THE ORIGIN AND NATURE OF MENINGEAL TUMORS

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Since the classical article of M. B. Schmidt meningeal tumors have been generally considered to arise from clusters of arachnoidal cells, and controversy concerning them has been largely terminological. Many have objected to the common term dural endothelioma on the grounds that the tumors arise from the arachnoidal membrane and that the neoplastic cells are not endothelial. Mallory, followed by Penfield, tried to prove that the typical cell in these tumors is a fibroblast and that, therefore, they should be called fibroblastomas. Cushing avoided the issue by speaking of them simply as meningiomas. But whatever the term used, it was, until lately, believed that these tumors were of mesodermal origin.

The matter was complicated by Oberling when he published his theory that the leptomeninx was of neuro-ectodermal origin. The French pathologists soon began to speak of neuro-epithelial and gliomatous types of meningeal tumors.

In view of the existing confusion in terminology, we have, during the past two years, been trying to form a personal opinion concerning these tumors. From our own clinic and through the kindness of numerous friends we have secured a considerable material for study, and our investigations have made us dissatisfied with the present terminology. We have found at least nine distinct histological types of tumors arising in the meninges. We will give an example of each of these and then our opinion concerning what conclusions can reasonably be drawn from their study as to the origin and nature of meningeal tumors in general.

METHOD OF STUDY

The tumors were fixed in formalin (10%) and Zenker’s fluid. On the formalin-fixed material the following staining and impregnation methods were used: hematoxylin and eosin, Van Gieson, Perdrau, silver nitrate, scarlet red, Globus' modification of the gold-sublimate method, Davidoff's modification of the phosphotungstic acid-hematoxylin method, resorcin-fuchsin. On the Zenker-fixed
tissue the following methods were used: methylene blue-eosin, aniline blue-orange G, neutral orange G-ethyl violet, phosphotungstic acid-hematoxylin, Verhoeff's method for elastin.

**Description of Cases**

I. **Mesenchymal Type**

Through the courtesy of Drs. C. Van Epps, G. H. Hansmann, and C. Obermann of Iowa City, we have been able to examine a meningeal tumor whose microscopic structure resembles very much that of the mesenchyme of the young embryo.


E. T., a white female, thirty-four years of age, was admitted to the University Hospital, State University of Iowa, on June 25, 1928. She stated that in November 1927, during the course of her eighth pregnancy, she had a fainting spell. She was unconscious for two hours and was unable to talk for an hour after regaining consciousness. She had suffered ten similar spells prior to her admission. Since the onset she had become increasingly irritable, excitable, and prone to worry. She suffered at times from dizzy spells, in which objects seemed to turn to the right. Since February 1928 she had had periodic attacks of severe headache in the top of the head, associated with pain in the neck. At times she would vomit with these headaches.

In July 1921 a "blood tumor" about 3 cm. in diameter had been removed from the right shoulder. A recurrence had been removed in February 1922. Subsequently it again recurred and was present at the time of admission.

On admission the patient was negativistic. There was slight blurring of the optic discs. Occasionally an increased patellar reflex and Babinski's sign could be elicited on the right side. A small reddish brown tumor 3 cm. in diameter was present on the posterior aspect of the right shoulder.

Lumbar puncture revealed nothing abnormal. Encephalography was done but gave no positive information. The tumor was removed from the shoulder and proved to be a capillary hemangioma.

A brain tumor was suspected but no definite diagnosis could be made, and the patient was discharged on July 27, 1928.

The patient was readmitted on November 9, 1928, in a stuporous condition. Examination revealed a choked disc of two diopters in the left eye, a right facial weakness (?) and a positive Babinski sign on the right. X-ray revealed a dilatation of the left middle meningeal artery and a slight thickening of the skull over the vertex anteriorly. On December 5, 1928, a craniotomy was attempted, but the hemorrhage was so profuse as to necessitate interrupting the procedure before the
PLATE I

CASE 1: MENINGEAL TUMOR OF MESENCHYMAL TYPE

Fig. 1. Hematoxylin-eosin, × 150. Note the loose structure and numerous capillaries.

Fig. 2. Perdrau's method, × 150. Numerous delicate fibrils of reticulin, especially around capillaries.
dura mater was opened. The surgeon felt that there was a subdural tumor. The patient died a few hours after the operation.

Necropsey (A-28-178) was performed by Drs. Karl Swanson and Charles F. Obermann. It was limited to examination of the brain. There was a large well encapsulated tumor which invaginated the superior surface of the left frontal lobe. It lay immediately anterior to the precentral gyrus and measured 4 x 4 x 6 cm. It was attached to the dura mater by a broad base (2 x 3 cm.). The neoplasm was separated from the falx by 0.5 cm. of nervous tissue. The tumor was completely encapsulated and readily lifted out of the depression in the brain. On section it was pink in color and firm in consistency. A fibrous septum could be seen extending from the dural attachment into the center of the tumor.

The tumor is found to be composed of a very loose tissue. The cells are largely bipolar, spindle-shaped cells with definite long, thin processes, eosinophilic cytoplasm, and oval nuclei which contain a moderate amount of diffusely scattered chromatin (Plate I, Fig. 1). There are also a few stellate cells. There are no mitotic figures seen. Blood vessels are very numerous throughout the tumor and have thin connective-tissue walls. There are no areas of degeneration. Mallory's phosphotungstic acid-hematoxylin method, after Davidoff's modification, reveals definite fibroglia in the tumor cells. Reticulin is abundant about the blood vessels and extends among the neoplastic cells as very delicate strands (Plate I, Fig. 2). There is practically no collagen in this tumor; a very little in the walls of the larger vessels. No elastic tissue and no mucin is found.

Comment: This tumor, microscopically, bears a surprisingly close resemblance to the mesenchyme which precedes the formation of the meninges. The loose arrangement of the cells, the delicate strands of reticulin, and the practical absence of collagen and elastin are quite typical.

There is no doubt in our minds that this meningeal tumor was entirely independent of the telangiectasis on the shoulder. It had none of the characteristics of a metastasis, and was of quite different structure.

II. Angioblastic Type

Tumors of angioblastic structure may arise in the leptomeninx. Such tumors have been described by Bailey, Cushing and Eisenhardt.

The following is an example from our own clinic.

M. M., a white male, twenty-seven years of age, was referred to this clinic by Dr. John MacKellar of Chicago. He was admitted on December 21, 1928, complaining of headache and loss of vision. He stated that four months before admission he began having headaches in the morning. These gradually increased in severity and duration. He had also suffered from spells of vomiting, more frequently during the preceding month. His vision had begun to fail a month after the onset of the headaches and was much worse at times. For a week or more prior to admission he had been unable to read and could see but very little with either eye, slightly more with the left. He had also noted that for two months the hair and scalp in the midfrontal region were hypersensitive.

The patient's wife informed us that in the last two months he had changed from the interested, affectionate, and helpful husband he had previously been and was now careless about his personal appearance and took no interest in her or in their household. He would come home in the evening and sit in a chair, paying no attention to anything, and doing nothing.

The left pupil was found to be larger than the right. There was general constriction of the visual fields. There was a choked disc of four diopters in each eye. It was noted that the patient seemed to take very little interest in his condition and did not seem to care what was done to him.

A roentgenogram of the skull taken at this time revealed a few indefinite areas of decreased density in the frontal bone just to the left of the mid-line.

Although the evidence was definitely in favor of a tumor of a frontal lobe, there was no lateralizing sign of value. For that reason a ventriculogram was made on December 27, 1928. This revealed a complete absence of any air in the anterior portion of the left lateral ventricle and a displacement of the septum pellucidum and right lateral ventricle to the right, showing that the tumor was on the left side.

On January 19, 1929, an osteoplastic flap was reflected in the left frontal region. The bone in the area seen in the roentgenogram just to the left of the mid-line was perforated with numerous holes, each of which bled profusely. This hemorrhage was finally controlled with muscle, and the bone-flap completed. The bleeding from the dura mater was also profuse and it became necessary to stop the operation at this point. The patient was given normal salt solution intravenously and a transfusion of blood. Five days later the second stage was attempted. The dura mater was reflected, exposing a large tumor in the left frontal lobe. As the tumor was separated from the brain, suddenly a profuse bleeding came from the depths. The tumor was then rapidly enucleated with the finger and the wound packed with cotton. An infusion of normal saline had previously been started and a transfusion of blood was now given. The packs were left in place and the patient returned to his room in fair condition. Three days later the packs of cotton were removed with little difficulty.

Immediately after the last operation the patient had a right hemiparesis, which gradually improved. The wound healed badly and a leak
of cerebrospinal fluid persisted for days. The patient was finally discharged on March 16, 1929. At that time he had only slight perception of light in the nasal half of the right visual field. The discs showed a secondary optic atrophy with a marked overgrowth of scar-tissue. The hemiparesis had almost completely disappeared.

The tumor removed measured 6.5 x 5.5 x 5.5 cm. It was quite firm in consistency and pinkish-gray in color. On sectioning the tumor we found that it contained many cystic spaces of varying size, from a few millimeters to 2 cm. in diameter. There were also many hemorrhagic areas.

The tumor is found on microscopic examination to be very cellular. The nuclei are oval with little chromatin. Mitotic figures are commonly found. Throughout the tissue there are numerous large and small spaces (Plate II, Fig. 1). Some of these are empty; others contain a few erythrocytes and coagulated serum. The larger spaces have a definite flattened endothelial lining but no supporting connective-tissue or muscular structure such as one would expect in a blood vessel of this size. The smaller spaces are obviously lined by the tumor cells themselves, while the moderate-sized spaces are often lined in part by a flattened endothelium which fades off into tumor-cells lining the remainder of the wall.

Impregnation with silver discloses a tangle of fibrils of reticulin surrounding all of the capillary spaces (Plate II, Fig. 2). There is very little collagen in the cellular areas and no fibroglia nor elastin.

Scattered throughout the tumor are sclerotic areas in which nuclei are absent and the neoplastic cells have been replaced by a scar of collagenic fibers.

Many neoplastic cells lie free in the lumina of the vascular spaces. The tissue is not properly fixed for a study of blood formation.

Comment: The structure of this tumor is entirely in accord with the view expressed previously by Bailey, Cushing and Eisenhardt, that in these neoplasms the cells are comparable to the angioblasts of Sabin.

We have examined another meningeal tumor of very similar structure from the laboratory of Dr. F. W. Hartman of Detroit. It is interesting that he noted in his description, written in 1926, that the tumor was quite different from the ordinary meningeal neoplasm and that the blood vessels were very abundant. He added: "They are apparently walled by the tumor cells themselves."

These tumors invariably recur, and death usually results in from three to six years. From reports we have obtained of our own case a recurrence is probably now taking place, but since the patient has taken up Christian Science we have been unable to verify the reports.
PLATE II
CASE 2: MENINGEAL TUMOR OF ANGIOLASTIC TYPE

Fig. 1. Hematoxylin-eosin, ×150. A myriad of capillary spaces, many of them widely dilated.

Fig. 2. Perdrau's method, ×150. The capillaries are surrounded by strands of reticulin.
III. Meningotheliomatous Type

In this fairly common type of meningeal tumor the cells form a sheet of cytoplasm in which the cellular boundaries are difficult to distinguish.


E. N., a white female, sixty-five years of age, was referred to this clinic by Dr. Peter Bassoe of Chicago. She was first admitted on December 13, 1929, complaining of paroxysmal attacks of severe pain in the left side of the face. The attacks of pain began eighteen years prior to admission. They had always been regarded as typical of the pain of trigeminal neuralgia. Soon after her first attack the patient had received injections of alcohol into the trigeminal nerve. Subsequently alcohol was injected many times, with varying degrees of relief. In 1923 another surgeon had attempted to section the posterior root of the Gasserian ganglion but had failed because of hemorrhage. He again attempted it in 1924 and, being unable to section the root, removed part of the ganglion. This afforded only partial relief from the pain and resulted in an anesthesia in the area of the mandibular division. On admission the pain was the same as it had been for many years and involved the areas of the first and second divisions of the left trigeminal nerve.

Further inquiry elicited a history of dyspnea, palpitation on exertion, and some precordial pain, all of two years duration.

General physical examination revealed considerable generalized arteriosclerosis, a blood pressure of 215/95, marked enlargement of the heart to the left, and numerous extrasystoles. The cardiologist felt that there was definite evidence of disease of the coronary vessels.

Neurological examination showed definite paresis of the musculature of the left side of the face, which had been present since the previous operations. There was also an enophthalmos on the left side, and the pupils were irregular and reacted poorly to light and on accommodation. The left pupil was slightly smaller than the right. There was a total anesthesia over the lower lip and the margin of the mandible on the left side. A large depressed area was palpable in the left temporal region.

Because of the patient's cardiac condition it was thought inadvisable to risk the dangers of an operation, and she was discharged. However, as the pain continued, she returned on March 4, 1930, stating that she could no longer stand the pain and wished to take the risk of an operation.

Because of the two previous operations in the temporal region, it was felt that the chance of a satisfactory result was greater if the suboccipital approach were used. Therefore, after intensive treatment with digitalis, the operation was performed on March 8, 1930. After reflecting a suboccipital flap and removing the bone in a sufficient area from the left
PLATE III

CASE 3: MENINGEAL TUMOR OF MENINGOTHELIOMATOUS TYPE

Fig. 1. Hematoxylin and eosin, ×150. Note the evenly distributed nuclei.

Fig. 2. Perdrau's method, ×150. No intercellular fibrillary material except around the blood vessels.
side, the cerebellum was retracted in order to expose the posterior root of the trigeminal nerve. In the position usually occupied by the fifth nerve there was a mass of reddish-gray tissue. Neither the nerve nor the pons could be seen. This mass was gradually separated from the surrounding structures and removed. The tumor was about 1.5 cm. in diameter. After removing the tumor, the side of the pons was clearly visible but the fifth nerve was never seen.

Following the operation the patient complained of being very weak and having entirely lost her sense of balance. However, after a few days she gradually recovered. She was discharged on March 20, 1930, twelve days after the operation. She has suffered no pain in the face since operation.

The tumor is found by microscopic examination to be composed of cells with a finely granular cytoplasm. The boundaries of the cells for the most part are very indistinct, the cells forming a fairly uniform sheet (Plate III, Fig. 1). The nuclei are large, round or oval and contain only a moderate amount of chromatin. Many of them are definitely vesicular, with the chromatin practically limited to the nuclear membrane. No mitotic figures are seen and no intercellular material.

The cells are arranged in large lobules which are separated by a thick, exceedingly vascular stroma. In some places there are small telangiectases. Much of the stroma is composed of collagenic fibers which are very thick, and appear hyalinized. Very few cells are present in the stroma. Perdrau’s method also reveals some fibers of reticulin in this stroma and in the walls of the blood vessels. No fibers of reticulin or collagen are seen among the tumor cells (Plate III, Fig. 2). No fibroglia and no elastin is found.

Comment: It is impossible to describe such cells as fibroblasts. They are much more nearly allied to the cells which line the subdural and subarachnoid spaces, and may be referred to as meningothelial. They have formed no fibroglia and none of the intercellular substances characteristic of fibroblasts.

IV. Psammomatous Type

This type differs from the preceding one only in the tendency of the cells to arrange themselves in whorls, in the center of which a hyaline degeneration occurs and later calcium and iron salts are deposited. These concretions attracted the attention of Virchow, who called them “psammoma” (sand-like) bodies.


Mrs. B. D., aged forty-four, referred by Dr. G. W. Hall of Chicago, was admitted on October 22, 1928, complaining of paralysis of both legs. She stated that a year prior to admission she had begun to note weakness
PLATE IV
CASE 4: MENINGEAL TUMOR OF PSAMMOMATOUS TYPE

Fig. 1. Hematoxylin-eosin, × 150. The neoplastic cells form whorls.

Fig. 2. Perdrau's method, × 150. No intercellular fibrils except around blood vessels and forming a sort of stroma.
in her legs, which had gradually progressed. During the previous six months she had also suffered from a burning sensation in both legs. For about this same time there had been occasional urinary incontinence. No history of pain could be obtained. (However, after the operation she complained of a burning pain below the right costal margin and stated that she had had a similar pain for the preceding two years.)

On admission, examination revealed a marked spastic paraplegia. The patient was unable to walk. There was weakness of all muscles of the lower extremities, more marked in the flexor groups. The deep tendon-reflexes were markedly exaggerated. Babinski's sign was present bilaterally. Defense reflexes could be elicited up to the level of the umbilicus. Beevor's sign was present. There was anesthesia to touch, heat, cold, and pain up to one inch above the umbilicus. A diagnosis of extramedullary tumor of the spinal cord at the 9th dorsal segment was made.

A laminectomy was performed on October 24, 1928, under local anesthesia. This exposed a tumor 1½ cm. in diameter attached to the dura mater by a broad base, at the level of the seventh dorsal spine. The ninth dorsal root on the right side was rather firmly adherent to the tumor. The tumor and the attached portion of dura mater were removed.

The patient recovered promptly and was discharged on November 12, 1928. When last seen on October 15, 1929, she had no complaints and was walking normally.

The tumor measured 17 x 10 x 12 mm. A small mass of bony hardness was found within it when sectioned.

The tissue, when examined microscopically, is found to be composed of spindle-shaped cells with a small amount of eosinophilic cytoplasm and round or oval vesicular nuclei of moderate size, containing a small amount of chromatin. No mitotic figures are seen. The cells are arranged in long bundles or more commonly in whorls (Plate IV, Fig. 1). These whorls of cells occasionally occur about small capillaries, but usually are simply wound about other cells. In many of these whorls the central cells are degenerated and granular. In others they are replaced by thick homogeneous hyaline bands, often with a small deposit of calcium-salts at the center (Cf. Plate XI). Sometimes concentric rings of calcification are seen.

Along one side the tumor is in contact with the dura mater. There is no histological evidence of invasion of the dura mater, and the tumor is readily separated from it. In this region there is a large nodule of bone within the tumor. The area containing the bone is in direct contact with the dura mater. Tumor cells are found in all parts of the nodule among the bony trabeculae, as well as practically completely surrounding it.

Reticulin is not found among the tumor cells except in a few whorls and in the walls of blood vessels (Plate IV, Fig. 2), where there is also some collagen. Perdrau's method reveals numerous argyrophilic granules among the tumor cells. Fibroglia and elastin are not found.
Comment: This is the most common type of meningeal tumor and the one on which textbook descriptions are usually based. Again only by a stretch of the imagination can the neoplastic cells be called fibroblasts. Fibroglia is rarely found; hyaline bands and globules are common, which give some of the staining reactions of collagen and even of elastin, but true fibers of collagen or elastin are often difficult to demonstrate among the neoplastic cells. Even reticulin may be absent except around the vessels.

Calcification is common and a small nodule of bone has been formed in the present case. No cartilage was present; the bone was of membranous type. Occasionally such a tumor may be so predominantly composed of bone as to merit being called an osteoma, as in the following case.

V. Osteoblastic Type

This tumor was so completely ossified that it cast a heavy shadow in the radiograph, clearly visible in the spinal canal.


Mrs. L. B. McK., aged forty-three, was admitted to the Billings Hospital June 23, 1930, complaining of weakness and coldness of the legs. She was referred by Dr. Roy Grinker.

Having previously been well, the patient had begun to suffer in June 1927 from a sensation of numbness and cold in both ankles, accompanied by swelling. Soon pains in both knees kept her awake at night. In September 1928 she began to drag her feet in walking, especially the right. These symptoms gradually increased until admission to the hospital. About six months previously she had had dribbling of urine and incontinence of feces. There was never any girdle sensation or pains.

There was found, on admission, a spastic paraplegia with an upper sensory level at D. 10. Only the right upper abdominal reflex was present. There was a positive Beevor's sign. The motor weakness was greater in the right leg, and in both legs predominated in the flexor muscles. There was diminution of sensation to pain, touch, and temperature, with total loss of vibratory sense and sense of position up to D. 10. The spinal fluid was normal and a manometric test revealed no block. Roentgen examination of the spine showed a calcified mass in the spinal canal opposite the intervertebral disc between the 7th and 8th dorsal vertebrae.

A laminectomy was performed on July 3, 1930. The laminae of D. 6, 7, and 8 were removed. The tumor was attached to the dorsal surface of the dura mater, pushing the spinal cord anteriorly. The right half of the cord was more compressed than the left. The tumor was entirely outside the subarachnoidal membrane, which peeled off the anterior surface of the tumor without opening the subarachnoid space.
The patient recovered promptly and was discharged July 25, 1930. When she was last examined on September 4, 1930, there was normal sensation in both legs to pain and touch, but vibratory sense was absent. The right leg was still weak and spastic. Control of bladder and rectum was good.

The tumor was an irregularly round mass measuring 10 x 12 x 15 mm. in diameter. It was hard as a stone and had to be decalcified before it could be sectioned.

Microscopically bands of osseous tissue predominate, with the non-osseous tissue appearing as a sort of fibrous marrow (Plate V, Fig. 1). Around the bony masses is a narrow zone in which calcium is deposited in the form of small granules. In addition there are typical concentric calcified psammoma bodies. The bone is of membranous type (Plate V, Fig. 2).

The interosseous tissue consists of elongated cells with nuclei of connective-tissue type. They form collagen and reticulin in abundance. Typical whorls are rare and no mitoses are seen.

Comment: This patient had gone the rounds of the clinics. Many lumbar punctures had been made and numerous roentgen photographs of the spine taken, all below the lesion.

VI. Fibroblastic Type

Although in the ordinary meningeal tumor fibroblasts are rare, yet occasionally such a tumor is encountered in which the cells have predominantly the structure of fibroblasts.


G. B., a white girl, fourteen years of age, was referred to this clinic by Dr. G. W. Hall of Chicago. She was admitted on May 22, 1929, complaining of headache and almost complete loss of vision. The headaches had begun three years before and had become progressively more severe. They had been almost entirely confined to the left side posteriorly. During the year prior to admission vision had been gradually failing. The patient had not noted a localized defect in the visual field. She had vomited almost daily during the preceding three weeks.

There was found, on examination, a complete amaurosis of the left eye, and only light perception with the right. There was a secondary atrophy bilaterally and a choking of about two diopters. Except for the eyes the neurological examination revealed nothing abnormal.

A ventriculogram revealed a displacement of the left lateral ventricle downward and forward and a shift of both ventricles toward the right. There was also a thickening of the inner table of the skull in the left parieto-occipital region which was not present on the right side. A diagnosis of tumor in the left occipital lobe was made.
PLATE V

CASE 5: MENINGEAL TUMOR OF OSTEOSTATIC TYPE

Fig. 1. Hematoxylin-eosin, X 150. Unossified cells resemble fibrous marrow.

Fig. 2. Perdrau's method, X 150. Showing fibrous character of the bone.
On May 24, 1929, an osteoplastic flap was turned down in the left occipitoparietal region. The exploring needle struck a cyst, and a considerable quantity of yellow fluid, which coagulated readily, was removed. This relieved the tension and on reflection of the dura mater a large, yellowish-gray, rather translucent tumor was exposed. It measured about 5 cm., and as much as possible was removed with the electric loop. It was impossible to remove all of it because of the patient's enfeebled condition. She recovered promptly after a transfusion of blood. The tumor was thought at operation to be a glioma.

Microscopic examination of the tumor removed showed it to be a meningeal neoplasm. Since mitoses were unusually numerous, the patient was given a course of roentgen therapy (550 R. units) and discharged on June 16, 1929. From September 14 to September 23 she was given a second course of x-ray treatments (600 R. units). During this period she was followed in the outpatient department. Her condition was satisfactory except for the almost complete amaurosis and occasional attacks of headache and vomiting.

On October 1, 1929, the patient was readmitted to the hospital for extirpation of the tumor. At that time the decompression made at the previous operation bulged about 3 cm. above the level of the skull. It was soft and pulsed. There was no choking of the optic discs, but a marked secondary optic atrophy. There was also a very slight right facial weakness, but no other neurological findings.

On October 5, 1929, the old bone-flap was again reflected. The tumor had herniated out of the brain considerably. A line of cleavage between the brain tissue and the tumor was then found and followed inward to a depth of about 5 cm., when the lateral ventricle was entered. It was then apparent that the tumor formed a part of the lateral wall of the ventricle and that the choroid plexus was adherent to its surface. This was separated from the tumor, which was then extirpated in its entirety. The tumor measured 7 x 6.5 x 4.5 cm. The patient made a good post-operative recovery and was soon discharged. The vision in her right eye has constantly improved, and she can now read large letters.

The tissue removed at the first operation is found to be very cellular and moderately vascular. The cells are fusiform in shape and grouped together in small bundles which run in various directions (Plate VI, Fig. 1). There is no whorl formation. The nuclei are oval in shape and constant in size. They contain a moderate amount of diffusely distributed chromatin. Mitotic figures are to be found throughout the section. Perdrau's silver method reveals a dense network of fine fibers of reticulin among the tumor cells (Plate VI, Fig. 2). There are also many coarse, wavy, elastic fibers but very little collagen. No fibroglia can be demonstrated. Granules of fat are collected in the neighborhood of rare giant cells.

The cells of the tumor removed at the second operation are identical with those seen in the first specimen, but instead of being closely packed are arranged in very narrow bands, between which there is a large amount of connective-tissue fibers. The special stains show a very marked increase in all types of fibers but a relatively greater increase of collagen
CASE 6: MENINGEAL TUMOR OF FIBROBLASTIC TYPE

Fig. 1. Hematoxylin-eosin, $\times 150$. Structure resembling that of a spindle-celled sarcoma.

Fig. 2. Perdrau's method, $\times 150$. Numerous strands of reticulin among the neoplastic cells.
than of reticulin. In certain regions are large edematous tissue-spaces, a great diminution in cellularity and many large multinucleated giant-cells (Plate X, Fig. 2). Many of the vessel walls are hyalinized and are very thick; many of them are thrombosed. In some areas all of the tissue is hyalinized and contains very few nuclei. There are also a few small cystic and hemorrhagic areas. The tumor is definitely encapsulated. No evidence of invasion of the brain is found.

Comment: This tumor is evidently very unlike any of the preceding types. It is comparable in structure to fibroblastic tumors seen elsewhere in the body, and seems not to be metastatic. The history of intracranial involvement is of over four years duration and there is no evidence of any tumor elsewhere. It is important to note that roentgen radiation transformed this rather rapidly growing lesion into a very benign type of growth. The increase in fibers, the decrease in cells, the hyalinization of tissue and blood vessels and the thrombosis of the latter are striking. It is generally considered that meningeal neoplasms are not amenable to roentgen therapy, but doubtless the more rapidly growing types are radiosensitive.

The failure to demonstrate fibroglia in the cells of the first tumor may have been due to the effects of the electric loop, which destroys the more delicate tinctorial reactions. The neoplastic cells certainly formed all the other intercellular fibrils characteristic of fibroblasts.

VII. Melanoblastic Type

Rarely a melanotic tumor arises primarily in the meninges. We have been able to examine such a tumor through the kindness of Dr. M. G. Peterman of Milwaukee. The clinical report has already appeared in the Transactions of the Resident and Ex-Resident Physicians of the Mayo Clinic, vol. IX, 1928.


A girl aged nine years was admitted to the Milwaukee Children's Hospital, December 28, 1927, with the complaint of headache and vomiting which had persisted for six months. She had had backache for three months and staggering gait for three weeks. The vomiting and headaches were not related to meals, exertion, or emotion.

General examination revealed a well developed, well nourished, rather precocious child. The following symptoms were noted: staggering gait; disturbed equilibrium; suggestive proptosis, especially of the left eye; positive Romberg's sign; and abdominal reflexes exaggerated, and patellar reflexes sluggish. Examination of the fundi showed papillitis
CASE 7: MENINGEAL TUMOR OF MELANOBlastic Type

Fig. 1. Hematoxylin-eosin, × 150. Note the lobules of polyhedral cells.

Fig. 2. Perdrau's method, × 150. The tumor is divided into lobules by strands of reticulin.
and edema of both discs. Neurological examination was otherwise negative, including study of all cranial nerves, reflexes, and sensation. The systolic blood pressure was 86, the diastolic 46. The temperature on admission was 98°, the pulse was 80, and the respiration 20.

A roentgenogram of the skull showed a thinning of the bones, separated suture-lines, marked digitations, and a normal sella. A diagnosis was made of a cerebellar neoplasm, probably in the median line.

On January 18, 1928, Dr. Stanley J. Seeger performed a cerebellar decompression. The cerebellum was exposed, but a tumor was not seen on superficial examination. The child made a good recovery, but meningocele developed. Repeated spinal punctures were done to relieve the increasing pressure. Two months after the operation, the pressure symptoms increased; the child complained of headache and vomited frequently. She grew progressively worse, and two and one-half months after operation she had generalized convulsions, after which she never fully regained consciousness. She became comatose and died April 29, 1928.

Necropsy, nineteen hours after death, revealed the following: The circumference of the head measured 49.5 cm. There was a healed operative scar (8 cm.) extending laterally across the lower occipital bone, from which protruded a large soft tumor, a meningocele, measuring 3 by 4 by 3 cm. The pupils were equal, 4 mm. The skull was opened with a Beneke incision. The cranial bones showed marked digitation. The dura mater was tense. The brain was soft and edematous. Scattered over the entire cortex of the cerebrum were multiple small, soft, dark brown masses measuring from 0.5 to 2 cm. in diameter and lying on the pia. The ventricles were markedly dilated. The subarachnoid space was obliterated. In the cerebellum, in the median line, slightly to the right and extending across the floor of the fourth ventricle, were two soft, dark brown masses measuring 3 × 4 × 2 cm. The lungs showed bronchopneumonia. The remainder of the examination did not reveal significant abnormalities. Pigmented masses were not found anywhere else in the body.

The tissue is found to be composed largely of polyhedral cells many of which are cuboidal or columnar in shape and arranged in rows, typical of this type of tumor (Plate VII, Fig. 2). There are also a few spindle-shaped cells present which are arranged in bundles. There is very little tendency toward perivascular arrangement. The most common type of arrangement is into small groups which are divided by a connective-tissue stroma, giving the tissue an alveolar appearance.

The cells, which are polyhedral in shape, can be divided into two classes: (1) small closely packed cells with little cytoplasm and small, round, darkly stained nuclei, and (2) larger cells having considerably more eosinophilic cytoplasm and large round oval nuclei with very little chromatin. The latter type is far more prevalent. Mitotic figures are common throughout.

The pigment is found in all parts of the tumor. It is present as small brown granules in the cytoplasm of the neoplastic cells. It is also
to be found in elongated spindle-shaped cells in some of the septa. With the specific silver method the pigment becomes black or very dark brown. It does not stain with Mallory's ammonium-sulphide technic for iron, nor does it take methyl green as do the lipofuscins.

Perdrau's silver-impregnation method for fibers of connective tissue reveals a beautiful network of reticulin. There is no elastin present and practically no collagen. The network of reticulin divides the tumor cells into alveoli (Plate VII, Fig. 2). These alveoli vary greatly in size. Many are very large, others are small and contain from 5 to 30 cells.

Comment: A thorough search was made for a primary source other than the meninges and none was found. The most common source of such tumors in children is in the retinae, in this case normal.

VIII. Sarcomatous Type

A tumor very similar in structure to type VII, but not pigmented, occurs rarely in the leptomeninx. It sometimes arises as cuffs around the cerebral blood vessels, rarely as a large mass, but usually is widely spread in the leptomeninx. It is called by various names—perithelioma, sarcomatosis, diffuse endotheliomatosis of the meninges, etc. The following is a typical example.

CASE 8: Pain and stiffness of the neck, vomiting, irritability, visual hallucinations, diplopia. Frequent relapses and remissions. Sudden death. Necropsy.

F. L., a white female, forty-five years of age, was referred by Dr. G. W. Hall of Chicago. She was admitted on January 13, 1930. According to her husband, she had had headaches, diagnosed as migraine, all of her life and there was a family history of migraine. In 1918, following the birth of her second and last child, she had suffered from a "nervous breakdown," characterized by "weakness, nervousness, and being tired." This lasted for three years. During this period the patient first complained of frequent attacks of pain and stiffness of the neck. For four months prior to admission this pain and stiffness had been more severe and constant. She tended to keep her head bent forward. In September 1922 her husband noted that she was becoming increasingly irritable. On December 30, 1929, she developed numbness of the right side of her face and neck and of her right hand. It was frequently observed that she could not feel objects, such as a handkerchief, with her right hand. About this same time she began vomiting profusely and continuously. She had visual hallucinations and saw objects, such as flowers, farm machinery, and people. She also developed an inward rotation of the right eye and complained of diplopia. This soon disappeared, only for the left eye to become similarly involved soon afterward. It was also observed that her respirations were frequently of a deep sighing type. On January 9 she became irrational and remained so.
The last four months of her illness had been characterized by frequent relapses and remissions.

The patient was found on admission to be very restless. There were constant purposeless movements of her extremities, especially of the arms. At times she seemed to make an effort to speak, but only unintelligible sounds resulted. Her respirations were of a deep, sighing type, 16 to 18 per minute. The temperature was normal; pulse 70 to 80, and blood pressure 170/92. Her neck was very stiff and there was a bilateral Kernig’s sign. There were right facial weakness and palsy of the left external rectus muscle. The optic discs were normal. All other cranial nerves were normal. The extremities seemed strong and there was no evident paresis. The reflexes, both cutaneous and deep, were generally diminished but equal on the two sides. There seemed to be a definite diminution in response to pin-prick on the right side of the body as compared with the left.

Spinal fluid obtained by lumbar puncture and examined at another hospital was reported to be normal. There was a leukocytosis of 15,000. The roentgenograms of the skull were not very satisfactory, but those obtained appeared normal.

A positive diagnosis was impossible, but it was thought that the patient might be suffering either from a tumor in the posterior fossa or an encephalitis. It was decided to take a ventriculogram the following morning, but she died in the course of the evening. Death was definitely due to respiratory failure, as the heart continued to beat long after respiration had ceased.

Permission was obtained for examination of the brain. This was made three hours post mortem. There was no gross evidence of tumor. The convolutions seemed somewhat flattened and hyperemic. The ventricles were slightly dilated. The leptomeninges was cloudy and thickened, especially around the base of the brain, but no tubercles were found.

Numerous blocks were cut from all parts of the surface of the hemispheres, the pons, medulla, and thalamus. They all present the same microscopic appearance. The leptomeninges practically everywhere is transformed into a diffuse tumor (Plate VIII, Fig. 1) which extends to the depths of the sulci and even accompanies the blood vessels for several millimeters into the cortex. The deeper vessels are not seen to be involved.

The neoplastic cells lie in an abundant network of reticulin (Plate VIII, Fig. 2). Collagen is found only around the larger blood vessels. Many of the cells, especially near the vessels, resemble lymphocytes; they have small, round, heavily-stained nuclei and very little cytoplasm. Other cells are elongated, but most numerous are polygonal or rounded cells with abundant eosinophilic cytoplasm and eccentrically situated nuclei. Many of these latter cells resemble signet-rings. Mitoses are frequent. There is no melanin.

Comment: It should be noted that this patient was an adult. Diffuse sarcomatosis of the meninges occurs predominantly in
PLATE VIII
CASE 8: MENINGEAL TUMOR OF SARCOMATOUS TYPE

Fig. 1. Hematoxylin-eosin, × 150. Rounded cells with excentric nuclei filling the subarachnoid space.

Fig. 2. Perdrau's method, × 150. Intricate network of reticulin formed by the neoplastic cells. Note the vessel entering the brain above.
adults. The diffuse meningeal tumor of childhood is almost always of cerebral origin and invades the meninges secondarily.

IX. Lipomatous Type

Although intracranial lipomas have always been regarded as a great rarity, there are many cases reported in the literature. Bostrom and Ewing both give extensive reviews. In all, we have found the records of some sixty cases of intracranial lipomas. The superior surface of the corpus callosum seems to be the most common site, there being seventeen reported there. The region about the tuber cinereum is also a common location; twelve in this region. There are four instances of lipomas in the region of the corpora quadrigemina reported (Verga, Taubner, Lorenz, and Bernhard). The case reported here makes a total of five known instances in which this unusual tumor has occurred in this location. In the cases reported by Verga and by Lorenz there were no symptoms relative to the lesion. In Taubner’s case the pupils were dilated, their reactions were sluggish, and the patient was psychotic.

Lipomas have also been observed in the spinal canal. They are usually extramedullary, but a few instances of true intramedullary lipomas have been reported by Sachs and Fincher and others. The case of Schmieden and Peiper was a tumor of this group but of more embryonic type, a lipoblastoma.

The following case is a typical example of this type of meningeal neoplasm.

Case 9: Carcinoma of breast with intracranial metastases. Accidental finding of lipoma at necropsy.

Mrs. F. P., thirty-two years of age, was admitted to Michael Reese Hospital, No. A-18346, on November 28, 1926. At the age of thirty she had had the left breast amputated for carcinoma. Two years later she returned with an extensive ulcerated metastasis over the left chest and axilla.

Physical examination revealed hyperresonance in the upper left apex with bronchial breathing over the entire chest. Diagnosis was made of recurrent carcinoma of the breast with chronic bronchitis and possible metastasis in the lungs. A roentgenogram of the lungs was normal. On January 27, 1927, an examination of the eyes because of persistent headaches showed a bilateral choked disc. The patient complained more and more of headaches, incessant vomiting, and coughing, and died on April 27, 1927.

Necropsy performed one hour after death revealed recurrent carcinoma involving the left wall of the chest and axilla, a metastasis in the
PLATE IX

MENTIGEAL TUMORS OF LIPOMBLASTIC TYPE

Fig. 1. Case 9. Lipoma. Hematoxylin and eosin, ×150. Large vacuoles from which the fat has been dissolved.

Fig. 2. Xanthoma. Hematoxylin-eosin, ×150. Note the vacuolated cells.
cerebellum, metastases in the lungs, liver, adrenal glands, and axillary lymph nodes. In addition there was found on examination of the brain a small lipoma in the region of the quadrigeminal bodies.

On October 29, 1924, it had been noted that the pupils were equal and reacted to light and accommodation and that there were no paralyses of the external ocular muscles. Apparently a complete neurological examination was never made.

The tumor is a yellowish soft mass, typical of adipose tissue, measuring 10 x 7 x 6 mm. and occupying the site of the left posterior colliculus and the posterior part of the anterior colliculus of the corpora quadrigemina. The tumor extends downward to the level of the aqueduct of Sylvius, which is displaced slightly to the right. It is separated from the aqueduct by about one millimeter of neural tissue.

Microscopically it is composed of large globules of fat surrounded by definite cell-membranes and seldom containing demonstrable nuclei (Plate IX, Fig. 1). These are typical fat-cells. There are a few connective-tissue strands, containing blood vessels, running through the tumor. The tumor has no complete capsule separating it from the nervous tissue, but in some places bands of collagen can be seen lying between the lipoma and the neural tissue. However, even at these points the connective tissue and nervous tissue are not sharply separated from one another, but the two are found intermingled.

The entire left posterior colliculus is absent, its only remnants being a few bundles of myelinated nerve fibers within the tumor itself. In some cases these can be seen to connect with the mid-brain below the tumor. In the nervous tissue just beneath the lipoma are a few small round masses of calcium salts, some of them apparently in small blood vessels.

Comment: It is obvious that this tumor has replaced the posterior colliculus. However, it seems unlikely that such a benign neoplasm could do so by invasion of the mid-brain.

In addition to these fully differentiated lipomas there are other tumors of the meninges which resemble in structure the xanthomata. Such a tumor we are able to reproduce (Plate IX, Fig. 2) through the kindness of Dr. Clovis Vincent of Paris.

Discussion

It is obvious from the foregoing descriptions that the meningeal tumors are overwhelmingly of the nature of connective tissue, which does not necessarily mean that they are mesodermal. The theory of the specificity of the three germinal layers is no longer accepted by embryologists. All of the mesenchyme of the body is derived ultimately from epithelium, either from the entoderm or the ectoderm, usually apparently from the region of junction
of these two germ-layers. Much of the loose unorganized tissue between the ectoderm and the entoderm (which is all that the term mesenchyme implies) is proliferated before the ectoderm in the midline invaginates to form the neural tube, but later a new proliferation takes place, from the angle formed by the superficial ectoderm and the neuro-ectoderm, which is known as the neural crest. Still later the mesenchyme of the head region is augmented by loose tissue proliferating from various places in the superficial ectoderm, known as epithelial placodes.

The ultimate fate of these different contingents to the development of the mesenchyme is not completely known. It has been claimed that the primary proliferation gives rise to the bony and vascular structures and to the dura mater. The neural crest is generally conceded to form the sympathetic nervous system and the neurilemma of the peripheral nerves. Latterly the leptomeninx, also, has been considered to be a derivative of the neural crest (Oberling). The placodes form various peripheral ganglia, the Schneiderian membrane, the lens of the eye, etc.

These developments have been reconstructed largely from the study of embryos at various ages where this loose mesenchymal tissue can be seen to have condensed and differentiated into these various structures. In this way only a probable course of events can be reconstructed from the static pictures studied. The appearances are often ambiguous and capable of more than one interpretation. For example, Stone and Landacre maintain that mesenchyme derived from the neural crest later becomes cartilage and other tissues in the head commonly thought to be derived from the primary proliferation.

More conclusive evidence has been sought from experimental studies. The classical experiments of Harrison seem to have proved that the neurilemmal sheaths of the peripheral nerves arise from the neural crest. Harvey and Burr sought by such experiments to prove a similar origin for the leptomeninx. Their conclusions were contradicted by Flexner, whose results seem to indicate that any mesenchyme in the body is capable of forming meninges around a transplanted bit of nervous tissue.

Another argument for the origin of the leptomeninx from the neural crest is derived from the presence in this membrane of melanophores. It is well known that the cells of the neural crest of certain amphibia contain granules of melanin, and such melanin-bearing cells are readily found in the leptomeninx of amphibia.
(Flexner), fishes (Coupin), and mammals including man (Snessarew). Weidenreich has, therefore, concluded that these melanophores in the leptomeninx arise from the neural crest.

It is well known, also, that in the pathological complex known as von Recklinghausen's disease one may find associated in the same patient tumors of the central nervous system, of the meninges, of the nerves, and of the skin (Parker). If it could be shown that all these structures have a common origin in the neural crest, this association would be more easily understood.

French pathologists accept the neuro-epithelial theory and speak of peripheral gliomas (Lhermitte), of neuro-epithelial tumors of the meninges (Roussy and Cornil), and of the nervous origin of nevi (Masson). The basis of the French position is largely theoretical. In acoustic neurinomas may be found fibrils which stain blue by the method of Lhermitte and Guccioni for neuroglial fibrils. But these fibrils might just as well be fibroglia, which stains in exactly the same way. Their presence does not constitute evidence that these tumors of the peripheral nerves are gliomatous in nature. The tumor which Roussy, Lhermitte and Cornil always reproduce as a meningioma of neuro-epithelial type is obviously the same tumor that we have just described as meningo-thelematous. Their process of reasoning is undoubtedly as follows: The tumor is composed of cells arising from the covering layer of the leptomeninx; the leptomeninx is of neuro-epithelial origin; therefore, the tumor is a meningioma of neuro-epithelial type. But the neoplastic cells resemble no other structures clearly of neuro-epithelial origin, and it seems to us preferable to speak of these tumors simply as meningothelial. The latter term is descriptive and involves us in no theory of their origin. Moreover, the tumor described by Roussy, Lhermitte and Cornil as a meningioma of fusiform glial type is obviously a fibroblastoma, the neoplastic cells, as the authors themselves admit, forming collagen in abundance. Their reason for calling it a glial tumor is again based largely on theory: since the tumor is accepted to be of neuro-epithelial origin, the formation of collagen by its cells must be due to their metaplasia. That nevi may be of neuro-epithelial origin proves in no way the neuro-epithelial nature of meningeal tumors.

The question, therefore, is largely one of systematic terminology in pathology. Roussy, while arguing against an embryological terminology for tumors of the brain, inconsistently employs a
much less firmly grounded embryogenic terminology for meningeal tumors.

We agree with Masson that in the present state of our ignorance it is best to classify tumors according to their family resemblances and to name them according to the histofunctional differentiation of their cells, which brings us into conflict with the system of Mallory and Penfield, who would reduce them all to fibroblastomas. Mallory's system for the classification of tumors is to determine typical adult cells and then to search for them in tumors. Whether these cells occur in an adult or in an embryonic condition, the tumors are designated in the same way. This system of classification is of little practical prognostic usefulness, for it does not take account of the fact that the more rapidly a tumor grows the less differentiated are its cells. Some sort of embryological terminology seems best to indicate the probable clinical course of a tumor.

Our material is too limited to permit us to conclude that this general correlation of rapidity of growth and embryological structure holds for meningeal tumors as it does for other tumors. It is known that some meningeal tumors recur more rapidly than others and that they occasionally penetrate the bone overlying them (Cushing, Phemister). Whether any structural peculiarity is characteristic of this behavior we cannot say. Craig seems to be the only author who has attempted such a study, and his pathological descriptions are so summary as to make them difficult of comparison.

We will now discuss the different types which we have found and attempt to understand them in the light of our admittedly imperfect knowledge of the origin and structure of the meninges.

1. The tumor which we have described as of mesenchymal type resembles strongly the mesenchyme of the developing embryo. The cells have very delicate cytoplasmic processes and are at times fusiform, at others stellate. No collagen and no elastin can be found, but myriads of very delicate fibrils of reticulin are present among the cells. The blood vessels are small, with delicate walls containing no collagen and no muscular cells. The tissue has a myxoid appearance, but no mucin can be demonstrated histologically. There can be little doubt that this tumor is composed essentially of very embryonic connective tissue. Fibroglia has been demonstrated in the mesenchyme by Fañanas.

2. The development of the blood vessels of the leptomeninx is difficult to study in the embryo, but there seems no reason to
suppose that they do not develop in situ from the same mesenchyme which forms the meninges. In these meningeal tumors of angio­
blastic type it can be seen that the vascular channels are merely open spaces in the tissue and most of them are lined by the neo­
plastic cells (Plate X, Fig. 1). This peculiarity was independently noted by Hartman. Occasionally the cells lining the vascular spaces have flattened to form an endothelium.

A closely allied tumor develops from the vascular anlagen of the leptomeninx of the region of the fourth ventricle, at times consisting of a tangle of capillary blood spaces, at other times of a more solid tissue composed essentially of endothelial cells. This is the hemangioblastoma or hemangio-endothelioma of the Lindau type. Many examples have been recently described by Cushing and Bailey, and Dandy and others. The growths are often associated with angiomatosis of the retina and other lesions to form a complex known as Lindau’s disease.

These two types of lesion show that the anlage of the lepto­
meninx possesses the capacity to proliferate hemangioblastomatous tumors.

3. The meningotheliomatous type of tumor reproduces so exactly the structure of the localized thickenings of the arachnoidal membrane, especially of the so-called pacchionian granulations, that its origin from the arachnoid may be accepted. This idea was first advanced by Cleland and subsequently supported by the studies of Robin, Schmidt, Cushing and Weed, and others. Cushing has shown, also, that this type of tumor arises usually in those localities where the arachnoidal granulations are most numerous. It is this type of meningeal tumor to which Roussy and Cornil refer as neuro-epithelial.

The type-cell is considered by Mallory, Penfield, van Wagenen, and others to be the fibroblast. But very few of the neoplastic cells can properly be described as fibroblasts. It is often impossible to demonstrate any intercellular substances except around the blood vessels. The cells are similar to those lining the sub­
arachnoid and subdural spaces, called by Weed mesothelial.

4. The psammomatous meningeal tumor differs from the pre­
ceding type only in the tendency of the neoplastic cells to form whorls which subsequently become calcified. Its origin is doubt­
less the same. The neoplastic cells may form no intercellular substances over large areas, yet in the whorls reticulin is often found which, when undergoing hyaline transformation, may stain feebly as collagen or elastin.
Fig. 1. Hematoxylin-eosin, × 300. Angioblastic meningeal tumor, showing neoplastic cells lining a vascular space. Note also cells lying free in the cavity.

Fig. 2. Hematoxylin-eosin, × SMr. Tumor giant cells after roentgen radiation.
There has been a great deal of controversy over the manner of formation of the psammoma-bodies. It has been possible for us to follow all stages of their formation both from the smaller blood vessels and from nests of neoplastic cells. In either case there occurs first a hyaline transformation of the tissue in which calcium salts are subsequently deposited. All stages of the process may be followed in the accompanying illustrations (Plate XII).

5. The formation of bone in the dura mater is common, especially in the falx cerebri (Halstead and Christopher, Cushing, Weed). Cleland maintained that this bone arose from cells of the arachnoid which had invaded the dura mater. Halstead and Christopher believed that the cells of the dura mater had retained an osteogenic function. Bony placques are not infrequently found, also, in the arachnoidal membrane (Cushing and Weed).

The presence of bone in meningeal tumors has often been reported by Cleland, Cushing and Weed, Weiser, Berner, and others. It cannot be used as an argument for the origin of meningeal tumors from either membrane, since it occurs in both in the absence of tumor. But the formation of bone is sufficient evidence of the connective-tissue nature of the cells of the arachnoidal membrane.

Encapsulated tumors of the meninges were long known as dural endotheliomas, the theory being that they arose from the endothelium on the under surface of the dura mater. It is true that most tumors of this sort are attached to the dura mater, but the demonstration of the resemblance between their microscopic structure and that of the pachionian bodies, and of the relationship of the location of the arachnoidal granulations to the sites of the tumors, as we have already said, lent support to the theory of an origin from the arachnoidal membrane. Moreover, such tumors have been found within the substance of the brain with no attachment to the dura mater.

Yet it is difficult to deny to the dura mater the possibility of forming tumors. In our case the tumor was attached to the dura mater by a broad base but peeled away from the arachnoid without opening the subarachnoidal space. Anyone without a preconceived idea of its origin would have said that the tumor arose from the dura mater.

At any rate, the formation of bone in meningeal tumors is not rare, and occasionally may proceed to such an extent that the tumor merits the name of osteoma. The bone is always of membranous type, no cartilage being formed.
Fig. 1. Hematoxylin-eosin, × 150. Typical psammoma bodies.

Fig. 2. Perdrau’s method, × 150. Showing the calcium deposited in concentric rings.
6. Although in the tumors we have so far discussed fibroblasts are not prominent, there is no doubt that meningeal tumors do occur which are composed essentially of young fibroblasts forming all of the intercellular fibrils of connective tissue. The cells of the tumor which we have described formed reticulin and elastin but very little collagen; yet after treatment with x-rays, when the rate of cellular division was much slower, collagen was produced in abundance. In the normal meninges the cells form all of these intercellular substances.

Another result of radiation on this tumor was to cause the formation of numerous giant-cells (Plate X, Fig. 2). Such cells are rarely found in meningeal tumors, but their formation is a common result of roentgen radiation of other neoplastic tissues.

7. The pigmented cells in the leptomeninges have long been known. They were recently investigated thoroughly by Snessarew. He found them most numerous at the junction of the medulla oblongata with the cervical cord, although occasionally present in all parts of the meninges. He described the cells as elongated and bipolar. Where they were numerous he thought he could demonstrate that they were connected by their processes to form a cellular net. The melanin occurs as small granules in the cytoplasm. There seems to be some extracellular pigment, but this appearance may be an artefact of preparation.

If one believes firmly in the epithelial origin of all melanin-bearing cells, the presence of such cells in the leptomeningo and the development of melanoblastomas from the leptomeningo constitute serious arguments for the epithelial origin of that membrane. But there are many who doubt the epithelial theory. Bloch divides melanin-bearing cells, according as they do or do not give his dopa reaction, into melanoblasts and melanophores. The latter do not form melanin and are considered to be of mesodermal origin. The melanin-bearing cells of the leptomeningo do not give a dopa reaction but it is difficult to understand whence the melanophores of the leptomeningo obtain their melanin if they do not make it. Weidenreich derives these melanophores from the neural crest while Bloch holds that they are mesodermal.

At any rate, sufficient cases are now on record to prove that melanoblastomas may arise primarily from the leptomeningo.

8. A tumor looking very much like the preceding type, but not pigmented, may arise in the leptomeningo and spread widely, or perhaps at times may arise simultaneously in many parts of the
PLATE XII

Fig. 1. Hematoxylin-eosin, $\times$ 300. Calcium beginning to be deposited in the center of a clump of cells.

Fig. 2. Hematoxylin-eosin, $\times$ 200. Calcium being deposited in the hyalinized walls of blood vessels.
subarachnoid space. It has been variously described as diffuse sarcomatosis or endotheliomatosis of the meninges. Occasionally such a tumor develops from the leptomeningeal sheaths of the blood vessels of the brain and is known as a perithelioma. These tumors have recently been discussed by one of us (Bailey).

9. Fat-cells are rather rare in the human leptomeninx but are normal constituents of the meninges of certain fishes, principally the ganoids (Coupin). Virchow was one of the first to maintain that lipomas may arise from the cells of the human meninges.

In all the preceding discussion there is little which indicates that the leptomeninx might be of gliomatous nature, but there exist a few observations of rather extensive gliomatous formations in the leptomeninx which must be explained.

Wolbach found, in a case of congenital rhabdomyoma of the heart, many small nodules of neuroglia in the meninges of the spinal cord beneath the dura mater. A few were embedded in the pia mater but none was connected with the nervous tissue. There were also two nodules in the velum interpositum which contained spaces lined with ependyma.

Russell and Cairns found, also, islands of neuroglia in the meninges of the spinal cord in a case of astrocytoma of the thalamus. The nodules were on the under surface of the arachnoidal membrane and were so isolated from the nervous tissue that Russell and Cairns interpreted them as metastases.

But such heterotopic nodules may be connected with the brain or cord, as in the case of a porencephalic child described by Globus, in which they communicated along the pial blood vessels.

More extensive gliomatous formations in the leptomeninx have been reported by Oberling, Schmincke, Buckley and others. In all these cases there was a more or less intimate connection between the meningeal glia and the surface of the brain.

It is interesting to note that these gliomatous formations are well differentiated and show no sign of active growth. They are also associated with various other malformations. Whereas infiltration of the meninges by rapidly growing gliomas, such as the medulloblastoma, is common and easily understood, it is a little difficult to believe that an astrocytoma could produce such an infiltration or metastasis, as supposed by Russell and Cairns.

Oberling tries to explain these cases on the basis of his neuro-epithelial theory. He supposes that the anlage of the leptomingeal space is less a membranous fold of the pia mater than an epithelial formation. He maintains that the basal membrane of the brain is formed by a cellular epithelium which differentiates into neuroglia. Thus, he attributes all gliomas to a degeneration of the cells of the neuroglial membrane.
meninx, originating from the neural crest, is able to differentiate both into neuroglia and meninges.

It seems to us that these cases are just as satisfactorily explained by supposing an invasion of the leptomeninx by neuroglial tissue during embryonic life or by undifferentiated neoplastic tissue which afterwards becomes differentiated in this abnormal situation to form heterotopic malformations. Such cases do not seem to us to argue for a neuro-epithelial origin of the leptomeninx.

**Conclusions**

It appears from this study that meningeal tumors, whatever their origin, are of the nature of connective tissue and are not gliomatous. Their relationships to each other may be schematically represented by the following diagram:

```
          Neuro-ectoderm          Mesoderm
           |                     |
     Mesectoderm (Melanin-Bearing)     Mesentoderm
          |                     |
    Meningeal Mesenchyme
         (Type I—Mesenchymatous)
          |                     |
        Lipoblast Type IX Lipomatous Type VIII Generalized Sarcomatosis
        Fibroblasts Type VI Fibroblastic Type IV Psammomatous
        Meningothelioma Type III Meningotheliomatous
        Angioblasts Type II Angioblastic
        Melanoblasts Type VII Melanoblastic
        Osteoblastic
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We believe, further, that the fibroblast is usually not the typical cell of these tumors and that they should be described in accordance with their structure as meningothelioma, fibroblastoma, lipoma, etc., of the meninges.

For the ordinary bulbous encapsulated tumor the name "meningioma" might be retained as a convenient, indifferent term to indicate a gross pathological and surgical entity. Such tumors are usually of meningotheliomatous, or psammomatous type, rarely fibroblastic.
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