in layer V or VI. One inverted giant pyramidal cell is present in layer V.

In the Cajal preparations the giant pyramidal cells of Betz are more darkly stained than any other cells in this area. Neurofibrils in the Betz cells are larger, more numerous, and extend farther in the apical and basal dendrites than in any other cells in this region of area FA. The neurofibrils are larger and more numerous in the cell-body than in the dendrites. They decrease in size and number as they proceed toward the ends of the dendrites, and granules increase in number. A few granules are present between neurofibrils in the cell-body. The neurofibrils are located in the cytoplasm only, the karyoplasm containing granules only. Neurofibrils in the Betz cells are more numerous, larger, and longer than in these cells in this region of area FAγ in the six-month cortex.

The larger ordinary and special pyramidal cells in layers V and VI and the large spindle cells in layer VI are stained more lightly than the giant pyramidal cells of Betz. A few neurofibrils are present in the largest of these cells only, but the neurofibrils are smaller and much less numerous than in the Betz cells. No neurofibrils are present in these cells in the cortex of the six-month infant.

The large cells in lamina IIIc are stained less deeply than the Betz cells, and are about the same color as the large ordinary and special cells in layers V and VI. A few small neurofibrils are present in the bodies and dendrites of the largest cells in lamina IIIc, but even in these cells granules predominate. The neurofibrils are less in number and granules are correspondingly more numerous than in the large ordinary and special cells in layers V and VI. No neurofibrils are present in these cells in the six-month cortex.

The cytoplasm in all other cells in this area is filled with granules and contains no neurofibrils.

FIBERS. The apical dendrites of the giant pyramidal cells of Betz in layer V are larger than those of any other cells in this area. These dendrites are larger than those of the giant pyramidal cells in this area in the six-month cortex. The terminal branches of the apical dendrites in layer I are slightly more numerous than in the six-month cortex. The terminal branches end as straight shafts among the tangential fibers in layer I. The collateral branches of the apical dendrites are larger and longer, but no more numerous than in the six-month cortex. The basal dendrites of the Betz cells are larger and longer and have more branches than those of corresponding cells in the cortex of the six-month infant.

Pedunculated bulbs are more numerous on the dendrites and their branches than in the six-month cortex. The bulbs have longer pedicles than in the six-month cortex. Increase in the number of bulbs is especially noticeable on the terminal branches of the apical dendrites.

The axons of the giant pyramidal cells of Betz are larger and have more myelin than those of any other cells in this area. The axons of the Betz cells are larger and have more myelin than those of corresponding cells in this area in the cortex of the six-month infant. The collateral branches of the axons are larger, longer, and have more myelin, but are no more numerous than in the six-month cortex. The myelin on the collaterals is considerably less in quantity than that on the axon itself.

The apical and basal dendrites of the large ordinary and special pyramidal and spindle cells in layers V and VI are larger, and the basal dendrites and collateral branches of the apical dendrites are longer, than those of corresponding cells in this area in the six-month cortex. The dendrites of these cells are not as large as the dendrites of the Betz cells in this area in the cortex of the fifteen-month infant. The apical dendrites of most of the large ordinary and special pyramidal and spindle cells in layer VI end in layer IV or III, but the apical dendrites of some of these cells reach layer II or layer I.

Pedunculated bulbs on the dendrites of these cells are more numerous than on corresponding cells in the six-month cortex, but are much less numerous than on the dendrites of the Betz cells in this area in the fifteen-month cortex.

The axons of the large ordinary and special pyramidal and spindle cells in layers V and VI are larger and have more myelin than those of corresponding cells in this area in the six-month cortex, but are much smaller and have much less myelin than the axons of the Betz cells in the cortex of the fifteen-month infant.

The bodies and apical dendrites of the largest pyramidal cells in lamina IIIc are as large as those of the smallest Betz cells in layer V. The basal dendrites and the collateral branches of the largest pyramidal cells in IIIc are generally smaller in caliber and shorter than those of the smallest Betz cells. The apical dendrites of the large pyramidal cells in lamina IIIc are larger and their terminal branches in layer I are larger and more numerous than those in corresponding cells in this area in the six-month cortex. The collateral branches of the apical dendrites of these cells are larger and longer, but no more numerous than those of corresponding cells in this area in the cortex of the six-month infant. The basal dendrites are larger, and their branches are larger and longer than in the cortex of the six-month infant.

Pedunculated bulbs are less numerous on the dendrites of the large pyramidal cells in lamina IIIc than on the dendrites of the large ordinary and special pyramidal and spindle cells in layers V and VI. The pedunculated bulbs are more numerous on the dendrites of the large pyramidal cells in lamina IIIc in this area in the fifteen-month cortex than in the cortex of the six-month infant. The distribution of the pedunculated bulbs on the dendrites is the same in the two ages, i.e., the bulbs are most numerous on the apical dendrites, are less in quantity on the basal dendrites and collateral branches of the apical dendrites, and are least in number on the terminal branches of the apical dendrites in layer I.

The axons of the large pyramidal cells in lamina IIIc are about the same size and have approximately the same amount of myelin as the largest ordinary pyramidal cells in layer V. The axons of the large pyramidal cells in IIIc are larger and have more myelin in the fifteen-month cortex than in the cortex of the six-month infant. The collateral branches of the axons always emerge at a right angle and extend horizontally in lamina IIIc or layer IV. The primary branches of the axons number from one to three, as in the six-month cortex, but they are larger, longer, and have more myelin and more secondary branches than in the cortex at six months. The secondary branches are very small and short, and are devoid of myelin.

The pyramidal cells in lamina IIIb are, in general, smaller than those in IIIc and their dendrites are smaller, shorter, and have fewer pedunculated bulbs. Occasionally there is present in IIIb a pyramidal cell which is as large, and has as large dendrites and as many pedunculated bulbs, as the average large cell in IIIc. The large pyramidal cells in lamina IIIa are smaller, have smaller and shorter dendrites and fewer pedunculated bulbs than the large pyramidal cells in lamina IIIb. The apical dendrites of the large pyramidal cells in laminae IIIa and IIIb are larger and their collateral branches are larger and longer, but no more numerous than corresponding cells in these laminae in this area in the six-month cortex. The terminal branches of the apical dendrites ending in layer I are more numerous than in the six-month cortex. The basal dendrites of these cells are larger and longer than in the cortex of the six-month infant.

Pedunculated bulbs on the dendrites of the large pyramidal cells in laminae IIIa and IIIb are more numerous than on corresponding cells in this area in the six-month cortex.

The axons of the large pyramidal cells in lamina IIIb are smaller and have less myelin than those of the large pyramidal cells in lamina IIIc. The axons of the large pyramidal cells in lamina IIIa are smaller and have less myelin than the axons of the large cells in IIIb. The axons of the large cells in laminae IIIa and IIIb are larger and have more myelin than those of corresponding cells in this area in the six-month cortex.

The dendrites of the pyramidal cells of layer IV are larger, longer, and have more pedunculated bulbs than those of corresponding cells in this area in the six-month cortex. The apical dendrites of these cells end in the lower part of layer III. The collateral branches of the apical dendrites and the basal dendrites are coarser and longer but no more numerous than in the cortex of the six-month infant. The axons of the small pyramidal cells in layer IV are larger and longer and their branches are longer than in the six-month cortex.

Small pyramidal cells are present in all six layers of the cortex. The dendrites of the small pyramidal and fusiform cells in layers V and VI are somewhat larger and longer and have more pedunculated bulbs than the small pyramidal cells in layer IV. Proceeding externally from layer IV the dendrites of the small pyramidal cells gradually become smaller and shorter, and the pedunculated bulbs on them gradually decrease in quantity.

The dendrites of the pyramidal cells of layer II are smaller, shorter, and have fewer pedunculated bulbs than those of any other cells in this area. The axons of these cells are smaller than those of any other cells. No indications of myelin are present on the axons. The dendrites of these cells are larger, longer, and have more pedunculated bulbs, and the axons are larger and longer than those of corresponding cells in the six-month cortex.

Golgi type II cells are present in all layers of the cortex in this area, but they are more numerous in layers II and IV than in any of the other layers. The dendrites are in about the same state of development as those of pyramidal cells of comparable size, and are larger, longer, and have more pedunculated bulbs than the dendrites of corresponding cells in the six-month cortex. The axons of the Golgi type II cells are coarser and have more branches and more myelin than those of corresponding cells in the cortex of the six-month infant.

The tangential fibers in layer I are much more numerous in the outer one-half of the layer than in the inner one-half. In the outer one-half the fibers number 18 to 20 to the unit of width (50 μ) in the Cajal sections. The fibers are small, intermediate, and large in size. The largest fibers in the Golgi sections measure 2.25 μ between varicosities. No branches have been observed on any tangential fiber.

The horizontal fibers in layer II are much smaller and fewer than the tangential fibers in layer I. The horizontal fibers number but 4 to 6 to the unit where they are the most numerous.

These fibers are slightly larger in lamina IIIa than in layer II, and number 10 to 12 to the unit. In lamina IIIb they are still larger, and number 12 to 14 per unit. In lamina IIIc and layer IV, where they constitute the outer band of Baillarger the horizontal fibers are larger and number 14 to 16 to the unit. The horizontal fibers in layers III and IV are small, intermediate, and large.

In lamina Va the horizontal fibers number 14 to 16 to the unit. In laminae Vb and VIa (the inner band of Baillarger) the horizontal fibers number 20 to 22 to the unit. The horizontal fibers in layers V and VI are small, intermediate, and large in size, but the fibers in layer VI are in general larger than corresponding fibers in any other layer except layer I. The largest horizontal fibers in the Golgi sections in layer VI measure 2.25 μ in diameter. In lamina VIb the horizontal fibers number 22 to 24 to the unit across the entire breadth of the lamina.

The subcortical association fibers, which are horizontal fibers lying immediately below layer VI, are small, intermediate, and large in size and are about the same size as the horizontal fibers in layer VI. They number 40 to 45 to the unit, and the largest fibers measure 2.25 μ in diameter.

In the center of the core of gyrus centralis anterior, where they are more numerous than elsewhere, the vertical exogenous fibers number 40 to 45 to the unit immediately under the cortex. The fibers are small, intermediate, and large in size, the largest in the Golgi sections measuring 2.25 μ between varicosities. All of the vertical fibers bear varicosities. The vertical fibers decrease in number and size as they ascend in the cortex, and all of them end as straight shafts. No collateral or terminal branches have been observed on any vertical fibers. Most of the ascending exogenous fibers end in layer V, some fewer end in layer IV, still fewer end in lamina IIIc, and occasional vertical fibers end in layers II and I. The vertical exogenous fibers can be distinguished from endogenous axons by the presence of varicosities on the former.

MYELINATION. The brains used for study of the condition of myelination in this area of the cortex fall into the following sequence as to the density of the stain in the Weigert sections, the first being the darkest in color: (1) 52–167, (2) 51–80, (3) 50–111, (4) 49–279, (5) 42–54, (6) 46–61, (7) 39–35. The decrease in density of stain from one brain to the next is definite but not great. The stain in brain 39–35 is darker than that in 41–91, the six-month brain with the most myelin in this area. The following description is based upon the sections of 52–167.

Stained tangential fibers in layer I are larger, more numerous, and darker in color in the walls and floor of a sulcus in the paracentral lobule than in the crown of gyrus centralis anterior. The stained fibers number 14 to 16 to the unit in the sulcus, and 12 to 14 in the crown. The stained fibers are small, intermediate, and large in size, and all bear varicosities. The largest fibers measure 2.25 μ in diameter between varicosities. No branches have been observed on any of the stained tangential fibers.

The horizontal fibers are more numerous, larger, and more darkly stained in the walls and floor of the sulcus than in the crown of gyrus centralis anterior. A small, lightly stained horizontal fiber is occasionally seen in layer II. In lamina IIIa the stained horizontal fibers number 3 or 4 to the unit, and they are larger and darker in color than those in layer II. The stained horizontal fibers number 5 to 7 to the unit in lamina IIIb, and they are larger and more darkly stained than those in IIIa. In lamina IIIc and layer IV (the outer band of Baillarger) the stained horizontal fibers number 8 to 10 to the unit, and they are larger and darker in color than those in IIIb. The horizontal fibers number 6 to 8 in lamina Va, and 10 to 12 in laminae Vb and VIa (the inner band of Baillarger). The stained fibers are darker and larger in Vb than in layer IV. In lamina VIb the stained horizontal fibers number 14 to 16 to the unit, and are about the same in size and color as those in lamina VIa. The stained horizontal fibers are small, intermediate, and large in size. The largest fibers measure 2.25 μ in diameter between varicosities.

The stained subcortical association fibers are small, intermediate, and large in size, and all bear varicosities. They are of about the same size and depth of stain as the horizontal fibers in lamina VIb. They number 22 to 24 to the unit. The largest fibers measure 2.25 μ in diameter between varicosities. The horizontal and subcortical association fibers are stained more darkly than the corresponding fibers in this area in the six-month cortex.

The stained vertical fibers number 35 to 40 to the unit. The largest stained vertical fibers measure 2.50 μ in diameter between varicosities. As the vertical fibers ascend in the cortex they decrease in number and in size, and become lighter in color. Most of the stained vertical fibers end in the inner band of Baillarger, and a few end in layer IV. Occasionally a stained vertical fiber ends in the lower part of lamina IIIb. The stained fibers ending in layer VI are more numerous and more darkly stained in the fifteen-month cortex than in the six-month cortex in this area. No branches have been observed on any of the stained horizontal and vertical fibers.

REGION OF THE UPPER TRUNK, SHOULDER, ARM, AND FOREARM

This region of area FAγ is generally considered as being in the part of gyrus centralis anterior immediately adjoining the narrow piece of the uppermost portion of the gyrus in which is located the region of the lower extremity. The giant pyramidal cells of Betz, which constitute the principal characteristic of area FAγ, are largest and most numerous in the middle two-fourths of the posterior wall of gyrus centralis anterior. In the cresyl violet sections the boundary between area FAγ and Economo's area PA in the floor of sulcus centralis is indistinct. In the lower one-fourth of the posterior wall of gyrus centralis anterior, and across the floor of sulcus centralis, the giant pyramidal cells of Betz gradually decrease in size and in depth of stain, and the cells in layer IV gradually increase in number. Similarly, there is no sharp boundary in the crown of gyrus centralis anterior between areas FAγ and FA. Here also the giant pyramidal cells gradually decrease in size and depth of stain and become continuous with the row of extra-large pyramidal cells in area FA. The inner granular layer becomes only slightly more prominent in the anterior lip of gyrus centralis anterior. In the cresyl violet sections of the fifteen-month infant the cortex in the walls and floor of sulcus precentralis, the location of the suppressor area 4s or the strip area of Hines, has no distinguishing characteristics and closely resembles the cortex in the anterior part of the crown of gyrus centralis anterior. In the posterior two-fourths of the anterior wall of gyrus centralis anterior in this region the cortex measures 2.37 mm. in breadth. It is illustrated in Figures 9, 10, 11, and 12.

CELL-BODIES

Layer I. In the cresyl violet sections the molecular layer measures 0.405 mm. in width. In the mid-region of the layer the neurons number 12 to the unit. They are more numerous near layer II. The cells resemble those in layer II in size and appearance. No horizontal cells of Cajal have been observed.

Layer II. The outer granular layer measures 0.15 mm. in breadth and contains 130 neurons to the unit. The layer consists of granule, pyramidal, and Golgi type II cells ranging in size from 9/6 μ to 16/12 μ. The outer boundary of the layer is fairly sharp, but the inner border is indistinct because the cells of layer II mingle freely with those of lamina IIIa.

Layer III. This layer measures 0.925 mm. in width. In the mid-region of lamina IIIa the neurons number 74 to the unit and measure 10/6–20/13 μ. In the mid-region of lamina IIIb the neurons number 46 to the unit and measure 10/6–25/15 μ, and in the mid-region of lamina IIIc they number 44 to the unit and range in size from 10/6 μ to 32/17 μ.

Layer IV. The inner granular layer is clearly visible but is less distinct than layer II. It consists of small nerve cells which number 75 to the unit and range in size from 9/6 μ to 14/9 μ. The upper and lower borders of the layer are indistinct and irregular because the large pyramidal cells of laminae IIIc and Va invade the granular layer. The layer measures 0.150 mm. in width.

Layer V. This layer has the same general appearance and characteristics in this region as in the region of the lower extremity. The breadth of the layer averages 0.295 mm. The small neurons measure 10/6–14/11 μ, and number 25 to the unit in lamina Va and 26 in lamina Vb. The large ordinary and special pyramidal cells range in size from 16/11 μ to 23/20 μ, and number 15 to the unit in Va and 12 in Vb. The giant pyramidal cells of Betz average 2 to the unit and measure 27/18–41/29 μ. The Betz cells are located chiefly in lamina Vb, but are also present in Va. They occur singly and in groups of 3 or 4.

Layer VI. This layer consists of small, intermediate, and large, pyramidal, spindle, and Golgi type II cells. The neurons number 49 to the unit in lamina VIa and 22 in VIb. The pyramidal cells measure 10/6–25/14 μ, and the spindle cells range in size from 18/6 μ to 32/13 μ. The layer measures 0.445 mm. in width.

The giant pyramidal cells in layer V are stained more darkly and contain more chromophil substance than any other cells in this area. The chromophil substance in these cells is more advanced in differentiation than in any other cells in this area. The substance is also greater in quantity and more advanced in differentiation than in the giant pyramidal cells in this area in the six-month cortex. The chromophil substance extends into the apical and basal dendrites in greater quantity and for a greater distance than in the six-month cortex. Nissl bodies are more numerous and clumps of chromophil substance are less numerous than in the six-month stage of development. The Nissl bodies are principally elongated. A few elongated Nissl bodies are present in the proximal part of the apical dendrites, but these structures are not present in the basal dendrites. The basal dendrites are stained for a much shorter distance than the apical dendrites. In the basal dendrites the chromophil substance is in the form of fine granules, except that a small, darkly stained clump is present at the point of origin of each branch. Only a few branches are stained. No collateral branches of apical dendrites are stained, but a small, dark clump indicates the place of origin of each branch. In the fifteen-month cortex the chromophil substance in the giant pyramidal cells in the region of the trunk, shoulder, and arm is more advanced in differentiation than in corresponding cells in the region of the lower extremity in area FAγ. Nissl bodies are more numerous and clumps of chromophil substance are less numerous than in the region of the lower extremity.

The nuclear membrane in each giant pyramidal cell is thick and darkly stained. In almost every giant cell a cone of darkly stained chromophil substance is resting on the nuclear membrane immediately under the origin of the apical dendrite. The apex of the cone is directed toward the apical dendrite, and strands of chromophil substance extend from the apex of the cone toward the base of the apical dendrite. Frequently, but not always, the nuclear membrane is especially thick and darkly stained subjacent to the points of origin of the basal dendrites. Usually an aggregation of small clumps of chromophil substance is present in the cytoplasm at the point of origin of a basal dendrite.

The axon hillocks are more clearly defined in the giant pyramidal cells in the fifteen-month cortex than in the six-month cortex. No chromophil substance is present in the axon hillock.

The large ordinary and special pyramidal and spindle cells in layers V and VI are next to the giant pyramidal cells as to the degree of differentiation of the chromophil substance. The substance is in the form of granules, small clumps and a few Nissl flakes. No well-formed Nissl bodies are present. In these cells the chromophil substance is greater in quantity, Nissl flakes are more numerous, and clumps are less numerous than in corresponding cells in the six-month cortex. The apical and basal dendrites are larger and stained for a greater distance than in the six-month cortex. The basal dendrites are smaller and stained for a shorter distance than the apical dendrites. A clump of darkly stained chromophil substance is usually present at the origin of each basal dendrite. In most of these cells a darkly stained cone of chromophil substance rests upon the surface of the nuclear membrane immediately below the origin of the apical dendrite. There are no distinguishable differences between these cells in this region and the