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THE PATHOLOGY OF MENINGIOMAS A STUDY OF 121 CASES*

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Although the biologic behavior of meningiomas is relatively uniform, their histologic appearance is variable. Because of this, numerous classifications¹⁻⁷ of two fundamental types have been proposed for them: embryologic and purely morphologic.

The embryologic approach, best exemplified in the study by Globus,⁵ aims at finding evidence of different stages of embryologic development of the meninges in the different appearances of the tumor. There are, however, several objections to this method. First, the origin of the meninges in neuro-ectoderm or mesoderm is still uncertain. In fact the importance of this origin probably has been over-emphasized. In discussing the classification of tumors in general, Willis⁸ recently stated: "The germ-layers, the status of which has of recent years greatly declined even for the embryologist, are devoid of significance for the pathologist." Secondly, the analogy between the neoplasm and the developing meninges based on microscopic appearance is easy to make but difficult to prove. Such an idea, therefore, must remain merely an hypothesis. Lastly, the correlation between prognosis and so-called histofunctional differentiation is so poor that classifications based on embryogenetic concepts cannot be justified even on clinical grounds.

In the morphologic approach an attempt is made to classify meningiomas by the histologic features considered most prominent. Such classifications are valuable to the pathologist, but difficulties are encountered when the schemes become too complicated. This is frequently the case since, as it is well known, meningiomas are extremely polymorphic. Cushing and Eisenhardt,⁶ in their morphologic classi-

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fication, thus achieved nine types subdivided into twenty variants, although they admitted that "Fine architectural distinctions, while of academic interest, are unimportant unless they can be shown to have some bearing on clinical treatment and prognosis." The latter obviously is not true of the existing classifications.

Based on a study of 121 meningiomas, it is our intention to present a new approach which affords a means for describing rather than classifying these neoplasms and in so doing sets up diagnostic criteria. The most important step in the understanding of these tumors was made by Schmidt⁹ in 1902, when he discovered that the cellular structure of meningiomas was comparable to cell clusters capping the arachnoid villi and the cell nests included in the dura mater. This work unfortunately was forgotten until Cushing,¹⁰ in 1922, re-emphasized the finding and further showed that the location of such cell nests were "favoured seats of origin" of meningiomas. The structural identity of normal arachnoid villi and the meningioma is indeed striking and offers the best criterion for recognition of the tumor. Such an origin explains why meningiomas, although arachnoidal in origin, are frequently adherent to the dura mater, but may occur in other regions such as the ventricular system or Sylvian fissure, without attachment to pachymeninges.

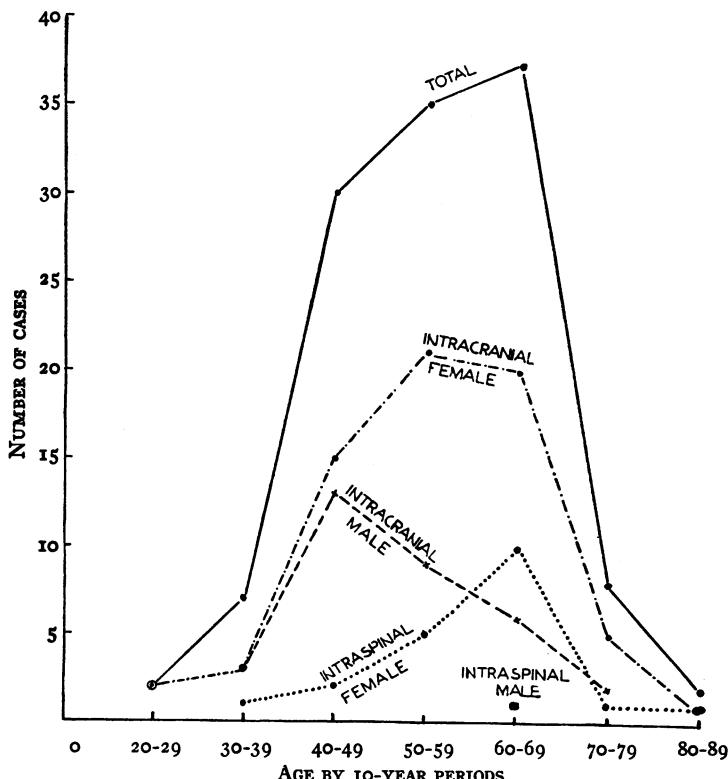
With this in mind, the description of meningiomas may be considered. These neoplasms are composed of two parts: (1) the basic cellular constituents which are meningocytic or fibroblastic cells organized at least in some places in a specific pattern known as a whorl; (2) the secondary components made up of different forms of tissue which may be absent, minimal, or prominent in the tumor. The meningeal origin of the neoplasm can be established with certainty only when some part of it contains meningocytic or fibroblastic cells arranged in a whorl pattern. The secondary components are not essential to the diagnosis although they are seen in recurrent patterns which frequently are of aid to the pathologist. The meningiomas will thus be considered using the following outline. It is emphasized that this is viewed as a description rather than as a classification.

<u>Basic cellular constituent</u>	<u>Secondary component</u>
Meningocytic or Fibroblastic or Mixed	Meningioma with (or without) { fibrous psammomatous angiomatous angioblastic lipomatous osseous chondromatous sarcomatous } components

Such a plan is flexible but precise and clear. Any meningioma can be defined exactly, if necessary, by addition of new components. For example, a tumor may be described as meningocytic meningioma with prominent angiomatic component. This concept not only provides rigid criteria for the diagnosis of the neoplasm but also enables the problem of differential diagnosis of other neoplasms of the meninges to be handled easily. As will be shown, these other tumors can reproduce the patterns of secondary components but do not contain the basic cellular constituents.

MATERIAL

Location, Age, and Sex (Text-fig. 1). Of the 121 meningiomas, 21 were situated intraspinally and 100 intracranially. It is peculiar that



Text-figure 1. Distribution of 121 meningiomas by age, sex, and location within the cranial cavity and along the vertebral canal. The age is that of the patient at the time of the first exploration, or at necropsy if not explored.

all the intraspinal tumors were located in the thoracic region except one at the sixth cervical level.

The youngest patient was 24 years old, the oldest 80. In 102 cases (84 per cent), the tumors were encountered in patients between 40

and 69 years of age, confirming the well known fact that meningiomas are seen most often in adults.

Of the 100 intracranial tumors, there were 67 in women and 33 in men, a ratio of 2:1. The predominance in females was still more striking in the spinal tumors which were present in 20 women and only one man. The peak of frequency was 10 years earlier in the males.

Duration of Symptoms. Duration is calculated as the time between the first symptom and discovery at operation. Twenty-two meningiomas (18 per cent) were discovered only at necropsy. Of the remainder, 52 (43 per cent) had a clinical duration of less than 2 years. The longest duration was 15 years. There was no relation between sex and duration.

Radiologic Signs. Only radiologic signs directly produced by the tumor are considered here, omitting manifestations of increased intracranial pressure or other diseases. Radiologic alterations were found in 24 cases (20 per cent). Condensation and hypervascularization were encountered more often than destruction of bone. These changes were most frequent in three locations: sphenoid ridge, parasagittal region, and on the convex surface of the brain.

PATHOLOGIC ANATOMY

Gross Appearance and Relationship to Brain and Its Envelopes

The meningiomas were extremely variable in size. They ranged from a "pinhead" to an enormous tumor covering the entire base of the right hemisphere. The largest tumor weighed 150 gm. The tumors were well limited and generally, but not always, encapsulated. Their external surface was often granular, berry-like, or lobulated. They were gray, brown, or red; firm, soft, or mixed in consistency, and rarely sandy or calcified. Numerous dilated vessels often were seen on the surface or on the adjacent dura. Hemorrhagic or necrotic foci in mixtures of different ages were encountered. Cystic cavities were present infrequently.

Meningiomas were usually single tumors; multiple meningiomas were encountered but four times. In one instance the tumor occurred as a diffuse meningiomatosis associated with neurofibromatosis. The possibility of multiple meningiomas must be kept in mind when considering the problem of recurrences.

Attachment to the dura mater, which is one of the best means of identification of a tumor of this type at the operating table, was absent in 2 cases. In one case there was a coarsely lobulated nodule suspended by a branch of the left middle cerebral artery in the base of the Sylvian

fissure near the midline. In the second case there was a lateral intra-ventricular tumor.

In relation to the brain, meningiomas are generally well demarcated, but they can send finger-like expansions into the neural parenchyma.¹¹ In one unusual case, the tumor was large and flat, attached to the dura mater, but covering the external surface of the right hemisphere from the motor to the occipital region, forming a giant meningioma "en plaque" but without alteration of bone (Fig. 1). Frequently, the brain adjacent to the tumor is compressed. As a result, in one case the cerebral tissue which underwent cystic degeneration was removed at the first exploration and diagnosed as cystic astrocytoma of the temporal lobe. Two years later, a second craniotomy revealed a meningioma of the middle fossa. It was realized then that compression by the meningioma had produced the misleading cystic gliosis.

Basic Cellular Constituents

"Basic cellular constituents" designates the cells which resemble arachnoid cells and are arranged in a pattern similar to the arachnoid villi (Fig. 2). This appearance is the key to the histologic diagnosis of meningioma. The cells belong to two chief types: meningocytic and fibroblastic. These terms are employed because they are established by usage and clear from a descriptive standpoint, though both designate elements which are arachnoidal in origin. The cell of meningocytic type is generally the larger. The nucleus is round or oval, clear, and usually without a nucleolus. The cytoplasm is acidophilic, homogeneous or slightly granular, and frequently has ill defined boundaries so that syncytial appearances are encountered. The cell of fibroblastic type is elongated. The nucleus is slender and dark, the cytoplasm reduced to a band around it and prolonged by fibrous ends well demonstrated by silver impregnation methods. Such an appearance must be distinguished from the fibrous component (discussed later). These two types and all their intermediate appearances may be encountered in any meningioma. In addition, peculiar features sometimes are met: foamy cells with laterally placed nuclei; abnormal nuclei which are enormous, or pyknotic, or vacuolated, or contain one or two nucleoli.

The tumor cells are arranged in the specific pattern of the whorl. This pattern is more or less obvious, sometimes involving the entire tumor, in other instances being only suggested. It was present in each of the 121 meningiomas of this study. The whorl may be found in three chief forms: The first is what may be called the syncytial or plasmodial whorl (Fig. 3). This is made up of meningocytic cells

forming either large syncytial areas or small plasmoidal formations resembling multinucleated cells. Often the whorl-like arrangement is not obvious and generally is more easily visible at low magnification. The second form of whorl may be called the loose-meshed whorl (Fig. 4). It is made up of fibroblastic cells attached to each other by their fibrous ends. The third form is a small concentric whorl (Fig. 5) composed of cells surrounded by concentric fibrous, acellular rings. This corresponds to the type II, variant 3 of Cushing and Eisenhardt.⁸ Whorls of this kind are much less frequent than those of the first two types. Of course, all transitional forms are possible and they are often intermingled in a single neoplasm. The whorls usually are not formed around blood vessels. Though the whorl is the best evidence of a meningioma, it is not always morphologically prominent and other patterns can be demonstrated.

The next important feature is the parallel arrangement. This is made up of meningocytic or, much more frequently, of fibroblastic cells disposed in straight or curved rows. The appearance, without achieving the true palisading arrangement, can be close to that of the neurofibroma. Because of this, the differential diagnosis on occasion may be very difficult. This is especially true if it is not certain whether the tumor has any attachment to the dura or nerve root. Whorls are sometimes very rare and only suggested in a meningioma; foamy cells and macrophages, so frequent in the neurofibroma, may occur in a meningioma. There is a definite morphologic difference between the parallel arrangement of cells in a meningioma and the palisading arrangement in a neurofibroma. In the first, the cells are oval, dense, and much more uniformly distributed (Fig. 6); while, in the second, there are some areas either without cells or poorly cellular, alternating with clusters of densely packed, dark cells (Fig. 7).

The pleomorphism of meningiomas is such that many other appearances may be encountered, but these were infrequent in this series of cases. Broad sheets of meningocytic cells forming a syncytium and penetrated in places by foamy and fatty cells sometimes were seen (Fig. 9). In a few cases there was a relative absence of organization, the cells being disposed without any order in large areas (Figs 8 and 10). A "disposition stellaire" has been mentioned by Bertrand, Guillaume, and Olteanu¹² to describe this lack of cellular arrangement.

Other frequently encountered cellular arrangements include small clusters of syncytial meningocytic cells in the middle of parallel rows of cells, and large syncytial formations surrounded by narrow strands of fibroblastic cells. It is important to emphasize that no matter how

unusual the cellular pattern, the presence of a whorl establishes the definitive diagnosis. In the only 2 cases in which this structure was not found on initial examination, serial sections thereafter disclosed typical whorls (Figs. 8, 10, 12, and 15).

The Secondary Components

The secondary components are responsible in large part for the notable polymorphism of meningiomas. They may be absent, minimal, or prominent, and are mixed in exceedingly diversified ways. The presence of these components contributes also to the difficulty in diagnosis. Other tumors arising in relation to meninges may reproduce exactly the appearance of the secondary components, but do not contain the basic cellular constituents in whorl pattern.

The Fibrous Component. The fibrous component appears generally either as thick strands of fibrous tissue dividing the tumor into large islands (Fig. 11) or as a delicate network (Fig. 13). A few slender, dark cells sometimes are encountered in the fibrous tissue. In one case (Figs. 12 and 15) this component was so striking that the tumor appeared like a "fibroma" of the dura mater. The discovery of several whorls in serial sections proved it was in reality a meningioma and actually of arachnoidal origin. In 2 other cases a fibrous core was surrounded by highly cellular tissue (Figs. 14 and 16). In two tumors the fibrous component formed thick bands of fibrous tissue having the form of whorls (Fig. 17). Some arachnoid cells remained in it and for the most part it was homogeneous. The fibrous component should be distinguished from what we have called the fibroblastic part of the tumor.

The Psammomatous Component. The psammomatous component is certainly one of the most suggestive findings, without being pathognomonic. A vascular or cellular origin for this structure has been discussed frequently in the past. It is our feeling that psammoma bodies more often have a cellular origin, being the result of transformation of a whorl. The successive steps in this transformation (cellular, hyalinized, incompletely calcified, and completely calcified whorls) are well shown in Figure 18. It is possible also to find calcification in the wall or the thrombosed lumen of a vessel or in the connective tissue strands of both the dura and the fibrous component of a meningioma. But such calcification is rarely seen and often is morphologically different from psammomas, being elongated and without the characteristic onion bulb pattern. Calcific formations, when present, may be single or moderately or extremely numerous, the tumor being sandy when cut or

casting a shadow in the roentgenogram. Psammoma bodies may be confluent and form calcified masses (Fig. 20). Finally, it must be pointed out that psammoma bodies may be encountered in normal meninges or choroid plexuses.

The Vascular Component. Two kinds of vascular component are found: one frequent, the other rare. The first is called angiomatous because it is characterized by well formed, mature vessels with thin or thick walls and in places narrow or obliterated lumina (Fig. 19). These vessels are often disposed in small clusters. The angioblastic appearance is quite different and in this series was prominent only in one case (Fig. 21). The tumor contains many vascular spaces, triangular or elongated, limited by several slender cells which fill the spaces between the vessels. The appearance can mimic that of hemangioblastoma. Criteria have been given to distinguish these tumors: the almost exclusive localization of hemangioblastoma in the posterior fossa; presence of a capsule in a meningioma, but of a cyst in a hemangioblastoma. The only reliable way to make the diagnosis of meningioma, in our opinion, is to find in the tumor meningocytic or fibroblastic cells arranged in whorls.

The Lipomatous Component. The simple presence of macrophages filled with lipid material and generally found along connective tissue does not constitute the lipomatous component (Fig. 22). This is composed of adipose tissue whose cells are large and round or oval; they are optically empty, presenting a small, dark, laterally placed nucleus which is limited by a thin membrane. The fatty cells are located within the neoplastic tissue itself (Fig. 23). The presence of true fat may be confirmed by specific fat stains, since distention of the tissue by edema or by young vascular spaces may present a similar appearance. Such a true lipomatous component was found only three times, whereas macrophages with lipid material are banal. The question of a lipoma may arise in these cases, until the discovery of typical meningiomatous tissue establishes the true diagnosis.

The Osseous Component. The most frequent relation between bone and meningioma is invasion of bone by neoplastic tissue filling haversian canals (Fig. 24), the bone itself being either unaltered, or destroyed, or excited to proliferation with osteoblasts appearing in concentric lamellae. The tumor itself, however, may form osseous tissue. This was found to be the case in one instance in which bone as well as osteoblasts were present in the center of the meningioma.

The Chondrous Component. The chondrous component is a rarity. In one case, a large cartilaginous formation was present (Fig. 25).

The Sarcomatous Component. The phrase meningioma with sarcomatous component is employed to emphasize that the tumor is a meningioma as well as a sarcoma. This enables the pathologist to distinguish other malignant tumors of the leptomeninges such as diffuse sarcomatosis and melanosis which are sometimes confused with meningiomas. By "sarcomatous component" is meant the addition to typical meningiomatous tissue of some features of malignancy such as mitotic figures, abnormal nuclei, necrosis, and hemorrhages, indicating a malignant evolution, at least from the pathologic standpoint (Figs. 26 and 27). Indeed, the prognosis is not necessarily bad in these cases, and the discordance between pathologic diagnosis and clinical experience has been stressed by some authors.^{6,12} This discrepancy is the chief reason for separating clearly a meningioma with sarcomatous component from a sarcoma of the meninges, the prognosis of the latter being considerably worse. Meningioma with sarcomatous component was encountered three times, a fatal outcome having occurred after 6 months in one case and after 10 months in another. The third patient is still living after 3 years.

Associated Diseases

Two cases with curious coincidental neoplasms were found. The first was a meningioma of the cerebral convexity discovered at necropsy in a female, 45 years old, who died of carcinoma of the breast with multiple metastases to cerebral dura, cerebrum, and cerebellum, and to the meningioma itself (Fig. 29). The second case was that of a meningioma of the cerebellopontine angle mingled with an ependymoma in the same location.

The classical association between multiple meningiomas and von Recklinghausen's neurofibromatosis was encountered in one instance. Small tumors of both types were numerous in this case and, peculiarly, several neurinomas were found within the spinal cord. Still more interesting in this case was the discovery of a third type of neoplastic tissue made up of large cells with stippled protoplasm and one or sometimes two lateral nuclei (Fig. 30). This tissue was intimately mixed with the meningiomatous part of a tumor arising from the falx and extending into the right cerebral hemisphere. This tissue had the appearance of a myoblastoma. Such an appearance has been seen before (Fig. 25, type I, variant 4 of Cushing and Eisenhardt⁶). It has been described as a muscular tumor by Abrikossoff¹³ although it may occur in regions without muscle. Later, Leroux and Delarue¹⁴ considered it as made up of "cellules mésenchymateuses de type histio-

cytaire." From a study of 51 cases, Fust and Custer¹⁵ concluded that it was a special type of neurofibroma, and recently Pearse¹⁶ interpreted it more especially as a perineural fibroblastoma. Our case is interesting because it is another example of the association between meningioma and neurofibroma, and furnishes an additional argument in favor of the neurogenic origin of the so-called myoblastoma.

Histologic and Clinical Correlations

Three components were most common in the meningiomas: fibrous, psammomatous, and angiomatic; the others were rare. There was no correlation between histologic appearance and clinical duration except for the sarcomatous component, which may be said in general to be a more rapidly growing neoplasm than the usual meningioma. The biologic behavior of meningiomas is, in fact, remarkably constant despite their polymorphism.

There was, on the contrary, some correlation between morphologic appearance and location of the neoplasm. Fibroblastic cells and parallel arrangement were prominent in tumors of the posterior fossa, in the psammomatous component in the spinal tumors, and in the meningiomas of the sphenoid ridge. Less frequently, a vascular component was found in the tumors on the cerebral convexity and in the parasagittal region. It is of interest that radiologic and macroscopic alterations of bone were most common also in those cases in which the meningiomas were on the sphenoid ridge, cerebral convexity, and in the parasagittal area.

Histologically, the important fact about these meningiomas, also stressed by previous authors, is that they were extremely polymorphic, a mixture of several of the various components having been seen in some of the tumors. An association of two sharply different types of tumor is seen in Figure 28. This demonstrates how discovery of a single component may be related to the plane of the section. These facts emphasize the difficulty in classifying meningiomas rigidly.

SUMMARY

A new approach to the interpretation of meningiomas is suggested, based on a clinicopathologic study of 121 cases. The present concept is that meningocytic or fibroblastic cells, alone or in combination, are the basic cellular constituents of these neoplasms. The diagnosis is established by the finding of such cells in the characteristic whorl pattern. There are thus meningocytic meningiomas, fibroblastic meningiomas, and mixed types. Secondary components (lipomatous, hemangiomatic, psammomatous) may or may not be associated with these

cells. The secondary components are not essential for the diagnosis, but for descriptive purposes may be included as in "fibroblastic meningioma with mild psammomatous component." The flexibility of this scheme permits adaptation of the diagnosis to the extreme polymorphism of meningiomas. The tumor is strictly defined in morphologic terms and can be described clearly and completely.

Mr. Antol Herskovitz prepared the photomicrographs.

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[*Illustrations follow*]

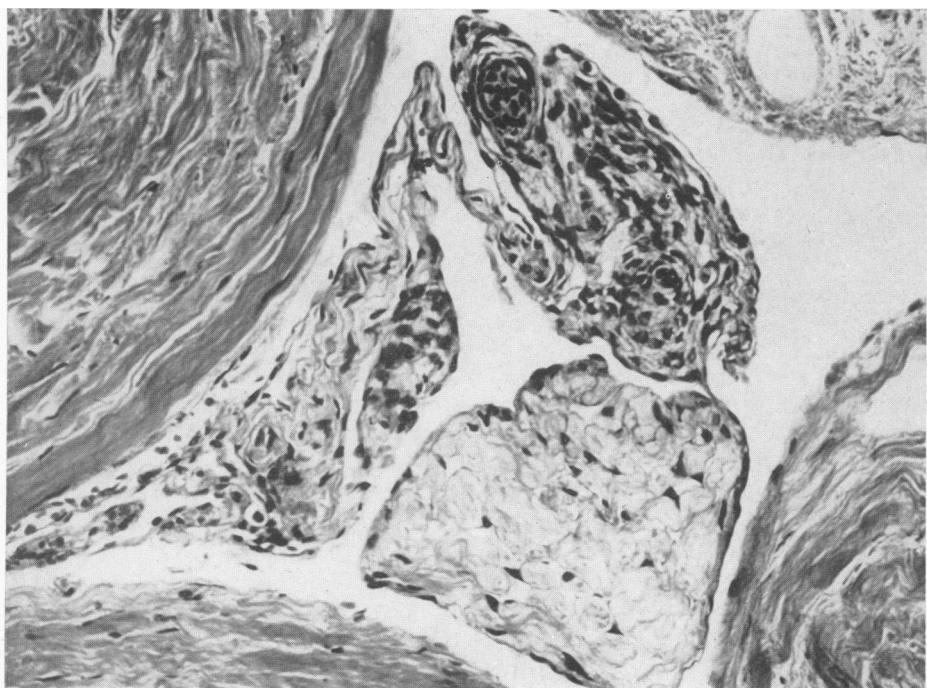
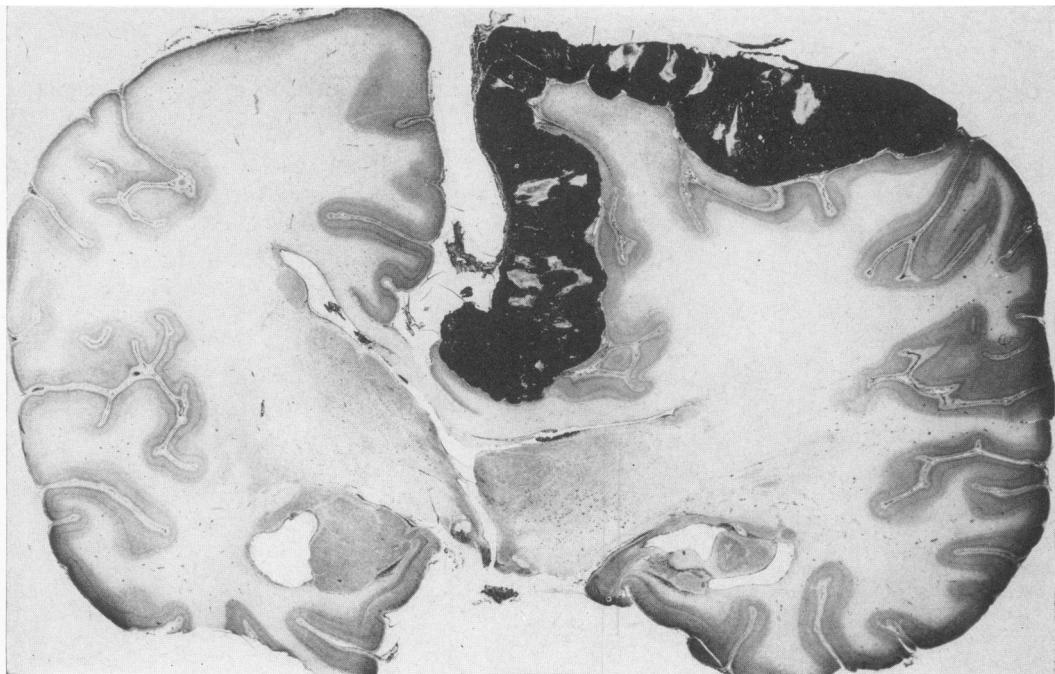
DESCRIPTION OF PLATES

All photomicrographs are of hematoxylin and eosin preparations except Figure 1 which was stained by the Nissl technic.

PLATE 108

FIG. 1. Giant meningioma shown in a coronal section of brain, extending over dorsal surface of brain and deep into the median fissure.

FIG. 2. Normal arachnoid villi in superior longitudinal sinus. $\times 230$.



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PLATE 109

FIG. 3. Syncytial whorls formed by meningocytic cells. $\times 550$.

FIG. 4. Whorls of loose-meshed type. $\times 550$.

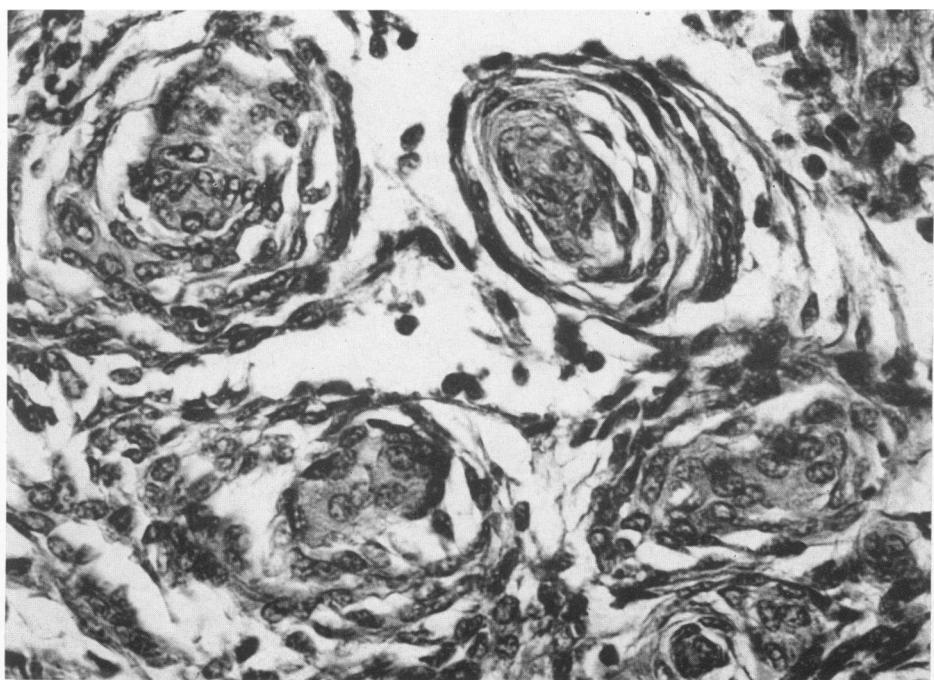
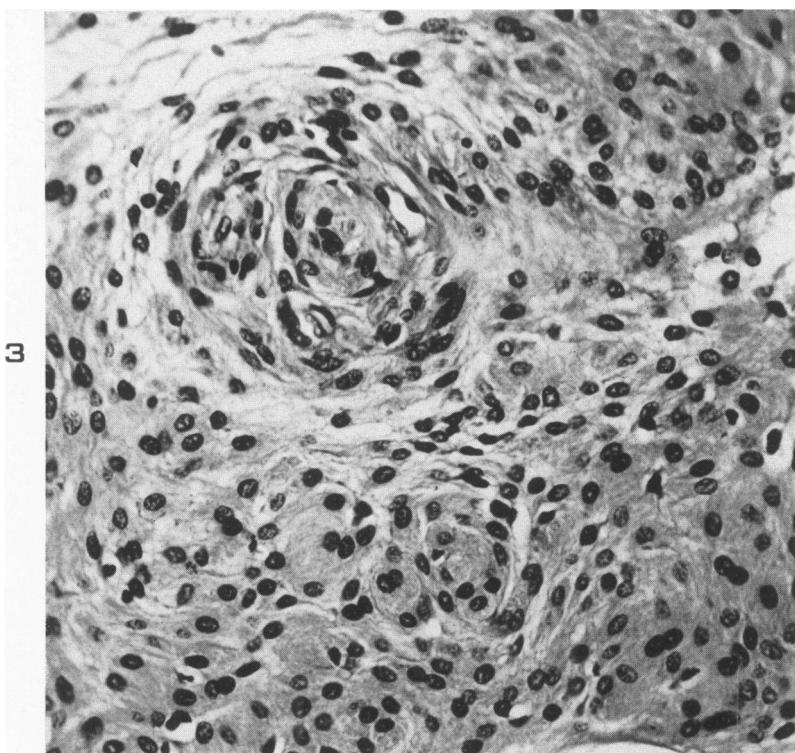
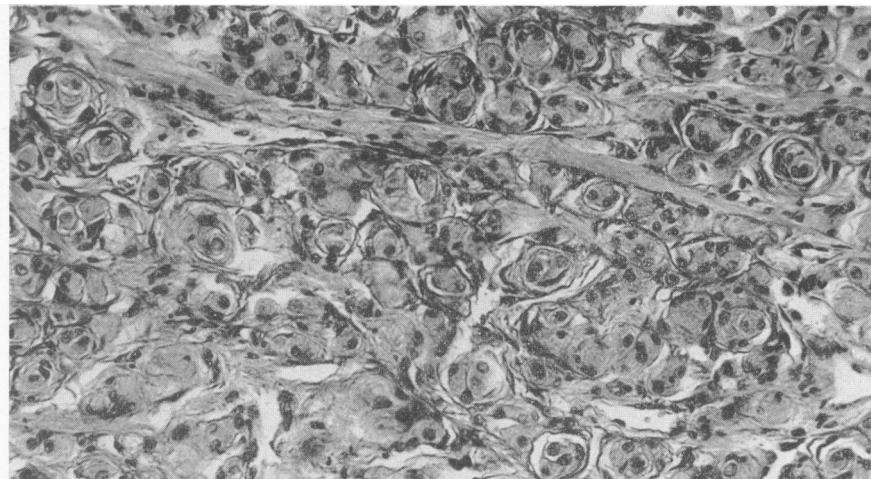


PLATE 110

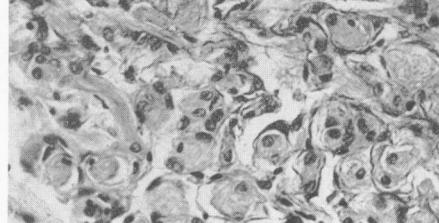
FIG. 5. Whorls of concentric small type. $\times 150$.

FIG. 6. Parallel arrangement formed by fibroblastic cells in a meningioma. $\times 150$.

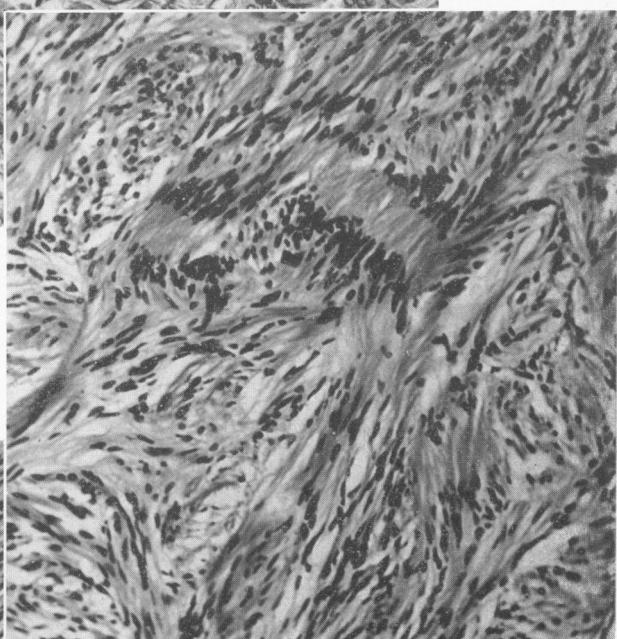
FIG. 7. Palisading arrangement in a neurofibroma. $\times 150$.



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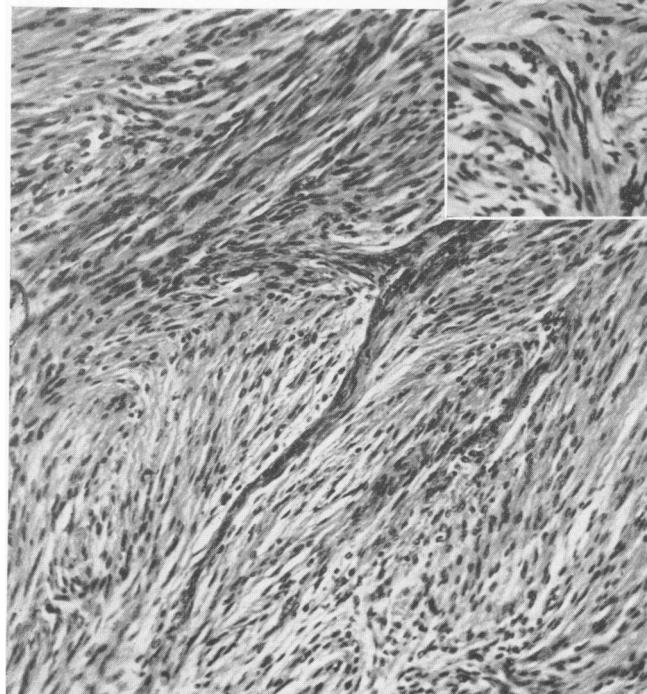


PLATE III

FIG. 8. Meningioma of unusual type in which cells are without special organization and the tumor cannot easily be identified as a meningioma. For comparison with Figure 10. $\times 150$.

FIG. 9. Broad sheets of meningocytic cells forming a syncytium and penetrated in places by foamy and fatty cells. Two psammoma bodies are visible. $\times 260$.

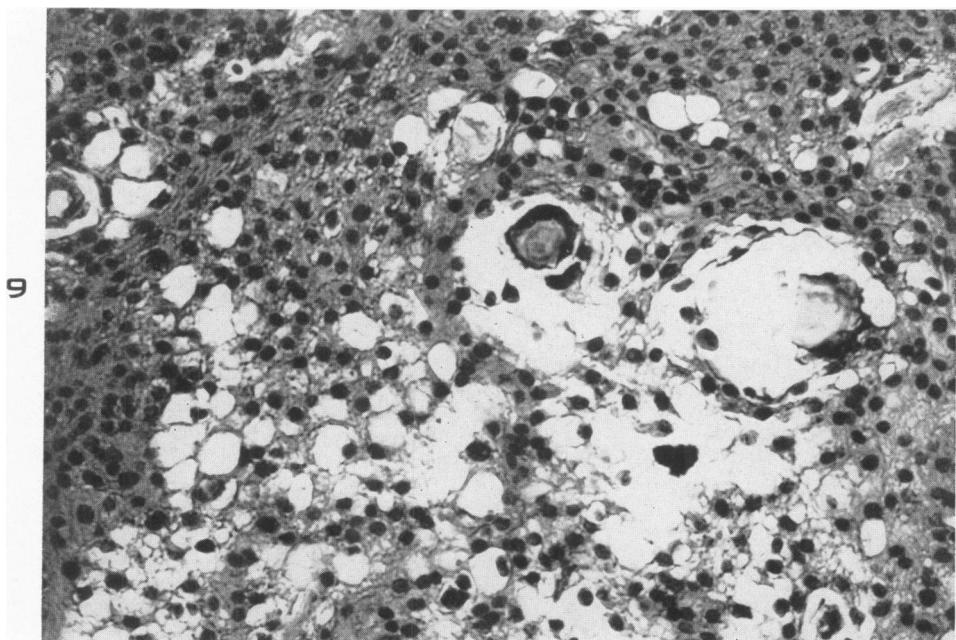
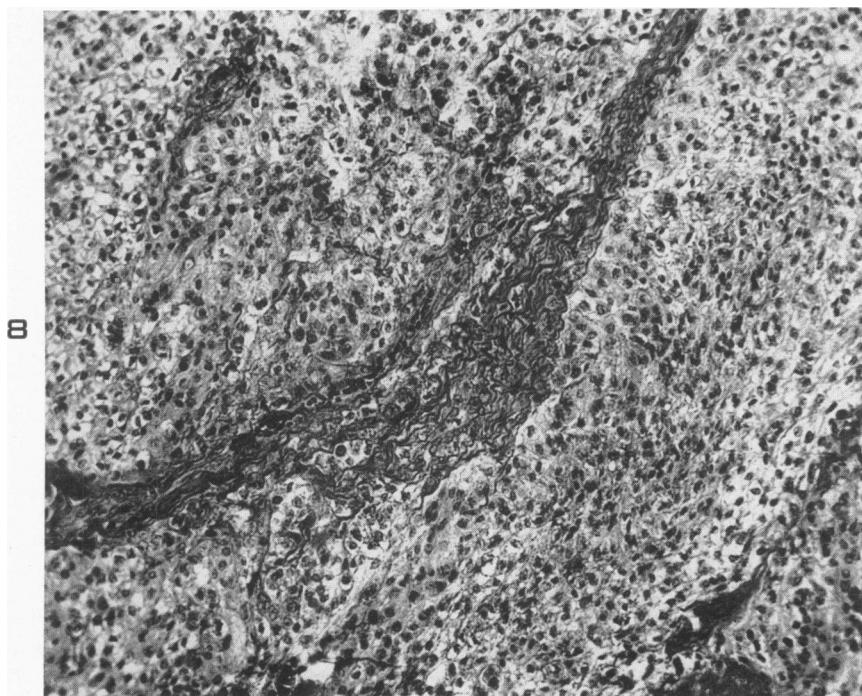
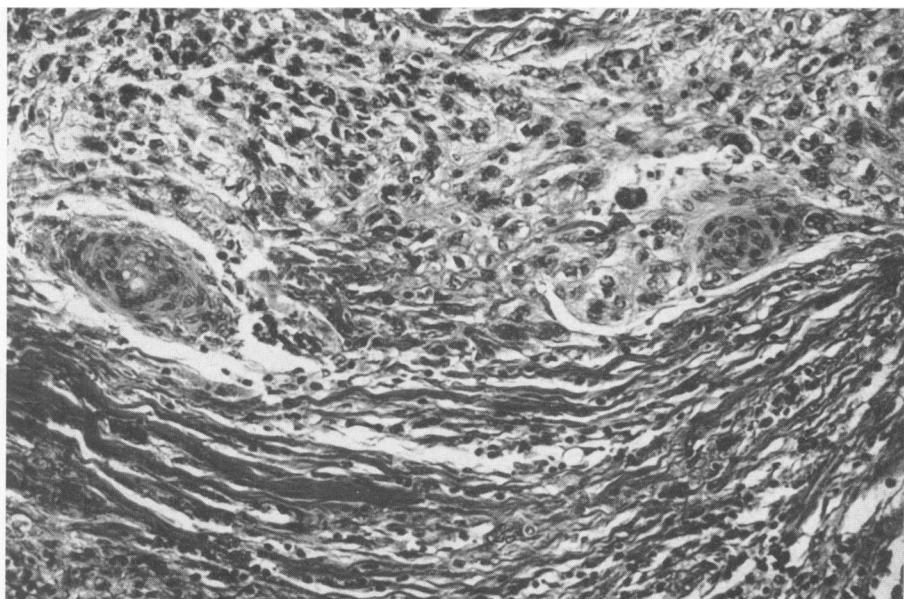


PLATE 112

FIG. 10. A portion of the tumor shown in Figure 8, found in serial sections, demonstrating two characteristic syncytial whorls. $\times 220$.

FIG. 11. Thick strands of fibrous tissue divide the tumor cells into small islands. $\times 150$.

10



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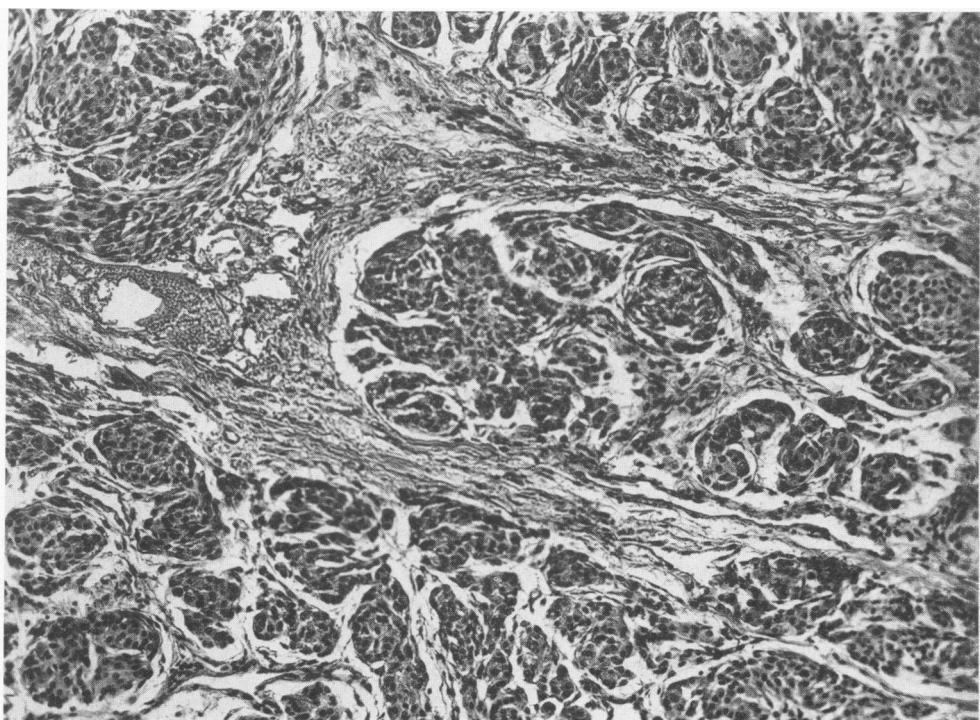
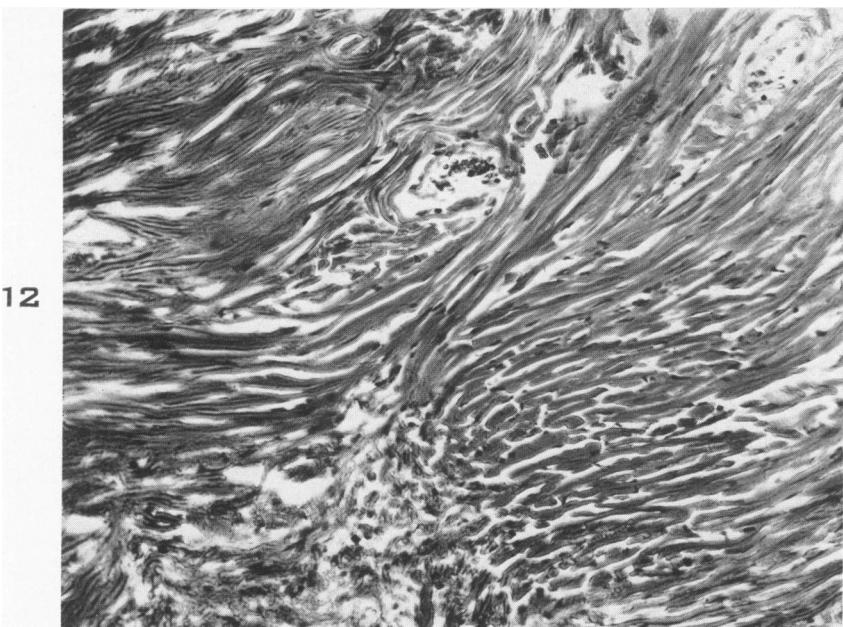


PLATE 113

FIG. 12. Unusual type of fibrous component resembling a scar. The tumor cannot be identified easily as a meningioma. For comparison with Figure 15. $\times 150$.

FIG. 13. Delicate network of fibrous tissue with some fibroblastic cells and slight admixture of meningocytic cells. This secondary fibrous component should not be confused with the pure fibroblastic type seen in Figure 6. $\times 150$.

12



13

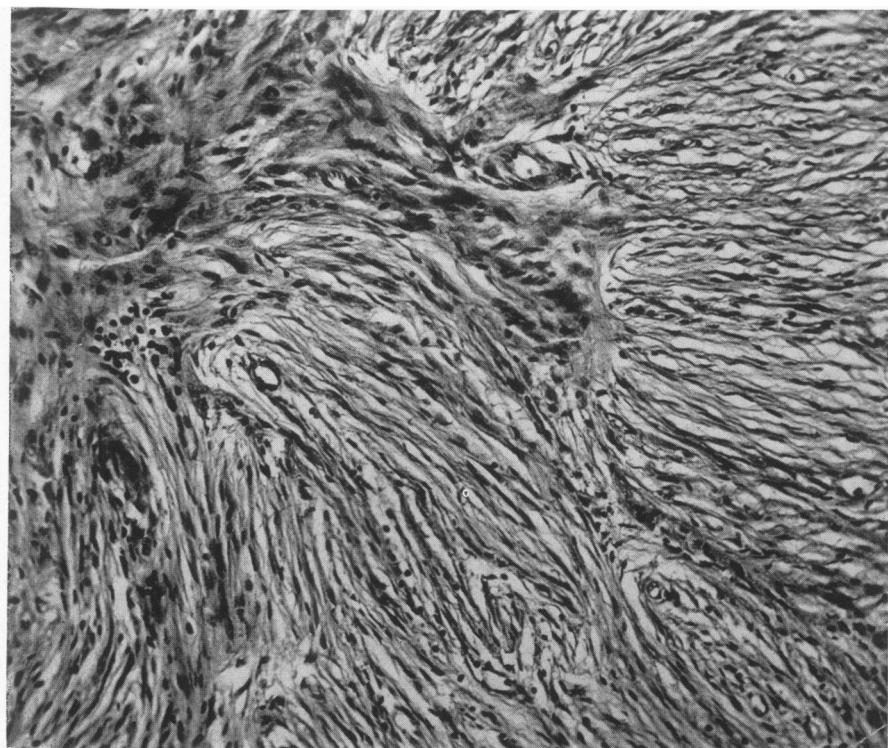


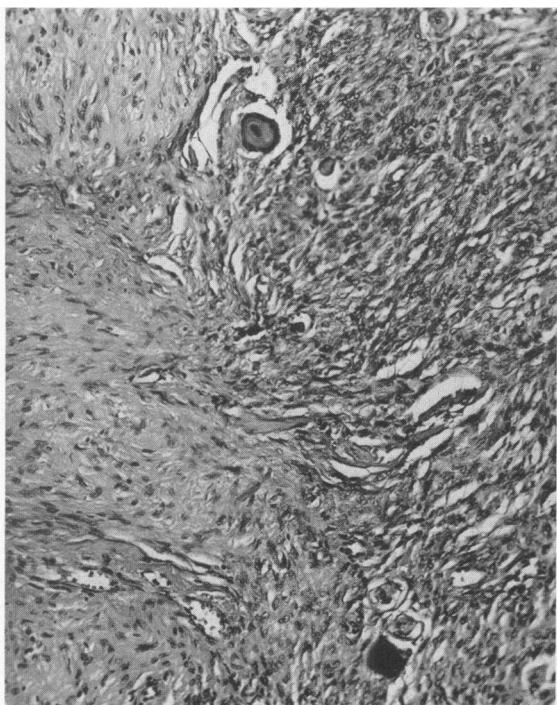
PLATE 114

FIG. 14. Higher magnification of the field shown in Figure 16, on the border of the fibrous core. $\times 150$.

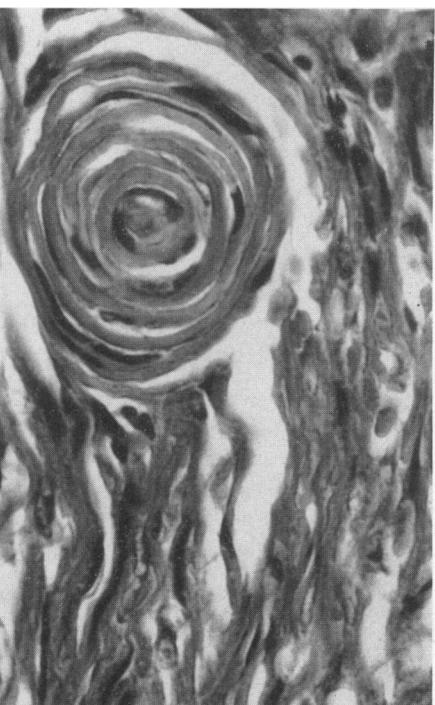
FIG. 15. A portion of the tumor shown in Figure 12, found in serial sections, demonstrating a characteristic whorl. $\times 700$.

FIG. 16. Fibrous core in a cellular meningioma. $\times 22$.

14



15



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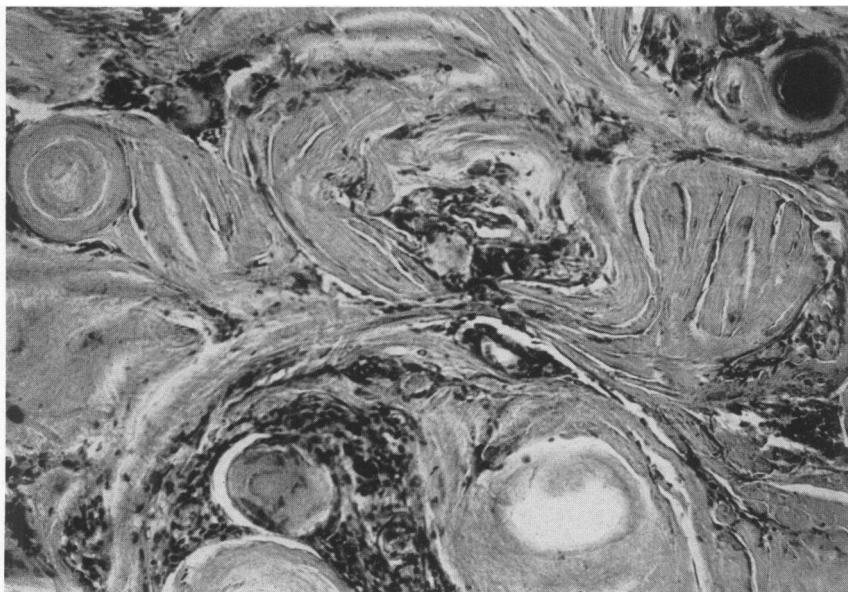
Pathology of Meningiomas

PLATE 115

FIG. 17. Thick, homogeneous, fibrous component forming whorls. $\times 120$.

FIG. 18. The various stages of formation of psammoma bodies are shown: cellular, hyalinized, partially and completely calcified whorls. $\times 230$.

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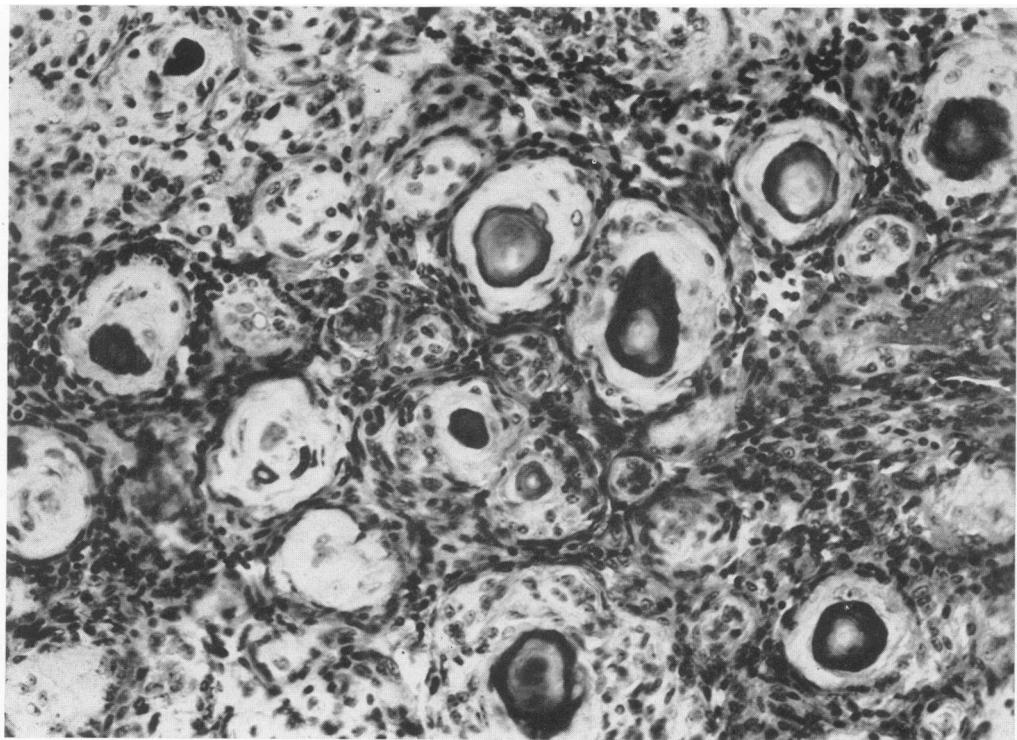


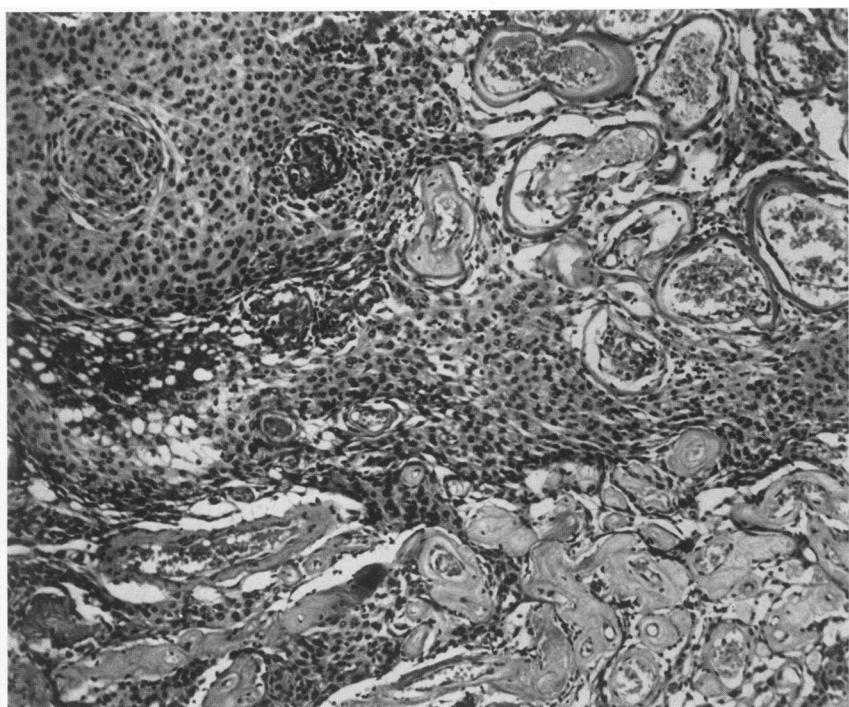
PLATE 116

FIG. 19. Angiomatous component in meningocytic meningioma. $\times 120$.

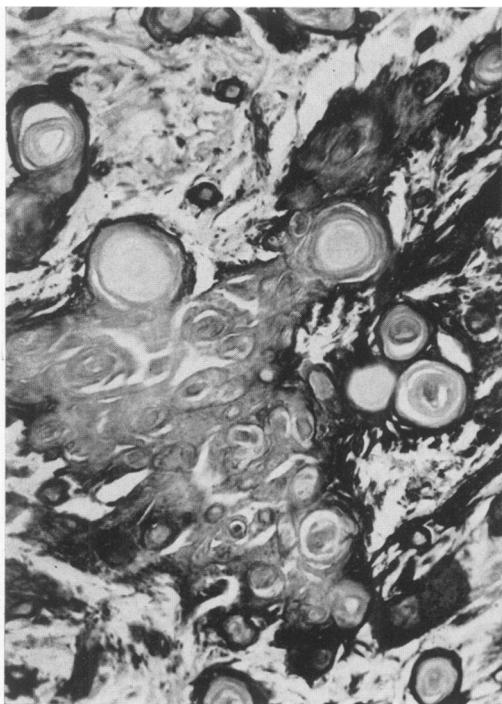
FIG. 20. Fusion of psammoma bodies to form large calcified zones. $\times 135$.

FIG. 21. Angioblastic component formed by numerous immature vascular spaces.
 $\times 225$.

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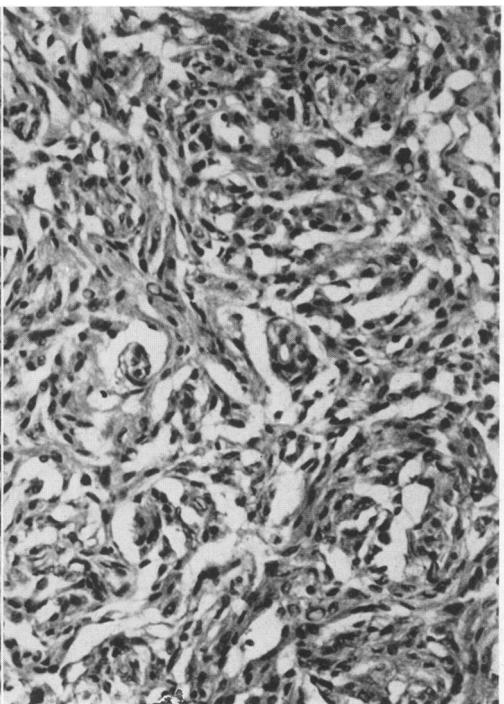


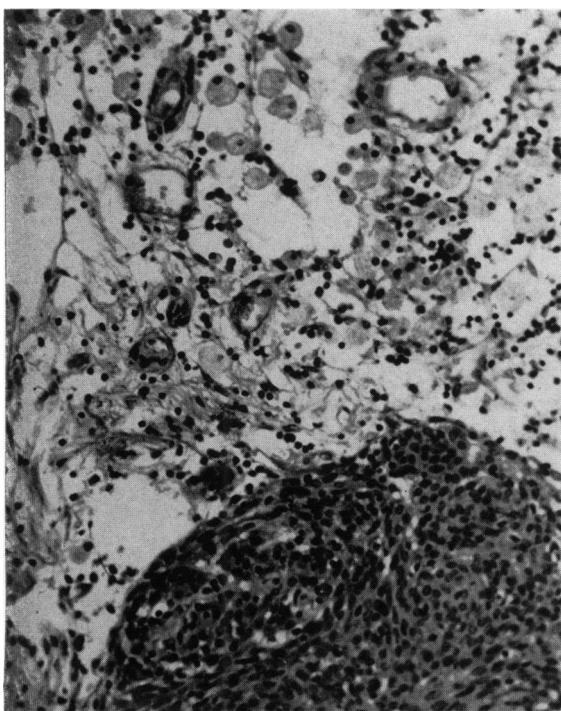
PLATE 117

FIG. 22. Lipid-laden macrophages and lymphocytes adjacent to meningocytic meningioma. $\times 150$.

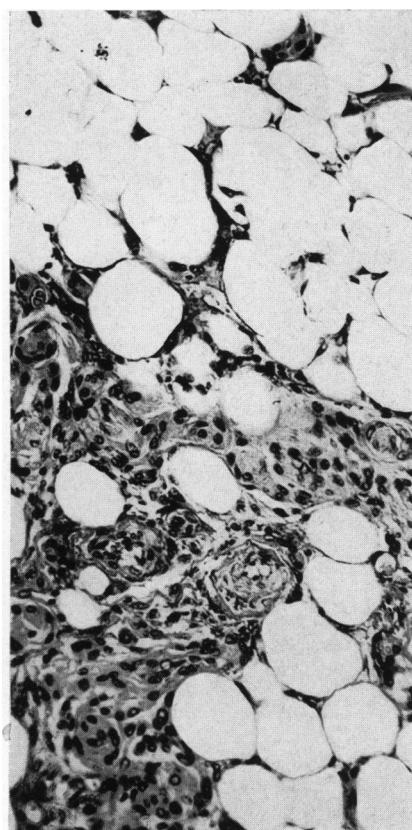
FIG. 23. True lipomatous component in meningocytic meningioma. $\times 150$.

FIG. 24. Invasion of haversian canals by neoplasm without alteration of surrounding bone. $\times 110$.

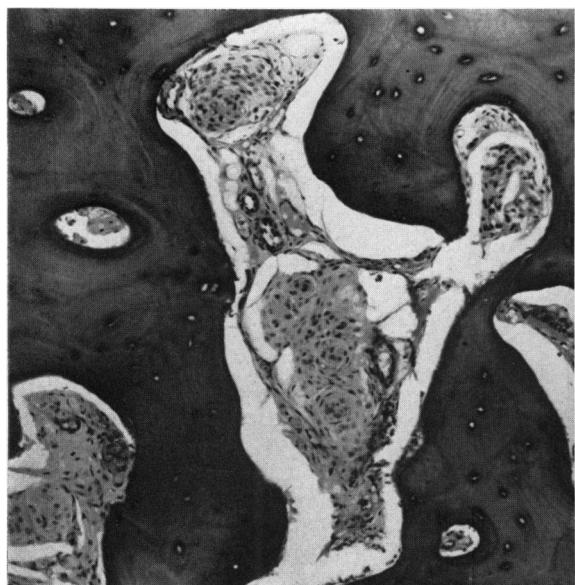
FIG. 25. Chondrous component in a meningioma. $\times 235$.



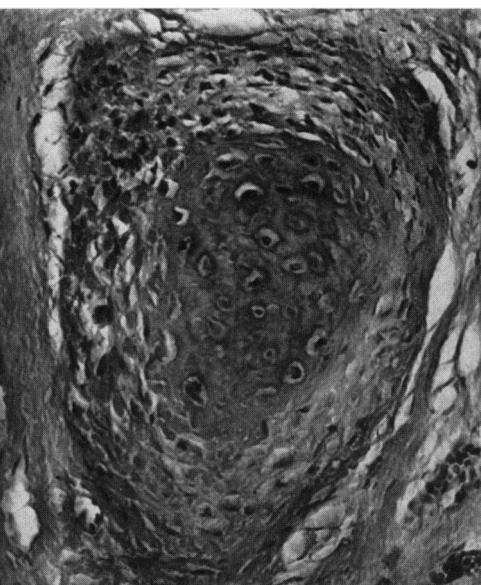
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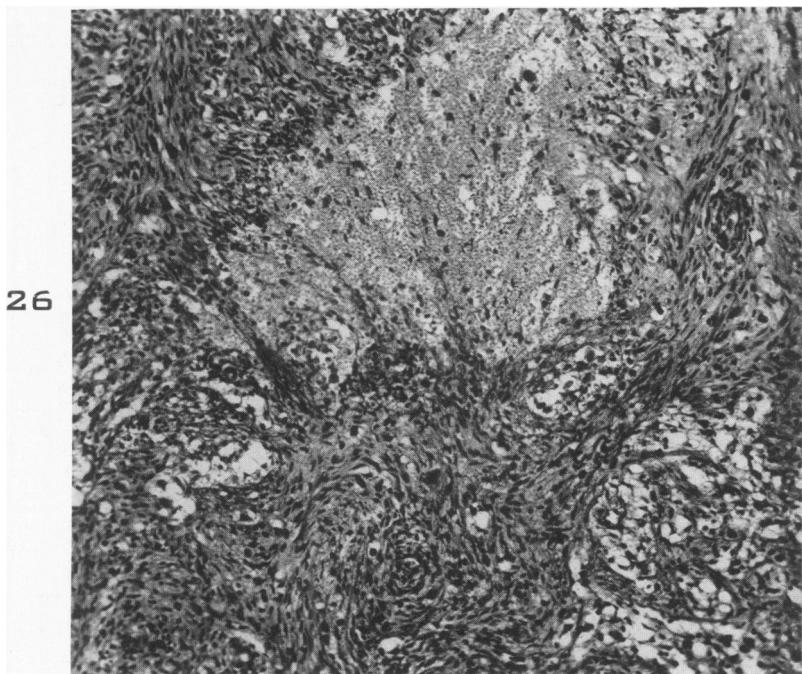
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PLATE 118

FIG. 26. Focus of necrosis in sarcomatous component of a fibroblastic meningioma.
Whorls and parallel arrangements of the basic cells are seen. $\times 150$.

FIG. 27. Pseudo-palisading arrangement around another focus of necrosis in same
tumor as in Figure 26. $\times 150$.

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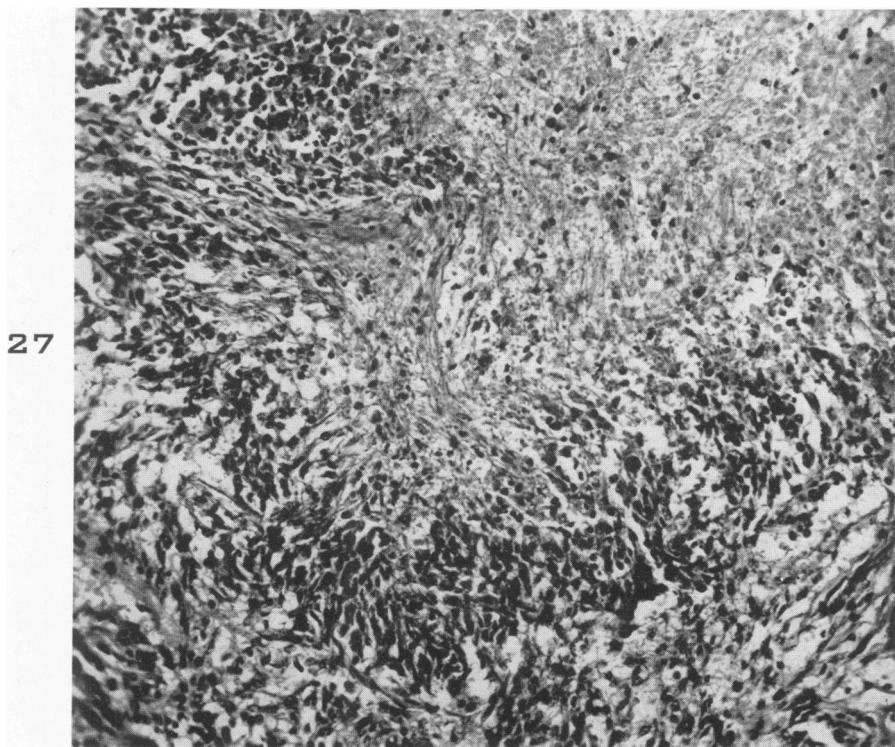


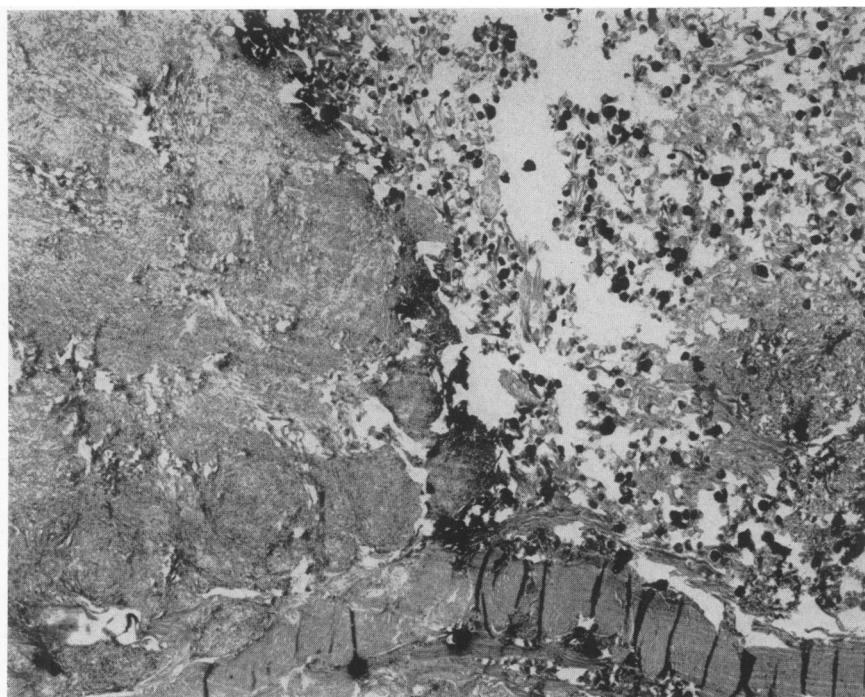
PLATE 119

FIG. 28. Two different types of meningioma in the same tumor lie sharply separated and attached to dura below. This illustrates how discovery of a single component may be a matter of chance. $\times 30$.

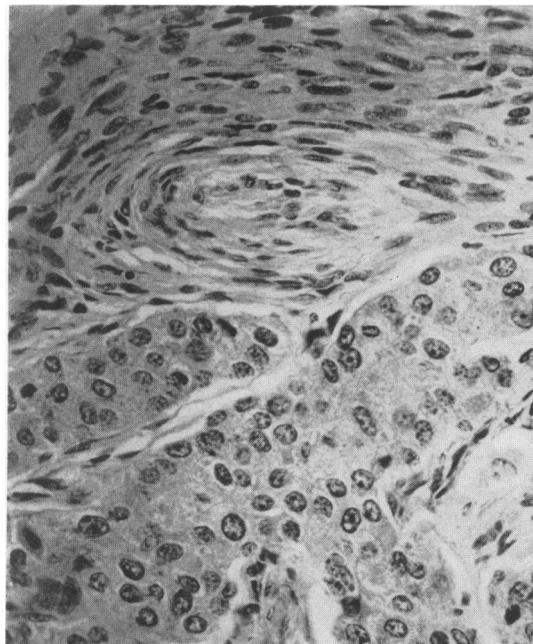
FIG. 29. Metastasis of carcinoma of breast to a meningioma. $\times 330$.

FIG. 30. Myoblastoma in association with fibroblastic meningioma. $\times 210$.

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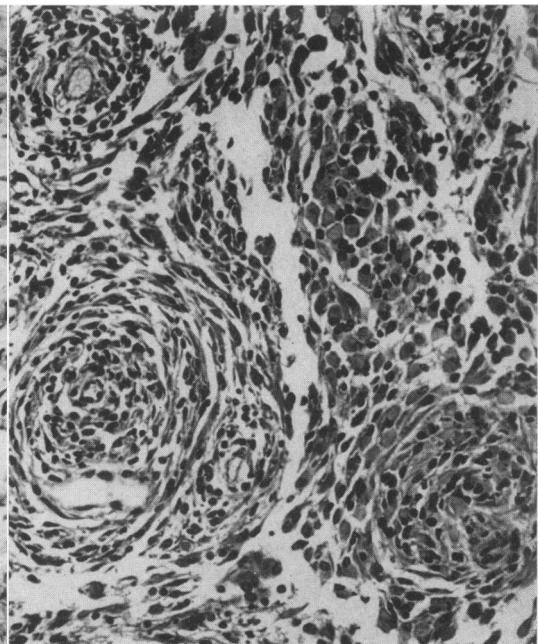


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