of hemiplegia. The upper limb is involved to a much greater extent than the lower limb. As a general rule the fingers are strongly flexed, sometimes bent forcibly into the palm of the hand; the wrist is flexed upon the forearm, and the latter is pronated and at the same time slightly flexed on the arm. Contracture of the pectoralis major muscle draws the arm against the chest. In the lower limb the contracture is confined chiefly to the muscles of the calf, which draw up the heel.

It is very often found, even in advanced cases, that the contracture disappears in great part when the patients awake in the morning. Then the fingers, which could not be extended previously without a very great effort on the part of the physician, are relaxed spontaneously, and the patient may even be able to execute voluntary movements. In a little while, however, the *status quo ante* is restored. This condition is always attended by a marked increase of all the tendon reflexes, and sometimes by increased mechanical excitability of the paralyzed muscles. It is generally believed that this form of contracture is due to descending degeneration of the lateral columns, but this view is not well founded. We have seen one case in which the contracture was absent, although well-marked descending degeneration was found at the autopsy. Were this theory true, the symptom in question should be present in all cases of hemorrhage or other lesion affecting the pyramidal tracts, but in reality it is not infrequently absent under such conditions.

The phenomenon known as "associated movements" is also observed quite often in hemiplegia, particularly when it occurs in childhood. As a rule, strong voluntary effort on the part of the non-paralyzed limbs is associated with an involuntary movement of the paralyzed parts. Much more rarely a vigorous attempt to move the paralyzed muscles is attended with an involuntary movement of the healthy side.

Post-hemiplegic chorea is another peculiar phenomenon, allied perhaps to the associated movements just referred to. It occurs with greatly preponderating frequency in the hemiplegia of childhood, but is observed not very rarely in adults. The period of its development varies greatly, but it never occurs until a very considerable amount of improvement has taken place. This symptom is also found to be much more pronounced in the upper than in the lower limb.

The movements are manifold in character. Sometimes they can be distinguished in no respect from ordinary chorea; and, as in the latter disease, in some cases the movements are increased on effort, in others they are diminished.

More rarely tremor is produced like that seen in paralysis agitans, or the movements may be coarser. Some cases have been observed in which the movements were of an ataxiform character, and it is even claimed that true ataxic disturbances may be produced. There is very little doubt that athetosis (slow, constant alternation of flexion and extension of the fingers, with corresponding movements, perhaps, in the upper portions of the arm, more rarely in the lower limb, particularly the toes) is merely a variety of post-hemiplegic chorea, though it may also occur independently of cerebral hemorrhage.

In children, in whom post-hemiplegic chorea is of very frequent occurrence, this symptom often becomes complicated with epileptiform convulsions, affecting at the onset only the paralyzed side, but later spreading usually to the other side.

DIAGNOSIS.—The recognition of cerebral hemorrhage is often attended with great difficulty, and indeed may be impossible. The disease is most frequently mistaken for cerebral embolism, since the symptoms of both affections may be identical. In such cases a provisional diagnosis can be made only from attendant circumstances. Embolism is usually associated with cardiac valvular disease, thrombosis of the heart, or aneurism of the arch of the aorta. As a matter of course, however, the existence of these lesions does not preclude the occurrence of cerebral hemorrhage. If the coma occurs with great suddenness, it is due more probably to embolism than to hemorrhage, and this is also true if the patient recovers, within a week, a considerable amount of power in the paralyzed side. Again, embolism is comparatively more frequent before the age of forty, though, as we have seen above, hemorrhage may also occur at any age, even in infancy and childhood. The determination of the coexistence of chronic interstitial nephritis favors the diagnosis of hemorrhage, on account of the vascular lesions so often present in the former disease. On the other hand, it must be remembered that the mere presence of albumin in the urine during an apoplectic attack possesses no significance whatever.

Cerebral hemorrhage must also be distinguished from cerebral thrombosis. In the latter affection, the comatose condition, if it develops at all, is usually much slower in its onset, though it must also be remembered that exceptionally the symptoms of thrombosis occur with great suddenness. The disease is peculiarly an affection of old age, and the radial, temporal, and other superficial arteries are generally found to be very atheromatous. When the thrombosis is the result of a syphilitic affection of the vessels, it is almost always preceded by another train of symptoms, a discussion of which will be found under the head of syphilitic lesions of the cerebral vessels.

Hemorrhage into the pons may also be mistaken for opium poisoning, if it is attended, as is usually the case, with strongly contracted pupils. In the former affection, however, the pulse and respiration are not so notably retarded as in the latter, and the coma is more profound. Epileptiform convulsions, also, are not an infrequent accompaniment of pons hemorrhage, and do not form a part of the history of opium poisoning. Of course the obscurity is cleared up if the patient recovers consciousness.

When the hemorrhage occurs during infancy or childhood, the disease must also be differentiated from tuberculous meningitis. This affection may also be attended with unconsciousness and sometimes distinct hemiplegia, even in cases in which the autopsy shows a tolerably uniform distribution of the lesion over both hemispheres of the brain. Meningitis, however, is attended with more marked prodromal symptoms than cerebral hemorrhage; the hemiplegia, if present, is not very profound, and is variable in degree at different times, as are also the other symptoms of the disease. In adults meningitis rarely simulates the history of cerebral hemorrhage.

But however careful we may be in the observation of the symptoms and of the attendant circumstances, very many cases will be encountered in which the diagnosis remains doubtful or is only cleared up by a post-mortem examination. Indeed, as was remarked in the paragraph on the pathological anatomy of the disease, even a post-mortem examination, if made long after the attack, may fail to decide the nature of the affection.

Even if a diagnosis of cerebral hemorrhage has been made, it is extremely difficult to localize the lesion accurately with any degree of certainty until the general pressure symptoms have cleared up, leaving only those which are due to the local lesion.

In the large majority of cases the most that can be done during the comatose stage is to determine the side on which the hemorrhage has occurred. The paralyzed side of the body is usually more relaxed than the non-paralyzed side, is often warmer, and the reflexes are entirely abolished; if conjugate deviation of the eyes and head is present, it is directed usually toward the side of the lesion. After the coma and the general pressure symptoms have subsided, localization of the lesion must be determined according to the principles laid down in this HANDBOOK under the headings, *Brain: Diagnosis of Local Lesions*, and *Brain: Functions of Cerebral Cortex*.

If the coma is very profound, and rigidity or convulsions make their appearance at the onset, together with serious respiratory and circulatory disturbances, the hemorrhage has probably occurred into the lateral ventricles (from surrounding parts). Hemorrhage into the pons is frequently attended by marked contraction of the pupils and profound coma, and when the paralysis can be determined, it is usually found to be alternate, *i.e.*, the face is paralyzed on one side, the limbs on the opposite side.

PROGNOSIS.—This varies according to the size and situation of the hemorrhage. Other things being equal, life is more endangered the larger the hemorrhage. However, even hemorrhages of small size, if situated in the pons Varolii or medulla oblongata, are apt to prove rapidly fatal, and hemorrhages in the latter locality very rarely terminate in recovery. The fatal event is due to direct interference with the functions of respiration and circulation. Cheyne-Stokes respiration is an extremely unfavorable symptom, and is almost always a precursor of impending dissolution.

Large hemorrhages into the hemispheres, or those which rupture into the ventricles, also prove fatal, usually by direct or indirect pressure on the centres of the pons and medulla. The more sudden the development of coma, the smaller the chances of recovery. Acute decubitus, which occurs during the comatose stage, is almost invariably followed by death. The coexistence of Bright's disease is also a very unfavorable complication.

As regards the extent of recovery from the paralysis, very little can be foretold in the first period of the disease. In the large majority of cases the sensory disturbances disappear in great part and very rapidly.

Power of motion is usually restored much more quickly in the lower than in the upper limb. When the reverse obtains, it has been generally held that an unfavorable termination will ensue, but this opinion does not appear to be well substantiated.

The occurrence of late rigidity must be regarded as an unfavorable symptom, insomuch as it interferes, in the first place, directly with the power of motion, and, in the second place, improvement in the latter usually ceases with the appearance of the former. This also holds good of post-hemiplegic chorea.

Symptoms of mental deterioration are usually permanent, and indeed, in many cases, are steadily progressive. As a rule, however, it is only after repeated attacks that a condition of mental impairment, amounting even to imbecility, develops. In very exceptional instances, epilepsy follows cerebral hemorrhage.

TREATMENT.—Prophylactic treatment is practically nil. If the prodromal symptoms are prolonged, the patient should be kept as quiet as possible, mentally and physically, and care taken that the bowels be kept thoroughly open. When the onset of a hemorrhage has been suspected, I have been in the habit of putting my patient to bed for a week, giving bromide of potassium in fifteen to thirty grain doses, t.i.d., and a mild laxative or enema daily.

If the hemorrhage has taken place or is occurring at the time the physician is called, very little, if anything, can be done to check it. Drugs given internally for this purpose do more harm than good. The most that should be done is to keep the head slightly elevated, and if the carotids and temporals are pulsating strongly, apply cold applications to the head or leeches to the forehead. If the pulse continues strong during the comatose stage, nothing more need be done. When evidences of heart failure arise ammonia and stimulants are indicated.

When the stationary stage of paralysis has developed, treatment is useless until after the lapse of a considerable period. The natural tendency of the paralysis is toward improvement (though complete recovery hardly ever occurs), and until this tendency becomes manifest, we may rest satisfied either that motor fibres are cut across or that pressure is still exerted at the site of the lesion, thus interfering with nervous conduction.

Almost the only means at our command to hasten recovery is the use of electricity. This may be employed in two ways, either to the brain itself or directly to the paralyzed parts.

The former method has been very little used hitherto, and, indeed, it is not probable that much good can be expected from it. The galvanic current alone is employed for this purpose. The positive pole is usually applied to the side on which the hemorrhage took place, the negative pole on the opposite side of the head. The current should be mild, and must never be strong enough to produce vertigo; the sittings should not exceed from two to five minutes in duration.

The ordinary method (and the one which promises by far the best results) of employing electricity in hemiplegia is the direct application of the faradic current to the paralyzed muscles. It has generally been held that this measure should not be employed until at least two or three months have elapsed since the occurrence of the hemorrhage, for fear of causing a recurrence of the disease. There is very little reason, however, to doubt that this fear is entirely unfounded, and that it is perfectly safe to begin the treatment within two or three weeks after the stationary period has begun.

The strength of current employed should be merely sufficient to produce distinct contraction of the paralyzed muscles; the sittings may be held every other day, and their duration may vary from five to fifteen minutes.

In a few cases an astonishing degree of improvement occurs after the first two or three applications, after which very little, if any, progress is made. As a rule, however, improvement, if it occur at all, is very gradual, and the treatment must be continued patiently for months.

When contractures of the paralyzed limbs have developed, another method should be employed. The one usually adopted is the application of the stabile galvanic current through the nerves and muscles (nervo-muscular current) of the flexor aspect of the limbs (the parts in which the contracture is usually situated) and the faradic current to the antagonists. Warm baths and massage are also useful for this purpose.

In some cases painful swelling of the joints is extremely annoying to the patient, and this complication is very intractable to treatment. It is best combated by the use of a strong stabile galvanic current passed directly through the joint, with the addition of repeated small blisters over the site of pain.

Iodide of potassium, in doses of from five to ten grains t.i.d., is usually administered as a matter of routine, but it is more than doubtful whether this drug exerts any beneficial effect.

In our hands ergot has never given good results, no matter in what stage of the disease it has been employed. Careful attention should always be paid to the condition of the bowels, particularly as the patients are apt to be constipated for a long time after the attack.

Leopold Putzel.

BRAIN: CEREBRO-SPINAL FLUID.—(Synonyms: *cœliolymph;* Ger., *Cerebrospinalflüssigkeit;* Fr., *liquide céphalo-rachidien;* Lat., *liquor cerebrospinalis.*)

ANATOMY.—The cerebro-spinal fluid is found in the encephalic and myelic ventricles, and in the subarachnoid and subdural spaces. It varies in amount from 60 to 200 c.c., increasing somewhat with age. It is not lymph and is sufficiently characteristic in its reactions to be distinguished from other serous fluids. The subarachnoid space is the interval between the arachnoid and the pia, very narrow on the upper and lateral aspects of the encephalon, crossed by numerous bands of arachnoid tissue, but enlarged in certain regions at the base, above the corpus callosum and over the optic lobes, called the cisternæ subarachnoidales.

These are in communication with one another and have as tributaries the clefts along the great fissures (flumina), which themselves have as tributaries the spaces along the secondary and tertiary fissures (rivi and rivuli of Duret). There are prolongations of this space around the optic, olfactory, and auditory nerves, and a connection with the lymph spaces around the other cranial and spinal nerves. Communications with the lymphatic vessels of the nasal mucous membrane and deep vessels and nodes of the neck also exist. These connections have been demonstrated by the injection of the subarachnoid space with colored fluids which have filled the lymph vessels of the nasal mucous membrane, traversed the lymph spaces of the nerves, and penetrated the deep cervical vessels and nodes. The colored fluid has also been observed to pass into the dural sinuses through the arachnoidal villi, probably indirectly by filtration. Flatau,[1] by the injection of colored fluids, was able to make them escape from the nose. Naunyn and Schreiber, quoted by Flatau, have demonstrated the same thing, using salt solution, the flow from the nose being accompanied by protrusion of the eyeball and chemosis.

According to Binswanger and Berger[2] the subarachnoid space also receives the lymph from the adventitial lymph spaces of the cerebral cortex. They observed that in cases of intraventricular hemorrhage in the human subject, blood would make its way into the subarachnoid space and thence into the intra-adventitial spaces of the cortex. Injection of a carmine mixture into the subarachnoid of a dog likewise filled the cortical intra-adventitial spaces.

These observations confirm those of Key and Retzius.

Subdural injection of colored material has demonstrated the following connections with the subdural space (Schwalbe[3]):

1. The deep lymph vessels and nodes of the neck.
2. The subdural spaces of the nerve roots and lymph paths of peripheral nerves (Key and Retzius).
3. The lymph paths of the dura through fine clefts (Michel).
4. The dural sinuses through the arachnoidal villi.

The ventricles communicate with the subarachnoid space by the foramen of Magendie (metapore) and the aperturæ laterales (foramina of Luschka). The connection described by Merkel and Mierzejewsky in the descending horn of the lateral ventricle is probably an artefact. The existence of the metapore and the aperturæ laterales has recently been confirmed by Blake.[4]

There is no direct connection between the subarachnoid and subdural spaces, but the lymphatics of the nasal mucous membrane, the lymph spaces of the nerves, and the cranial sinuses through the arachnoidal villi can be injected from both cavities.

The histology of the choroid plexuses of the lateral ventricles has recently been investigated by Findlay,[5] who finds that there are for the most part several layers of cells on the villi and that the surface cells may contain globules which are extruded, leaving the empty cell membrane. These globules may be found in the ventricular fluid. They darken with osmic acid and are probably fatty in nature.

Blood-vessels are very numerous in the choroid plexuses, and nerves too have been demonstrated in the plexuses of the lateral and fourth ventricles (Benedikt), so that structurally they are secretory in character.

The morphological elements are very scarce in the normal fluid and consist of a few leucocytes, endothelial cells, and occasional globules of a fatty nature derived from the cells of the choroid plexuses.

The experiments of Key and Retzius,[6] confirmed by Kollman, seem to show that one of the outflow paths for the subarachnoid and subdural spaces is by the way of the arachnoidal villi into the cranial sinuses. More recently it has been demonstrated that normal saline solution tinged with methylene blue and injected into the subarachnoid space can be traced passing into the sinuses and veins, and in a few minutes the blue is found in the stomach and bladder; but it is only after one hour of steady injection that the deep cervical nodes begin to be tinged. The rapid absorption then takes place rather by the blood-vessels than by the lymphatics.

The amount of cerebro-spinal fluid increases with age and with brain atrophy, and decreases in those diseases in which the volume of the brain is augmented; it also varies with the amount of blood in the intracranial vessels.

PHYSIOLOGY.—The cerebro-spinal fluid forms a water bed on which rests the base of the middle and posterior parts of the encephalon. It performs an important function in protecting the brain from injury and the circle of Willis from compression. It also helps to dissipate the force of a blow, so that less injury is done at the point of its reception. This may result in a disruption of brain substance in a region far removed from the place of injury. For example, a blow received on the front of the head in a direction downward and backward may cause hemorrhages in the region of the medulla and fourth ventricle, as a result of the ventricular fluid trying to pass through the narrow aqueduct of Sylvius (Park[7]):

Sudden tapping of this water bed may occasionally result in injury to the brain from the sudden changed relations of the encephalon to its rigid bony case; also where the ventricles have been distended, the sudden withdrawal of fluid may leave parts unsupported, resulting in injury to the brain tissue.

According to A. and E. Cavazzani[8] secretion and absorption of the cerebro-spinal fluid proceed slowly. To test the rate of secretion, ferrocyanide of potassium was injected into the peritoneal cavity of a curarized dog. The salt did not appear in the cerebro-spinal fluid until after an hour had elapsed.

To test the rapidity of absorption the posterior occipito-atlantal ligaments were opened and 4 c.c. of a fifty-per cent. solution of iodide of potassium was injected into the arachnoid space, and the same solution was also injected into the encephalic arachnoid cavity. The salt was found in the urine in a minimal time of twenty minutes, and a maximal time of two hours. The great difference of time in absorption was accounted for by the variations in pressure of the cerebro-spinal fluid and the blood.

Thomson's[9] observations, in several cases, of the spontaneous flow of cerebro-spinal fluid from the nose show that the secretion may be quite rapid, the flow averaging 500 c.c. in twenty-four hours. Hill[10] has shown that the rate of secretion depends on the cerebral capillary pressure and that this can be easily raised by (*a*) compression of the abdomen, (*b*) by assumption of the horizontal position, and sometimes (*c*) by forced expiration with the glottis closed, *i.e.*, in straining. When, however, the amount of fluid is increased, its chemical characters change, the proportion of solids decreasing.

A. Spina[11] has shown that increased arterial pressure due to intravenous injections of suprarenal extract in curarized dogs causes a clear fluid to exude from the cerebral surface drop by drop. This fluid he considers a transudate. It is probable that the cerebro-spinal fluid retains its peculiar characters under normal conditions of pressure only, and after it is withdrawn, its place is taken largely by extraventricular serous transudate.

There are three sources for cerebro-spinal fluid, and its character is dependent upon the proportions furnished by the different sources. The first and most important origin is as a secretion into the ventricle from the choroid plexuses; second in importance, as a transudate into the subarachnoid and subdural cavities; and third, from the intra-adventitial lymph spaces of the cortex. The relative amount of the intra- and extraventricular fluid varies from time to time, depending on the intravascular and intracranial pressures, a preponderance of the intravascular pressure resulting especially in an increase of the extraventricular fluid. The tension of the cerebro-spinal fluid is from 5 to 7.3 mm. of mercury, and about equals that of the blood in the capillaries, varying however in different individuals.

The osmotic tension of the cerebro-spinal fluid is greater than that of serum (Zanier).

The cerebrum increases in volume with the cardiac systole and expiration, and decreases with the cardiac diastole and inspiration. Accompanying the cerebral movements is an ebb and flow of the cerebro-spinal fluid from the cranial into the spinal spaces where extra room can be had by the expansion of the ligaments and the spaces around the spinal nerves. More room may also be had for the brain by the expression of blood from the

encephalic veins and sinuses. There is, however, very little motion of translation of the fluid accompanying the cerebral movements (Elder). Whenever the intracranial pressure exceeds the cerebral venous pressure, the fluid rapidly leaks away, and hence may be left out of account in the pathology of compression (Hill).

The effect of intravenous injection of cerebro-spinal fluid has been investigated by Mott and Halliburton.[12] They found that if the fluid is taken from animals, or from cases of meningocele or chronic hydrocephalus in man, and injected into the veins of animals, no effect is produced. If, on the contrary, the fluid is obtained from cases of brain atrophy, especially from cases of general paralysis of the insane, then a marked lowering of arterial tension is noticed, partly cardiac in origin but principally due to the local action of the poison on the neuromuscular apparatus of the peripheral vessels, especially in the splanchnic area. This is believed to be due to a toxic substance called cholin derived from the disintegration of the lecithin in the brain.

CHEMISTRY.—There are several ways in which the cerebro-spinal fluid may be obtained for examination. (1) From cases of chronic hydrocephalus, either by puncture during life or after death. In acute hydrocephalus the fluid is not normal, but is an exudate. (2) In cases of meningocele and spina bifida the fluid is normal, but only the first tapping can be so considered, as its character changes in the later tappings. (3) By lumbar puncture. (4) The fluid may be collected in cases of fracture at the base of the cranium, as it drops from the nose or ear. (5) In cases of spontaneous flowing from the nose and ear. (6) In animals, by establishing a permanent fistula, as suggested and employed by Cavazzani,[13] to study qualitative and quantitative variations.

The cerebro-spinal fluid is a clear watery fluid, slightly saline to the taste, of low specific gravity, about 1.007. The density increases in proportion to the greater amount of transuded to secreted fluid, and it is also higher in the morning than in the evening (Thomson). Its reaction is slightly alkaline or neutral, being more alkaline in the morning than at night. The reaction has been investigated in diseased conditions by Turner,[14] who found in thirty-seven cases of insanity that it was acid to phenolphthalein, alkaline to methyl orange; and in thirty cases tested with litmus there was an amphoteric reaction in twenty-nine, the red paper finally turning blue, with an acid reaction in one case only. These same reactions were found whether the test was made immediately after death or several hours later.

The chemical composition of the cerebro-spinal fluid is shown in the following analysis, made by Halliburton,[15] of fluid removed from cases of spina bifida.

	Case 1. Female aged nineteen years, in parts per 1,000.	Case 2. Child aged eleven days, first tapping, in parts per 1,000.	Case 3. Child aged thirteen weeks, fourth tapping, in parts per 1,000.
Water	989.75	989.877	991.658
Solids	10.25	10.123	8.342
Proteids	.842	1.602	.199
Extractives	} 9.626	.631	3.028
Salts	}	7.890	5.115

A comparison of the relative proportion of solids in several of the watery fluids of the body is shown in the subjoined table (Beaunis):

	Water.	Solids.
Lymph	95.8	4.2
Serum	95.9	4.1
Aqueous humor	98.6	1.4
Tears	98.2	1.8
Cerebro-spinal fluid	98.8	1.2

In normal cerebro-spinal fluid, proteids are small in amount, and somewhat variable in quantity and kind. Fibrinogen is absent, as no fibrin is formed by the addition of fibrin ferment. Serum albumin is absent, as all of the proteid is precipitated by saturation with magnesium sulphate. There are probably present, however, serum globulin, generally proto-albumose, sometimes hetero-albumose, and occasionally peptones. An increase in proteids is likely to occur in tappings subsequent to the first, but never equalling that found in inflammatory hydrocephalus.

The following analysis, in the case of a boy six months old with chronic hydrocephalus, illustrates this (Halliburton[15]):

	Specific gravity.	PROTEID.		
		Percentages of total proteids.	Kinds of proteid present.	Reducing substance.
First tapping.	1.006	0.045	Globulin .... Proto-albumose. Hetero-albumose.	Traces.
Second "	1.010	0.069	Same as first tapping.	Fairly abundant.
Third "	1.010	0.272	Serum globulin. Serum albumin. Traces of albumoses.	More abundant.

One of the most interesting features of the chemistry of the cerebro-spinal fluid is the presence of a substance which, like sugar, reduces copper salts. It has been considered grape sugar by many observers (Bernard, Cavazzani, Nawratzki,[16] and Panzer[17]).

Nawratzki studied this fluid in the calf, horse, and man. In the calf, working with two litres of fluid, he found a substance which reduces copper and bismuth oxide in alkaline solution, and gives the phenylhydrazin reaction. He obtained crystals having the form and melting point of phenylglucosazon, 205°–206° C. He failed to find pyrocatechin, peptone, or albumose, and considers the proteid a globulin. He claims that the reducing substance disappears shortly after death, and cites two cases in which the fluid drawn by lumbar puncture during life showed strong reducing action, but in the same individuals after death this action was lost. Halliburton always finds the reducing substance, but claims it is not grape sugar, for the following reasons: (1) It does not reduce bismuth salts; (2) it does not ferment with yeast; (3) it does not rotate the polarization plane; (4) it does not yield a crystalline compound with phenylhydrazin, as does sugar.

This reducing body can be obtained as follows:

"Acidified alcohol is added in excess to the fluid, to precipitate proteids; this is filtered off. The filtrate is evaporated to dryness over a water bath; the dry residue is again taken up with alcohol, filtered, and again evaporated to dryness" (Halliburton).

The crystalline deposit is the reducing substance and belongs to the aromatic group of organic compounds. It is soluble in ether, alcohol, and water, gives a green coloration with ferric chloride, brown with caustic alkalies, has a pungent taste and an acid reaction, and its crystals are needle-like and similar to those of pyrocatechin. Halliburton considers the reducing substance a normal constituent of the cerebro-spinal fluid, contrary to Hoppe-Seyler, who finds it subsequent to the first tapping only. It certainly increases in amount after the first tapping (see analysis). Whether it exists in a combined or an uncombined state is not known.

Some observers have noted an unusual preponderance of potassium salts, but later ones have found the proportion no greater than that of the blood, lymph, or transudates generally.

Briefly stated, the chief chemical characteristics of the cerebro-spinal fluid are the following:

1. It is a clear watery fluid, faintly alkaline, of low specific gravity, about 1.007.
2. It contains no fibrin and gives no precipitate (mucin) on adding acetic acid.
3. On boiling not more than a trace of turbidity (serum globulin) is observed.
4. It reduces Fehling's solution.
5. A reducing substance, obtained by evaporating to dryness an alcoholic extract of the fluid, is found in needle-like crystals having a pungent taste and an acid reaction, and resembling pyrocatechin. This reducing substance does not ferment with yeast, nor give the phenylhydrazin reaction, nor turn the polarization plane.
6. It contains a small proportion of proteids and generally no albumin.

Pathological and Clinical Considerations. — Since Quincke called attention to the value of puncture of the vertebral canal as a diagnostic and therapeutic measure, and to the ease with which it could be performed, resort to it has frequently been had.

The method of procedure is as follows:

The patient is preferably placed in the recumbent posture on the left side, with the body strongly flexed in the lumbar region. The puncture is made with a long aspirating needle between the second and third or the third and fourth lumbar vertebræ, a few millimetres outside the median line. In a child of about two years, the puncture should be opposite the mid-point between the lumbar spines, and at a depth of about 2 cm. the subarachnoid chamber will be reached. In the adult the puncture should be made at a point opposite the middle third of the lower border of the spine above, on account of the downward inclination of the spines, and the needle should slope toward the median line. If the puncture be made in the median line, it should be at the mid-point between the spines; and in children the needle should penetrate in a nearly horizontal direction, while in the adult it should slope upward parallel to the spines. Sahli[18] recommends that the puncture be made between the fifth lumbar and the base of the sacrum, especially if the morphological elements are to be sought for. Anæsthesia is, as a rule, unnecessary.

Where there are symptoms of intracranial pressure and only small amounts of fluid can be obtained by puncture, the cause will probably be an interruption of the connection between the encephalic and spinal spaces, due to exudate or tumor, especially of the cerebellum. It is possible, however, that the lack of fluid might be due to the closure of the aqueduct of Sylvius or the metapore. Small quantities of fluid exclude tuberculous meningitis, acute hydrocephalus, and tetanus.

The cerebro-spinal pressure can be judged by the strength of flow from the cannula, a strong spurt indicating an increased pressure, slow-coming drops a decreased pressure. It can be more accurately measured by attaching the cannula to a mercury, or, better, to a water manometer, the normal pressure being from 5 to 7.3 mm. mercury. When the pressure is much raised (15 to 60 mm. of mercury) meningitis or brain tumor is indicated. The specific gravity is somewhat variable, but an increased density points to meningitis, although this affection may exist with normal specific gravity.

Proteids may be found increased in tuberculous meningitis, decreased in brain tumors and serous meningitis. The variation in different cases of the same kind is so great that the proportion of proteids loses considerably in diagnostic significance. Lichtheim and Quincke claim to find sugar in most cases of brain tumor. This does not agree with the observations of Fürbringer, who found sugar only in cases of diabetes associated with tuberculosis.

Microscopic Examination.—A turbid appearance is due to leucocytes and indicates inflammation, but in tuberculous meningitis the fluid is clear.

In tuberculous meningitis, tumor, abscess, and chronic hydrocephalus only a few leucocytes and endothelial cells are to be found, while in acute meningitis the leucocytes are more plentiful, and in the purulent form they are very numerous. It is important, before advising operation in cases of abscess of brain and sinus thrombosis, to exclude purulent meningitis. This is often readily done by a microscopic examination of the puncture fluid.

Pure blood in the subarachnoid space indicates either extensive brain laceration or intraventricular hemorrhages. In subdural hemorrhages, a small amount of blood may be found; but in epidural hæmatoma, and in hemorrhagic pachymeningitis only very small quantities of blood are found. In severe traumatic cases the presence of nearly pure blood would indicate serious brain injury and contraindicate operation, and vice versa; the absence of blood might indicate the advisability of an operation. In non-inflammatory diseases of the brain, as tumors or abscess, no clotting occurs, except a slight one in tuberculous meningitis.

In cases in which tuberculous meningitis is suspected, some of the puncture fluid should be centrifugalized and examined for tubercle bacilli. Fürbringer has found the bacilli in thirty out of thirty-seven cases. Other organisms that have been found are the diplococcus intracellularis (Weichselbaum) in cases of epidemic cerebro-spinal meningitis, and the streptococcus and the diplococcus pneumoniæ in purulent meningitis secondary to otitis media. The staphylococcus pyogenes aureus and albus are also sometimes found.

St. Clair Thomson has collected from the literature nine cases of undoubted spontaneous flow of the cerebro-spinal fluid from the nose, and twelve probable cases. This condition he has named cerebro-spinal rhinorrhœa. It affects the sexes about equally, and is a disease of adult middle life, frequently presenting cerebral and eye symptoms. The flow is usually from the left side of the nose and is generally continuous day and night, but long or short periods of intermission may occur.

The method of escape of the fluid was found in one case to be through an aperture in the cribriform plate of the ethmoid. A possible explanation is that the lymph vessels of the nasal mucous membrane, which are in communication with the subarachnoid cavity, may furnish the exit. No efficient method of treatment has been found. One case of spontaneous flow from the ear is recorded in which the membrana tympani was intact and no evidence of injury or disease was present.

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BRAIN, CIRCULATION OF.—All the larger intracranial vessels and most of their easily visible branches lie in the enveloping membranes—dura, pia, and their processes. Over the convexity only minute branches enter or leave the brain proper. The largest arterial twigs directly entering the cerebrum are those of the (basal) pre- and post-perforated spaces. The largest

EXPLANATION OF
PLATE XVI.