On the specific gravity of different parts of the human brain / by H. Charlton Bastian.

ON THE

SPECIFIC GRAVITY

OF

DIFFERENT PARTS

OF THE

HUMAN BRAIN.

BY

H. CHARLTON BASTIAN,
M.A., M.B. Lond., F.L.S.,
MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS.

LONDON:
PRINTED BY J. E. ADLARD,
BARTHOLOMEW CLOSE.

1865.

[*Reprinted from the* 'JOURNAL OF MENTAL SCIENCE,' *published by authority of the* MEDICO-PSYCHOLOGICAL ASSOCIATION, *No.* 56, *January,* 1866.]

ON THE

SPECIFIC GRAVITY OF DIFFERENT PARTS OF THE HUMAN BRAIN.

BY

H. CHARLTON BASTIAN, M.A., M.B. Lond., F.L.S.

The question of the specific gravity of the brain has already engaged the attention of several British investigators, the results of whose labours have from time to time been made known, but with the exception of a few isolated observations little has been done to this subject by continental anatomists or pathologists. At a time like the present, when the attention of scientific men is directed with renewed interest to all details concerning weight, form, and configuration of the human brain, it seems reasonable to suppose that more complete observations upon the specific gravities of its several parts would be of itself a matter of scientific interest, independently of the importance attaching to the subject on account of the probable light which such an investigation might throw upon the *situations* of change in brain tissue, in connection with certain obscure forms of cerebral disease. The observations of previous inquirers have been directed to the estimation of the specific weights of the cerebrum and cerebellum as a whole, of the gray and white matter separately, and of the combined central ganglia of the cerebrum. These investigations have been made by some, upon the brains of sane, and by others, upon those of insane individuals; and amongst the forty persons whose brains I have myself examined, there are also representatives of these two classes, though a large majority is included under the former denomination. Whilst the actual number of brains inspected by myself is, therefore, limited, still the examination of their several parts has been more complete, so that this com-

munication contains a record not only of differences found to exist in the specific gravity of gray matter taken from frontal, parietal, and occipital convolutions respectively; but, also, I believe for the first time, of the specific weights of the optic thalami, pons, medulla oblongata, and different parts of the corpora striata, taken separately. Some of the facts so ascertained are very interesting, and seem to justify their early publication. Owing, also, to the existence of certain discrepancies in the results arrived at by preceding investigators and myself, it seems desirable that these discrepancies as well as our respective methods should be considered, with a view, if possible, of ensuring greater uniformity of results for the future. Investigations of a delicate nature such as these, when conducted by different observers, are comparatively useless for the purposes of comparison, unless some uniform method be adopted. These considerations have induced me to make known the results of my own observations sooner than I should otherwise have done, and will, I hope, be deemed a sufficient justification for my bringing them forward before they are sufficiently numerous to enable me to draw any very safe deductions from them. The present paper may, therefore, be considered as a first contribution towards the elucidation of a subject, at which I hope to work more thoroughly in the future.

Dr. Bucknill, whilst physician to the Devon County Asylum, was the first to institute a series of observations upon the specific gravity of the brain, with a view of estimating the amount of 'relative' atrophy of this organ in the insane, in conjunction with another series of experiments for determining the amount of 'positive' atrophy of the organ in the same individuals. His first communication on this subject, containing the results of the examination of thirty-two cases, is to be found in the 'Asylum Report' for 1852, and his next,* giving the details of the examination of another thirty cases, was published during the same year. He ascertained the specific gravity by immersing portions of the encephalon in a solution of sulphate of magnesia, when by "adding water or a strong solution of the salt, until the cerebral mass hangs suspended in the fluid, without any tendency to float or sink; and then by testing with the hydrometer, the specific gravity is thus found with great delicacy and facility, a difference of half a degree in the density of the fluid being indicated by the rise or fall of the substance immersed."

In this second and more complete series of thirty cases—all chronic, and including instances of dementia, imbecility, idiotcy, chronic mania, melancholia, epilepsy, and general paralysis—the average specific gravity of the cerebrum was found to be 1·0409, the extremes being 1·036 and 1·046; and of the cerebellum the average was 1·043, the

* 'Lancet,' Dec. 25, 1852, p. 588.

extremes ranging between 1·039 and 1·046. In the first series, containing a few acute cases, the specific gravity of the cerebrum varied between 1·036 and 1·052, the mean being 1·041; whilst that of the cerebellum varied between 1·037 and 1·053, its mean being 1·042. Unfortunately, however, these results, as far as the cerebrum is concerned, are rendered comparatively valueless, owing to the method adopted. Dr. Bucknill says:—"In many instances I took the specific gravity of the whole organ, but finding it was invariably lower than any of its parts, and that it was impossible to free so large a mass from air bubbles, I discarded the results as untrustworthy;" and further on he states that the figures in his tables "refer to large pieces of brain containing a fair proportion of vesicular and tubular substance." This is, indeed, as unsatisfactory a process as the other, since subsequent observations have shown the differences existing between the specific gravities of the gray and white matter of the cerebrum; for, how is it possible to ensure precisely the same relative proportions between these two substances in all the portions of brain taken for examination? And even were it possible to do this, the result would still be a crude one, capable only of being compared with others of the same kind, and revealing nothing with regard to the separate specific gravities of gray and white matter respectively—each of which, as is now known, may vary independently of the other, and so exert more than a fair share of influence upon the number obtained. A high specific gravity of gray matter might even be masked by a slight softening of the white substance—a combination occasionally met with amongst the insane, and which, when it occurs, would, by this method, yield a mean number in every way deceptive.

About the same time that Dr. Bucknill published his second table, Dr. Aitken's attention was attracted to the subject of the specific gravity of the brain by some observations which he made on the central ganglia in a case of chorea.* He found the combined corpus striatum and optic thalamus on the right side to have a specific gravity of 1·025, and on the left 1·031. This induced him to make other observations upon the brains of persons dying in the Royal Infirmary of Glasgow, in order to compare the specific weights of the central ganglia on the two sides of the body with one another, and with that of the cerebrum and the cerebellum. The results of the examination of eight cases, including the one of chorea, are given in the paper above referred to. His method of estimating the specific gravities seems to be the same as that adopted by Dr. Bucknill, and the same objections apply to the results as far as the cerebrum is concerned, and also with minor force to the estimation of the specific weight of the corpus striatum and optic

* 'Glasgow Medical Journal,' No. I., 1853.

thalamus taken together. But the recognition of a difference in the specific gravity of such important parts as the central ganglia on the two sides of the brain, was in itself a most interesting fact, and an important one also, since besides calling attention to the specific gravity of these central parts, it led Dr. Aitken to initiate the practice of comparing the specific gravities of parts on the two sides of the brain.* As will be seen hereafter, the specific weights of the central ganglia in this case were unusually low, whilst in two other cases he found their numbers considerably higher than what I should imagine to be the probable average of the two bodies thus taken together. Both Dr. Bucknill and Dr. Aitken found the specific gravity of the cerebellum higher than that of the cerebrum, and subsequent observations have tended to confirm this result.

We are indebted to Dr. Sankey for a valuable and elaborate paper† upon the specific gravity of the brain, containing the results of an examination of this organ in upwards of seventy individuals who died in the London Fever Hospital. His observations were limited to the gray matter of the convolutions, and the white substance of the cerebrum, and, unfortunately, did not extend to the central ganglia. Inasmuch as the gray and white matter were examined separately, his method was free from the objections formerly stated, and his inquiries have furnished us with some valuable data concerning the specific gravity of these parts in sane individuals dying from ordinary diseases.‡ He introduced also a very convenient method of taking the specific gravities which, with some slight modifications, has been followed both by Dr. Skae and myself. Dr. Sankey's observations led him to place the mean specific gravity of the gray matter of the convolutions at 1·0346, the extremes met with being 1·028 and 1·046; whilst he ascertained the mean of the white substance to be 1·0412, with extremes of 1·032 and 1·048.

Dr. Skae, the next worker in this field, as a result of the examination of the brain in sixty-two persons dying in the Royal Edinburgh Asylum, published a valuable paper,§ "On the Weight and Specific Gravity of the Brain in the Insane," and, for the purposes of comparison, tabulated the results of his inquiry into the specific gravity of the gray and white matter of the cerebrum, in parallel columns with those of Dr. Sankey. He says: "A glance

* It was at the strong recommendation of Professor Aitken that I was induced to take up the question of the specific gravity of the brain in the insane, as a method of investigation which promised to yield some definite, and valuable results.

† 'Brit. and For. Med.-Chir. Review,' January, 1853, p. 240.

‡ It must not be forgotten, however, that the majority of his cases also suffered from fever, as this seems to have a marked influence upon the specific gravity of the brain.

§ 'Edin. Month. Jour. of Med. Sc.,' Oct. 1854, p. 289.

at the tables will at once show that the specific gravity in the cases of insanity was almost uniformly higher, and this observation applies to both the gray and the white matter." He gives the mean specific gravity of the gray matter as 1·0391, the lowest density met with being 1·030, and the highest, 1·049; and the mean of the white as 1·0424, with extremes varying between 1·034 and 1·053. Dr. Skae also examined the cerebellum of twenty-seven insane patients, as well as in a few sane individuals, and after comparing the results, he says: "From these data, although limited, I infer that the specific gravity of the cerebellum is increased in insanity, and attains a greater increase in relation to that of the cerebrum than it does in persons dying sane."

In an article on "The Pathology of Insanity,"* Dr. Bucknill has given a very interesting table compiled from the results of post-mortem examinations in sixty-three cases of insanity, and including more recent observations upon the specific gravity of the brain. These latter results are the more valuable because in the case of the cerebrum, he has now given us the benefit of his observations upon the specific gravity of the gray and white matter taken separately. He found the specific gravity of the gray matter in the insane to vary between 1·030 and 1·048, and the average to be 1·037, whilst that of the white substance varied between 1·033 and 1·046, and had a mean of 1·039. Dr. Bucknill also gives the average specific gravity of the cerebellum in this series as 1·040, the extremes being 1·030 and 1·049; he does not state, however, whether these results were from the examination of the whole organ, or of parts only, as in his previous experiments.

Dr. Peacock has published more recently† a limited number of observations upon the specific gravity of the encephalon, cerebrum, and cerebellum, and of the combined pons and medulla. The difference now ascertained to exist between the specific gravities of the pons and of the medulla oblongata when taken separately, render an examination of their combined specific gravity undesirable for the future. The method employed by Dr. Peacock was different from that adopted by previous observers; he resorted to the process of weighing in air and then in distilled water, and deducing the specific gravity of the body from its observed loss of weight in water, by a proportional formula. Of course, with a delicate balance and due precautions, this method would be as capable of yielding accurate results as the other, but it must not be forgotten that during the process of weighing in water, there would be the same difficulties to contend with as Dr. Bucknill speaks of in his attempts to ascertain the specific gravity of the cerebrum as a whole,

* January, 1855, p. 207, 'Brit. and For. Med.-Chir. Review.'
† 'Trans. of Patholog. Soc.,' vol. xii (1860-61), p. 27.

viz., the freeing of so large a mass from air bubbles. Dr. Bucknill always found the specific gravity of the cerebrum as a whole less than that of its parts; and unless special precautions were taken, this may probably have been due, in part, to the entrance and lodgment of air in the ventricles. Both Dr. Bucknill and Dr. Peacock are silent upon the point as to whether, before attempting to estimate the specific gravity of the cerebrum, they were careful to strip off the pia mater and arachnoid. It seems right that this should always be done, not only as a matter of accuracy, but because the neglect to do so would so greatly increase the risk of vitiated results from the presence of air in the larger vessels, and from the increased liability to the entanglement of air bubbles by the membranes themselves. The mean specific gravity of the entire encephalon of twelve persons dying from other than cerebral diseases, Dr. Peacock found to be 1·036, of the cerebrum 1·0349, and of the cerebellum 1·040.

If we arrange the principal results hitherto arrived at by these various observers, upon the specific gravity of the brain and its parts, in a tabular form, as on next page, we shall be the better able to compare them, and such a table will be useful hereafter for reference.

Specific Gravity of the Encephalon and its parts by previous Observers.

The large central figures of each group give the ***average*** result, and the smaller ones the ***extremes*** met with.

Name of Observer.	Encephalon.	Total Cerebrum.		Parts of Cerebrum.					Total Cerebellum.		Parts of Cerebellum.			
				Gray matter.		White matter.		Combined central ganglia.			Gray matter.		White matter.	
	Sane.	Sane.	Insane.	Sane.	Insane.	Sane.	Insane.	Sane.	Sane.	Insane.	Sane.	Insane.	Sane.	Insane.
Dr. Bucknill*	...	...	1·036 **1·041** 1·052	...	...	...	...	...	...	1·037 **1·042** 1·053				
			1·036 **1·040** 1·046	...	...	...	...	...	...	1·039 **1·043** 1·046				
			... ...	...	1·030 **1·037** 1·048	... ...	1·033 **1·039** 1·046	...	...	1·030 **1·040** 1·049				
Dr. Aitken† ...	...	1·033 **1·037** 1·046	...	...	...	...	...	1·025 **1·040** 1·047	1·038 **1·043** 1·049					
Dr. Sankey‡ ...	...	...	...	1·028 **1·0346** 1·046	... ...	1·032 **1·0412** 1·048								
Dr. Skae§	...	...	...	...	1·030 **1·0391** 1·049	... ...	1·034 **1·0424** 1·053	... ...	... ...	... ...	... **1·042** ...	1·036 **1·040** 1·044	... **1·0433** ...	1·0430 **1·0438** 1·0444
Dr. Peacock‖	1·0321 **1·036** 1·0392	1·0326 **1·0349** 1·0368	... ...	... ...	... ...	... ...	... ...	... ...	1·0375 **1·0405** 1·0429					

* The numbers in the upper row were derived from the examination of 32 cases; those of the second from 30, and those of the third from an examination of 63 cases. The first two sets of numbers do not strictly represent the specific gravity of the "total cerebrum," but of "large pieces of brain containing a fair proportion of vesicular and tubular substance."

† The figures relating to the cerebrum were derived from an examination of 6 cases, and those to the cerebellum from 5 cases.

‡ Results from an examination of 73 cases.

§ Numbers relating to cerebrum from an examination of 62 cases, those to cerebellum in the insane from 27, and in the sane from 5.

‖ Numbers derived from an examination of 12 cases, the persons being entirely free from cerebral disease.

The method of ascertaining the specific gravities, introduced by Dr. Sankey, to which I have before alluded, is this:—a number of tall glasses are taken, each of which is filled (beginning with the lowest), with a saline solution of gradually increasing density. In practice, it seems sufficient to adjust the density of the solutions, in the successive glasses, to alternate numbers only of the ordinary hydrometer scale; and, supposing the even numbers be taken, a series from 1·024—1·054 inclusive, making a total of sixteen glasses, would, with rare exceptions, be found sufficient for any investigation into the specific gravity of different parts of the human brain. The solutions being once prepared of the requisite density, the surest way of maintaining them in this condition, or rather of guarding against unknown alterations in strength, is to place in each glass two of the specific gravity beads which were formerly employed by barometer makers. Thus, if we have, for instance, three glasses containing solutions of the respective densities of 1·032, 1·034, and 1·036, we must put into each glass beads whose specific gravities are marked at one degree higher and one degree lower than the contained fluid; so that the glass whose fluid is marked at the specific gravity of 1·034, should contain beads marked 1·035 and 1·033, the former of which would sink to the bottom of the glass and the latter would float;* whilst in the 1·036 solution, another 1·035 bead would float, and one marked 1·037 should touch the bottom of the glass. Any alteration in the density of the solution would be at once revealed by a change in the position of the beads—increased density from evaporation would be detected by a proportionate rise in the position of the lower bead, whilst a diminution in density from any cause would be shown by a sinking of the upper one. The solutions so prepared and ranged in order, the method of proceeding is sufficiently simple. If, for instance, we have a small portion of gray matter from one of the convolutions, just removed and on the point of the knife, all that we have to do is to hold it about two or three inches above one of the solutions—say, 1·032—and then push it off the blade by means of a probe or any other convenient instrument. After the first down-rush into the fluid, due to the momentum, has expended itself, we can see almost immediately whether the portion of brain substance continues to sink, rises, or has a tendency to remain stationary at any level to which it has fallen. If the latter were the case, the specific gravity of the portion of gray matter in the instance chosen would be 1·032, but if instead of floating indifferently in any stratum of this solution it sank to the bottom,

* In Dr. Sankey's original description he has stated it the reverse way, thus, he says that in a solution of the density of 1·050 the 1·051 bead would float, and that marked 1·049 would sink. This, of course, was an oversight; but as he made a statement of this kind twice, it seems desirable, for the sake of clearness, to notice it.

whilst a similar piece taken in the same manner—or even the original portion rapidly removed by means of a forceps—floated in the solution just above marked 1·034, we may pretty safely conclude that the specific gravity of the gray matter is 1·033, or just intermediate between the densities of the two fluids in which it behaves so differently. The principal liability to error to be guarded against in this operation is the adhesion of minute air bubbles to the portion of brain, and to obviate this risk as far as possible, no number should be recorded unless the same result has been obtained in three or four successive trials.* The salt originally used for the preparation of the solutions by Dr. Sankey was chloride of sodium, but he has since come to the conclusion that a solution of sugar, or better still, of sulphate of magnesia, is preferable owing to its slower and less decided action upon the portions of brain substance immersed in it. Whichever solution is used, and more especially with that of chloride of sodium, it is necessary to be guided only by the behaviour of the portion of the brain when first immersed in the fluid, since, as pointed out by Dr. Sankey, portions of brain will, after remaining in the solutions for a short time, sink in those in which they at first floated. With a view to uniformity in the conditions, Dr. Skae followed Dr. Sankey's example, and employed solutions of common salt, though he did not make use of the specific gravity beads. Speaking of his solutions he says, "to insure accuracy and avoid fallacies arising from the spontaneous evaporation of the fluid, their specific gravity was in every experiment tested afresh by the urinometer at the time of the observation." In my own observations, I have employed solutions of sulphate of magnesia containing specific gravity beads.†

If solutions made at the time, as in Dr. Bucknill's experiments, are employed, a most necessary caution is to see that a thorough

* To do away, as much as possible, with this source of error from air bubbles, it is also desirable that the solutions to be employed should be made at least several hours before they are used, to give time for the disappearance of the minute bubbles necessarily produced by the mixture and stirring of the fluids. Occasionally, soon after the due adjustment of the solutions, some of the lower beads may be found floating at the surface, being buoyed up by the accumulation and contact of some of these minute air bubbles. A few slight knocks with a glass rod will at once dislodge them, and allow the bead again to take up its proper position at the bottom of the glass.

† There is a possible error to be guarded against of a most important kind, and that is the employment of inaccurate instruments; I have tested my beads by comparing results obtained with them, and with a carefully made hydrometer having a long open scale, and have always found them tally with one another. The ordinary cheap urinometers are sometimes most untrustworthy. One which I purchased for half-a-crown I found to be just seven degrees wrong; and Dr. Beale speaks as follows concerning them:—"As sold, these instruments are often nearly useless, in consequence of the carelessness displayed in their manufacture. Out of twenty instruments, I have found several differing as much as ten degrees from each other."

intermixture of the fluids has taken place, the adjustment of the density by merely "adding water or a strong solution of the salt until the cerebral mass hangs suspended in the fluid, without any tendency to float or sink," is by no means sufficient unless the addition is supplemented each time by a vigorous stirring. I have found, by experiment, that when a concentrated saline solution is added to water or a weaker solution, by simply pouring the one into the other, a very rough kind of admixture only takes place, and that a solution of homogeneous density is not produced by the tendency to diffusion alone, till after the expiration of a much longer period than might have been imagined. The heavier solution gravitates to the bottom of the glass, and a partial intermixture only takes place, so that we get a fluid the ascending strata of which are progressively less in density. In a solution of sulphate of magnesia thus prepared, I immediately placed three specific gravity beads, numbered 1·025, 1·027, and 1·029, and almost at once, as soon as the movements in the fluid had subsided, the beads took up positions at very slightly different levels, at about three inches from the bottom of the glass, the fluid itself having only a total height of four inches. These relative positions they maintained, with no appreciable variation; and after one hour had expired, I carefully removed with a pipette the upper strata of fluid for a depth of about three quarters of an inch, and found, after brisk stirring, this portion of the solution to have a specific gravity of 1·020; whilst the lowest strata, for the same depth, removed and treated in a similar manner, had a specific gravity of 1·051. On again pouring into one glass the three portions of the original solution and thoroughly mixing them, all three beads immediately rose to the surface, and the now homogeneous fluid had a specific gravity, as ascertained by the hydrometer, of 1·034. In another solution, prepared in the same manner, now before me, the three beads have maintained almost similar positions, with very slight change, for more than forty-eight hours. These results were somewhat startling, as one might have thought that the laws of diffusion would have come into more active operation. It shows, at all events, how necessary it is to guard against possible errors creeping into observations, from imperfect admixture of solutions of different density. Of course, I by no means mean to imply that preceding observers have not been fully aware of these facts; only it seems right to call attention to them, since inattention to their indications might become a source of error in the future.

Before I had proceeded very far with my own observations, I discovered a difference in the specific gravity of the gray matter taken from different convolutions; and this I have since found to be almost invariably the case, and pretty constant in kind. The amount of time at my disposal compelled me to put a limit to

these investigations, so that I have confined myself to an examination of the *gray matter* from three situations on each side of the cerebrum :—(*a*) from the 'upper frontal' convolution; (*b*) from the upper part of the 'anterior ascending parietal' convolution; and (*c*) from the 'upper occipital' convolution.* In all cases, after removing the membranes from these parts, small pieces of the gray matter were sliced off with a sharp knife, the lowest strata not being included, in order to avoid, as far as possible, all chance of an accidental admixture of white matter. The portions taken from the occipital convolutions were removed with extra care, on account of the smaller depth of gray matter on the convolutions in this region. The *white matter* taken for examination was removed from near the centre of each hemisphere. In examining the *fornix*, portions of its body were selected. To ascertain the specific gravity of the *corpora striata*, I was at first in the habit of taking portions (after making a transverse section) from (*a*) the intra-ventricular portions of gray matter only, cutting a small piece out from the face of the section adjoining the ventricular surface; but latterly, after discovering the marked difference in the density of these parts, I have also taken cuttings (as free as possible from white fibres) from (*b*) the extra-ventricular portions (*nuclei lenticulares*) of these bodies. In determining the density of the *optic thalami* and the *pons varolii*, portions have been taken from near their centres. At first I was in the habit of ascertaining the specific gravity of the gray matter only of the *cerebellum*, by taking portions of about $\frac{1}{5}''$ in thickness from near the middle of each side of its under surface, after having stripped off its membranes and made sections through it in these situations;† but latterly, I have also estimated the specific weight of the central white matter of the cerebellum. In examining the *medulla oblongata*, I have first, whilst it was still in connection with the pons, carefully stripped the membranes from it, and then, after severing it from this body and also cutting away any part of the cord, by means of a section level with the lower extremi-

* For the names of the various convolutions, see Gratiolet's work, 'Sur les Plis Cérébraux de l'Homme;' or else an admirable memoir by Professor Marshall ('Philos. Transact.,' 1864, p. 501), "On the Brain of a Bushwoman; and on the Brains of two Idiots of European Descent."

† The results so obtained are not quite as perfect as could be desired, since it is impossible to take such portions from the cerebellum without including along with the gray matter some small ramifications of the white substance. The sections were made in the situations indicated, because in these regions it was found that fragments agreeing as nearly as possible with one another could be most easily taken for examination—that is to say, fragments always containing about the same relative amount of admixed white substance. The fact, however (as will be hereafter seen), that in so many cases the white matter of the cerebellum has the same specific gravity as these other superficial portions, consisting mostly of gray matter, makes this slight admixture of far less consequence than it would be if, as in the cerebrum, the gray and white matter differed considerably in their respective specific weights.

ties of the anterior pyramids, have estimated its specific gravity as a whole.

Unfortunately, the examination of ten of the brains of the eleven insane persons has not been so complete as that to which the eleventh and most of the other twenty-nine cases have been subjected. These were my first observations on the subject, and as I gradually discovered the very considerable variations in the specific gravities of the different parts of the brain in different individuals, and especially the variations in that of the gray matter in the same brain, I became anxious to examine this organ in a certain number of sane individuals after the same method, so as to ascertain, if possible, what amount of importance could be attached to these deviations, and whether or not they would seem to have any connection with the mental condition of the individual.

As the specific gravities have been taken of so many parts of the brain in each case, and the variations in the different cases are so dissimilar, the only satisfactory way of recording these observations seems to be to give each series of numbers separately, in order that they may be readily compared with one another, and the method of their variation, if possible, detected. This I have therefore done, giving, in addition, particulars as to sex, age, interval between death and autopsy, as well as nature of illness and principal pathological conditions met with after death. Where the brain was notably congested or anæmic, I have mentioned the fact, and in the remaining cases a medium condition of vascularity may be considered to have existed. The cases have been numbered also for facility of reference, and in each table have been ranged in order of age.

Of the twenty-nine cases in which the brains of sane persons were submitted to examination, and the results given in the following tables, twenty-five only will be taken account of hereafter for the purpose of estimating averages. The four cases omitted are numbered I, II, XXI, and XXVII. The two former were not included, on account of the brains having been taken from children only two years of age, and the two latter because the evidence as to the mental condition of the individuals was not of a sufficiently decided nature.

The examination of the brain in Nos. XXI and XXVII amongst the sane, and in all the insane cases with the exception of No. XXXI, were made in this country at varying periods of the year, and therefore at periods of different atmospheric temperature; but in all the remaining cases the investigations were carried on this summer at Berlin,*

* This portion of the work was done in the Pathological Institute of Berlin, where, through the kindness and courtesy of Professor Virchow and his two assistants, Drs. Klebs and Colnheim, every facility was afforded me for carrying on these investigations, and I now most gratefully acknowledge my obligations to them. As the brains occasionally remained on the wooden trays for about half

the temperature of the room, during the fortnight that I was working there, varying only from about 71° to 77° Fahr., whilst that of the solutions was about three or four degrees lower than that of the air.

The slight increase in the temperature of the solutions in these later experiments above that of 60° Fahr., at which all observations upon specific gravity should be conducted, when taken in conjunction, too, with the part compensation afforded by the simultaneous action of the increased temperature upon the bulk of the beads themselves, could produce only a very infinitesimal amount of vitiation in the correctness of the results. And, indeed, seeing that water in its passage through a range of temperature from 32° to 212° Fahr., apparently increases in bulk only by about $\frac{1}{22}$ of its original volume, it does not seem likely, either, that any degree to which the temperature of the solution would fall would exercise a very appreciable influence upon the correctness of the observations.* It must be borne in mind that the maximum fall which could have any effect

an hour after the ordinary pathological examination, before I could proceed to estimate their specific gravities, and these trays were sometimes wet, I made a few experiments to ascertain what amount of influence, if any, such a length of exposure to air, or contact with a wet tray, would exercise upon the specific gravity of the white and gray matter of the brain, and found that within this period these conditions appeared to exercise no appreciable influence whatever. Thus, white matter, after lying (even completely) in water for a period of thirty minutes, was found to have the same specific gravity as before immersion; and no change, either, was found in the specific gravity of the gray matter of the convolutions, after allowing portions of the brain, covered by the arachnoid, to remain for a similar period with this surface downwards, in contact with a thin stratum of fluid upon a wet tray—the portions of gray matter examined before and after being taken from what were nearly adjacent portions of the same convolutions. And with regard to the influence of the high summer temperature, no increase of density could be detected after such short periods of exposure, provided the convolutions were still covered by the arachnoid, whilst as far as the white matter was concerned it was always easy to take portions from beneath a surface which had been at all exposed. Alterations from atmospheric influence were also guarded against, as much as possible, by throwing a towel over the brain during these occasional intervals.

* Whilst this paper has been going through the press, I have made some experiments in order to ascertain what amount of error can result from inattention to the temperature of solutions, and have been much pleased to find this so very insignificant when sp. gr. beads are employed, as to render attention to this point of little importance. Thus the compensating variation in the beads is such, that I have found, after adjusting a solution of sulphate of magnesia at a temperature of 60° Fahr., to a specific gravity of 1·028, the solution could be raised to a temperature of 84° Fahr. before the 1·027 bead sank midway in the solution; whilst, on the other hand, when the solution was cooled to 40° Fahr., the deviation was still less, since the 1·029 bead still remained at the bottom of the bottle. During these experiments a thermometer was kept in the solution, and due precautions were taken to prevent alteration in the density of the solution from evaporation. If the solutions, instead of being prepared at the temperature of 60° Fahr., have been adjusted to the beads at a time when the temperature of the weather is above or below this point, a little reflection will show that this of itself tends to diminish the small amount of possible error before alluded to, and so makes attention to temperature even of less importance.

of this kind would only be to the extent of 20° Fahr., since it has been proved that saline solutions exhibit the same changes in bulk in passing from a temperature of 40° Fahr. to 32° Fahr. as are so well known to take place with pure water. The progressively increasing re-expansions of the solutions at temperatures below that at which water attains its maximum density would, therefore, have a corresponding tendency to assimilate the density of the solutions to that which would exist at the prescribed temperature of 60° Fahr.

I have been thus precise in describing my method of proceeding, not only for the information of any others who may wish to follow up this investigation in such a way that their observations could be compared with mine, but because it is only fair that the exact conditions of the experiments should be made known, in order that others may form an opinion as to the trustworthiness of the results.

Specific Gravity of different parts of the Brain of Sane Individuals.

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cerebellum	Pons.	Medulla
I.	2	F.	20	Measles followed by broncho-pneumonia. *Congestion of brain.*	R. *a.* 1·027 *b.* 1·027 *c.* 1·035 L. *a.* 1·027 *b.* 1·029 *c.* 1·033	R. 1·035 L. 1·035	1·029	R. *a.* 1·033 *b.* 1·037 L. *a.* 1·033 *b.* 1·037	R. 1·039 L. 1·039	R. 1·035 L. 1·035 W. 1·036	1·041	1·033
II.	2	F.	36	Scarlet fever. No notable pathological change recognised.	R. *a.* 1·029 *b.* 1·029 *c.* 1·033 L. *a.* 1·029 *b.* 1·031 *c.* 1·033	R. 1·035 L. 1·035	1·029	R. *a.* 1·035 *b.* 1·037 L. *a.* 1·035 *b.* 1·037	R. 1·039 L. 1·039	R. 1·038 L. 1·038 W. 1·038	1·043	1·033

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cerebellum.	Pons.	Medulla.
III.	6	M.	36	Scarlet fever some months before death. Body rather emaciated; slight capillary bronchitis of both lungs; liver fatty; mesenteric glands enlarged. Brain slightly congested; white matter in posterior part of hemispheres much softened, easily breaking up when water is poured upon it.	R. *a.* 1·027 *b.* 1·026 *c.* 1·029 L. *a.* 1·027 *b.* 1·029 *c.* 1·029	R. 1·039 Softer part 1·031 L. 1·037 Softer part 1·031	1·029	R. *a.* 1·031 *b.* 1·041 L. *a.* 1·031 *b.* 1·041	R. 1·040 L. 1·040	R. 1·035 L. 1·035	1·043	1·035
IV.	20	M.	32	*General anasarca;* hypertrophy of heart, with mitral insufficiency and thickening of aortic valves; lungs very tough, firm, and dark coloured; nutmeg liver, very tough; kidneys having cortical substance, narrow, with pale, fatty look.	R. *a.* 1·029 *b.* 1·029 *c.* 1·029 L. *a.* 1·030 *b.* 1·031 *c.* 1·031	R. 1·039 L. 1·039	1·035	R. *a.* 1·035 *b.* 1·039 L. *a.* 1·035 *b.* 1·039	R. 1·043 L. 1·041	R. 1·037 L. 1·037	1·041	1·035
V.	20	M.	24	Death on fourth day, of scarlet fever. Brain slightly congested; arachnoid natural.	R. *a.* 1·031 *b.* 1·033 *c.* 1·033 L. *a.* 1·031 *b.* 1·031 *c.* 1·035	R. 1·039 L. 1·039	1·035	R. *a.* 1·037 *b.* 1·041 L. *a.* 1·039 *b.* 1·041	R. 1·041 L. 1·041	R. 1·039 L. 1·039 W. 1·039	1·041	1·036

VI.	24	M.	22	Typhoid fever; death in third week. *Brain congested;* membranes normal.	R. *a.* 1·027 *b.* 1·029 *c.* 1·031 L. *a.* 1·027 *b.* 1·029 *c.* 1·031	R. 1·039 L. 1·039	1·029	R. *a.* 1·035 *b.* 1·041 L. *a.* 1·035 *b.* 1·041	R. 1·043 L. 1·043	R. 1·039 L. 1·039 W. 1·039	1·043	1·035
VII.	24	M.	17	Traumatic peritonitis, following operation for abscess in abdominal wall.	R. *a.* 1·027 *b.* 1·027 *c.* 1·029 L. *a.* 1·027 *b.* 1·027 *c.* 1·029	R. 1·037 L. 1·037	1·027	R. *a.* 1·035 *b.* 1·041 L. *a.* 1·035 *b.* 1·041	R. 1·041 L. 1·041	R. 1·037 L. 1·037 W. 1·037	1·039	1·035
VIII.	24	M.	55	Large chronic abscess in liver; peritonitis and double pleurisy; membranes of brain normal.	R. *a.* 1·030 *b.* 1·031 *c.* 1·033 L. *a.* 1·033 *b.* 1·033 *c.* 1·035	R. 1·039 L. 1·039	1·033	R. *a.* 1·037 *b.* 1·041 L. *a.* 1·035 *b.* 1·041	R. 1·041 L. 1·041	R. 1·039 L. 1·039	1·039 to 1·040	1·035
IX.	25	F.	17	Necrosis of petrous portion of temporal bone (right), near and below mastoid cells; gangrene of dura mater over necrosed bone, and also two superficial patches of gangrene on corresponding portions of right half of cerebellum, about $\frac{1}{2}$″ in diameter. *Brain congested;* thrombosis in right lateral and petrosal sinuses, and also of internal jugular on same side. Disease of two or three years' duration; no delirium during life, but semi-comatose condition during last two hours of life.	R. *a.* 1·035 *b.* 1·035 *c.* 1·037 L. *a.* 1·035 *b.* 1·035 *c.* 1·035	R. 1·043 L. 1·043	1·033	R. *a.* 1·035 *b.* 1·043 L. *a.* 1·035 *b.* 1·043	R. 1·043 L. 1·043	R. 1·043 L. 1·043	1·045	1·038

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cerebellum.	Pons.	Medulla.
X.	28	M.	32	Disease of left knee-joint, with large suppurating cavities in muscles above and below; early stage of inflammation of lungs; septicæmia with secondary fever; delirium before death. *Brain congested;* great thickening and opacity of arachnoid on upper surface, especially on either side of middle line.	R. *a.* 1·029 *b.* 1·029 *c* 1·031 L. *a.* 1·029 *b.* 1·029 *c.* 1·033	R. 1·041 L. 1·041	1·033	R. *a.* 1·035 *b.* 1·043 L. *a.* 1·033 *b.* 1·043	R. 1·043 L. 1·043	R. 1·041 L. 1·041 W. 1·043	1·043	1·035
XI.	29	M.	35	Necrosis of rib, with empyema and peritonitis; increase of sub-arachnoid fluid, with slight thickening of membrane.	R. *a.* 1·027 *b.* 1·029 *c.* 1·031 L. *a.* 1·029 *b.* 1·029 *c.* 1·031	R. 1·039 L. 1·039	1·029	R. *a.* 1·035 *b.* 1·041 L. *a.* 1·035 *b.* 1·041	R. 1·043 L. 1·043	R. 1·037 L. 1·037 W. 1·037	1·043	1·035
XII.	31	F.	21	Post-puerperal inflammation of left knee-joint, with abscesses in muscles around; endocarditis; slight inflammation of liver; kidneys slightly granular; *brain anæmic;* Death in seventh week after parturition.	R. *a.* 1·030 *b.* 1·031 *c.* 1·037 L. *a.* 1·030 *b.* 1·031 *c.* 1·037	R. 1·041 L. 1·041	1·035	R. *a.* 1·037 *b.* 1·041 L. *a.* 1·037 *b.* 1·041	R. 1·041 L. 1·041	R. 1·041 L. 1·041 W. 1·039	1·043	1·037

XIII.	34	F.	11	Sarcomatous tumour of right ovary, about seven inches in diameter; spleen large, soft; liver large; swelling of glands behind tongue; enteritis follicularis. Death sudden; fever and heat of skin during last day of life only.	R. *a.* 1·027 *b.* 1·031 *c.* 1·035 L. *a.* 1·027 *b.* 1·029 *c.* 1·037	R. 1·037 L. 1·037	1·035	R. *a.* 1·035 *b.* 1·039 L. *a.* 1·035 *b.* 1·039	R. 1·039 L. 1·039	R. 1·039 L. 1·039 W. 1·037	1·039	1·035
XIV.	36	M.	12	Phthisis. Membranes and brain substance normal in appearance; convolutions extremely well developed, small, but very numerous and closely packed; ascending parietal convolutions very complex.	R. *a.* 1·029 *b.* 1·029 *c.* 1·031 L. *a.* 1·029 *b.* 1·029 *c.* 1·031	R. 1·043 L. 1·043	1·031	R. *a.* 1·035 *b.* 1·041 L. *a.* 1·035 *b.* 1·041	R. 1·043 L. 1·043	R. 1·041 L. 1·041	1·045	1·038
XV.	40	M.	20	A drunkard; delirium tremens and pleuro-pneumonia. Thickening of calvaria; dura mater very adherent to base of skull; great thickening and vascularity of occipital bone at and on each side of the internal occipital protuberance; thickening and opacity of arachnoid; *great congestion of brain.*	R. *a.* 1·029 *b.* 1·029 *c.* 1·031 L. *a.* 1·031 *b.* 1·030 *c.* 1·035	R. 1·043 L. 1·043	1·035	R. *a.* 1·041 *b.* 1·043 L. *a.* 1·041 *b.* 1·043	R. 1·045 L. 1·045	R. 1·041 L. 1·041	1·043	1·039
XVI.	40	M.	14	Epilepsy; temporary paralysis of left side for one day shortly before death; skull-cap thick, diplöe full of blood; four deep, sharply defined depressions for Pacchionian glands; great congestion of internal organs; heart healthy. *Brain considerably congested.*	R. *a.* 1·031 *b.* 1·031 *c.* 1·031 L. *a.* 1·031 *b.* 1·031 *c.* 1·031	R. 1·041 L. 1·041	1·039	R. *a.* 1·035 *b.* 1·043 L. *a.* 1·035 *b.* 1·043	R. 1·043 L. 1·043	R. 1·043 L. 1·043 W. 1·043	1·043	—

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cerebellum.	Pons.	Medulla.
XVII.	40	M.	24	Abscess and ulceration of left parotid gland; typhoid fever three months before.	R. *a.* 1·029 *b.* 1·027 *c.* 1·029 L. *a.* 1·027 *b.* 1·029 *c.* 1·029	R. 1·040 L. 1·040	1·037	R. *a.* 1·032 L. *a.* 1·031	R. 1·039 to 1·042 L. 1·042 to 1·043	R. 1·037 L. 1·037	1·043	1·035
XVIII.	44	M.	52	Phthisis and tubercular ulceration of intestine. Thickening and opacity of arachnoid.	R. *a.* 1·025 *b.* 1·029 *c.* 1·031 L. *a.* 1·026 *b.* 1·029 *c.* 1·031	R. 1·040 L. 1·040	1·030	R. *a.* 1·033 *b.* 1·042 L. *a.* 1·033 *b.* 1·042	R. 1·042 L. 1·042	R. 1·039 L. 1·039 W. 1·039	1·042	1·035
XIX.	51	M.	29	Bronchitis and œdema pulmonum; kidneys large and congested. Diplöe of calvaria very full of blood; *brain much congested.*	R. *a.* 1·027 *b.* 1·029 *c* 1·033-7 L. *a.* 1·029 *b.* 1·031 *c.* 1·031	R. 1·041 L. 1·041	1·035	R. *a.* 1·035 *b.* 1·043 L. *a.* 1·035 *b.* 1·043	R. 1·043 L. 1·043	R. 1·041 L. 1·041 W. 1·041	1·043	1·035

XX.	55	F.	10	Phthisis; much tubercle in both lungs, with cavities at apices. Thickening and slight opacity of arachnoid, with considerable increase of sub-arachnoid fluid.	R. *a.* 1·029 *b.* 1·029 *c.* 1·029 L. *a.* 1·029 *b.* 1·029 *c.* 1·029	R. 1·041 L. 1·041	1·035	R. *a.* 1·041 *b.* 1·043 L. *a.* 1·041 *b.* 1·043	R. 1·043 L. 1·043	R. 1·041 L. 1·041 W. 1·041	1·043	1·039
XXI.	55	M.	18	Chronic bronchitis. Hypertrophy of heart, with mitral insufficiency; anasarca of lower half of body, with ascites; great congestion of internal organs. Dura mater very adherent to calvaria anteriorly; *extreme congestion of these parts as well as of brain;* slight opacity of arachnoid on either side of middle line; very slight increase of sub-arachnoid fluid.	R. *a.* 1·031 *b.* 1·031 *c.* 1·033 L. *a.* 1·031 *b.* 1·031 *c.* 1·035	R. 1·041 L. 1·041	1·035	R. *a.* 1·035 *b.* — L. *a.* 1·035 *b.* —	R. 1·045 L. 1·045	R. 1·041 L. 1·041	1·045	1·039
XXII.	60	M.	50	Heart and renal disease; general anasarca. Slight thickening and opacity of arachnoid. *Anæmic condition of brain.*	R. *a.* 1·029 *b.* 1·031 *c.* 1·031 L. *a.* 1·029 *b* 1·031 *c.* 1·033	R. 1·039 L. 1·039	1·031	R. *a.* 1·033 *b.* 1·043 L. *a.* 1·033 *b.* 1·043	R. 1·043 L. 1·043	R. 1·043 L. 1·043	1·043	1·035
XXIII.	60	F.	28	During life paralysis of left side of body and right side of face. Cancer of uterus; small cysts in ovaries; atrophy of heart.								

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cere-bellum.	Pons.	Medulla.
XXIII. *continued*				Much fluid beneath arachnoid, with great thickening and opacity of the membrane; medium vascularity of brain; pulpy softening of some of occipital convolutions on left side, some more extensive on right; remains of an old clot (tolerably firm, and of a dirty, reddish-brown colour) in white matter below, and slightly posterior to inner side of right optic thalamus; white matter much softened in neighbourhood, and also more slightly in anterior portions of same hemisphere.	R. *a.* 1·033 *b.* 1·033 *c.* 1·026 to 1·029 L. *a.* 1·033 *b.* 1·033 *c.* 1·029 to 1·035	R. 1·031 to 1·034 L. 1·041	1·032	R. *a.* 1·037 *b.* 1·043 L. *a.* 1·037 *b.* 1·043	R. 1·043 L. 1·043	R. 1·041 L. 1·041 W. 1·041	1·045	1·038
XXIV.	64	M.	27	A drunkard; delirium tremens with bronchitis and right pleurisy; thickening and opacity of arachnoid.	R. *a.* 1·027 *b.* 1·029 *c.* 1·031 L. *a.* 1·027 *b.* 1·029 *c.* 1·031	R. 1·041 L. 1·041	1·029	R. *a.* 1·035 *b.* 1·041 L. *a.* 1·035 *b.* 1·041	R. 1·043 L. 1·043	R. 1·039 L. 1·039 W. 1·043	1·041	1·036
XXV.	64	M.	18	Phthisis; resection of bones of left tarsus; gradually sank after operation. Skull-cap thick; thickening and opacity of arachnoid; ventricles filled with fluid.	R. *a.* 1·027 *b.* 1·027 *c.* 1·031 L. *a.* 1·027 *b.* 1·029 *c.* 1·031	R. 1·039 L. 1·039	1·025	R. *a.* 1·031 *b.* 1·041 L. *a.* 1·031 *b.* 1·041	R. 1·043 L. 1·043	R. 1·035 L. 1·035 W. 1·039	1·044	1·035

XXVI.	65	M.	24	Right facial paralysis and right hemiplegia of four days' duration. Great opacity of arachnoid, with considerable increase of sub-arachnoid fluid. No naked eye appearances accounting for hemiplegia.	R. *a*. 1·025 *b*. 1·029 *c*. 1·030 L. *a* 1·027 *b*. 1·029 *c*. 1·029	R. 1·038 to 1·039 L. 1·035	1·025	R. *a*. 1·035 *b*. 1·041 L. *a*. 1·035 *b*. 1·041	R. 1·039 to 1·041 L. 1·039	R. 1·035 L. 1·035	1·040	1·035
XXVII.	68	M.	24	Chronic bronchitis; hypertrophy and dilatation of heart, with considerable disease of aortic valves. Anasarca of lower half of body. Skull-cap thin; dura very adherent anteriorly; thickening and opacity of arachnoid, with slight increase of fluid beneath.	R. *b*. 1·029 L. *b*. 1·029	R. 1·037 L. 1·037	—	R. *a*. 1·029 L. *a*. 1·029	—	R. 1·041 L. 1·041	—	—
XXVIII.	70	M.	30	Cancer of œsophagus opening into bronchus. Medium vascularity of brain.	R. *a*. 1·029 *b*. 1·029 *c*. 1·034 L. *a*. 1·030 *b*. 1·030 *c*. 1·034	R. 1·042 L. 1·042	1·033	R. *a*. 1·033 *b*. 1·043 L. *a*. 1·033 *b*. 1·043	R. 1·043 L. 1·043	R. 1·037 L. 1·037 W. 1·041	1·043	1·037
XXIX.	73	M.	24	Anasarca of lower half of body; granular degeneration of kidneys; hypertrophy of left ventricle of heart, but no notable valvular disease; extreme congestion of lungs. Carcinomatous ulceration of stomach (early stage). *Congestion of brain;* thickening and opacity of arachnoid, with increase of sub-arachnoid fluid.	R. *a*. 1·029 *b*. 1·027 *c*. 1·027 L. *a*. 1·029 *b*. 1·029 *c*. 1·029	R. 1·039 L. 1·039	1·029	R. *a*. 1·031 *b*. 1·041 L. *a*. 1·031 *b*. 1·041	R. 1·043 L. 1·043	R. 1·040 L. 1·040 W. 1·040	1·043	1·035

Specific Gravity of different parts of the Brain of Insane Individuals.

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cere-bellum.	Pons.	Medulla.
XXX.	36	M.	36	Chronic mania, with delusions; phthisis; large cavity in right lung, and recent pleurisy on right side. Slight opacity of arachnoid on either side of longitudinal sinus, with slight increase of fluid beneath. Brain substance of medium vascularity, very firm and consistent.	R. *b.* 1·037 L. *b.* 1·037	R. 1·042 L. 1·042	—	—	R. 1·042 L. 1·042	R. 1·038 L. 1·038	—	—
XXXI.	38	F.	16	Melancholia of three and a half months' duration; delusions and hallucinations; suicidal tendencies (several attempts). Suffocated herself by stuffing a large piece of linen into pharynx, where it was found after death covering top of larynx. *Congestion of brain;* arachnoid normal; no increase of fluid beneath; three symmetrical patches of softening in each corpus striatum, the largest about $\frac{1}{3}$″ in diameter in *nucleus lenticularis*, two upper about size of peas, in *nuc. caudatus* on each side. No trace of paralysis during life.	R. *a.* — *b.* 1·031-2 *c.* 1·031 L. *a.* 1·032 *b.* 1·031-2 *c.* 1·032	R. 1·039 L. 1·039	1·032	R. *a.* 1·039 L. *a.* 1·039 Deep softened portion 1·031	R. 1·039 L. 1·039	R. 1·039 L. 1·039	1·041	1·038

XXXII.	39	F.	50	Chronic mania; weak minded, and rather incoherent; no constant or well-marked delusions. Phthisis; tubercular ulceration of intestine; peritonitis; skull-cap thick; arachnoid normal; brain anæmic.	R. *b.* 1·030 L. *b.* 1·031	R. 1·041 L. 1·042	1·029	R. *a.* 1·033 L. *a.* 1·033	R. 1·041 L. 1·041	R. 1·039 L. 1·039	1·043	—	—
XXXIII.	44	M.	23	Chronic mania; very incoherent; delusions numerous, but not constant; diarrhœa; anæmia; body much emaciated; great accumulation of foreign bodies in rectum. Arachnoid thickened and opaque over the whole of vertex, with increase of sub-arachnoid flnid.	R. *b.* 1·034 L. *b.* 1·034	R. 1·042 L. 1·042	1·029	R. *a.* 1·037 L. *a.* 1·037	R. 1·040 L. 1·040	R. 1·039 L. 1·039	1·045	—	—
XXXIV.	44	M.	30	Epilepsy, with chronic mania; very excitable, and destructive at times of fits. Turned on face, and was suffocated during a fit. *Extreme congestion of brain* and organs of body generally; slight opacity of arachnoid; no notable increase of sub-arachnoid fluid.	R. *a.* 1·031 *b.* — *c.* 1·036 L. *a.* 1·031 *b.* — *c.* 1·036	R. 1·042 L. 1·042	1·035	R. *a.* 1·037 L. *a.* 1·037	R. 1·045 L. 1·045	R. 1·044 L. 1·044	1·045	—	—
XXXV.	49	F.	26	Chronic mania; no well-marked delusions. Chronic pleurisy; anasarca; ascites; pulmonary apoplexy (circumscribed). Skull-cap thickened; sutures obliterated; arachnoid slightly opaque anteriorly; considerable increase of sub-arachnoid fluid. Local atrophy of convolutions; sharp bony spicules in middle fossa of base of skull.	R. *b.* 1·034 L. *b.* 1·034	R. 1·038 L. 1·038	1·037	R. *a.* 1·034 L. *a.* 1·034	R. 1·041 L. 1·041	R. 1·038 L. 1·038	—	—	—

No. of Case.	Age.	Sex.	No. of Hours between Death and Autopsy.	Nature of Illness and Pathological States met with after Death.	Gray Matter.	White Matter.	Fornix.	Corpora Striata.	Opt. Thalami.	Cerebellum.	Pons.	Medulla.
XXXVI.	52	M.	16	Chronic mania, with delusions; amyloid disease of kidney; hypertrophy and dilatation of heart; slight disease of aortic valves; extreme anæmia; anasarca. Dura very adherent; thickening and opacity of arachnoid; great increase of sub-arachnoid fluid; ventricles filled with fluid. *Brain extremely anæmic.*	R. *a.* 1·033 *b.* — *c.* 1·035 L. *a.* 1·033 *b.* — *c.* 1·035	R. 1·042 L. 1·042	1·032	R. *a.* 1·039 L. *a.* 1·039	R. 1·043 L. 1·043	R. 1·041 L. 1·041	1·043	—
XXXVII.	57	M.	16	General paralysis, last stage; phthisis; gangrenous cavities in both lungs; recent pleurisy; body extremely emaciated; thickening and opacity of arachnoid over vertex, and also in lateral regions; very great increase of sub-arachnoid fluid; membrane here and there rather adherent to convolutions, which were flattened and pressed together; diminished consistence of cerebral matter generally, and decided softening of white matter of nearly the whole of left hemisphere; slight atheroma of vessels at base; ventricles greatly distended with fluid. During life frequent convulsive attacks; right side always principally affected.	R. *a.* 1·029 *b.* 1·029 *c.* 1·031 L. *a.* 1·029 *b.* 1·031 *c.* 1·034	R. 1·039 L. Ant. and mid. portion 1·026 to 1·033 post. 1·039	1·026	R. *a.* 1·035 L. *a.* 1·035	R. 1·043 L. 1·043	R. 1·039 L. 1·035	1·043	1·041

XXXVIII	65	M.	32	Chronic mania, with complete incoherency. Central pneumonia, with a gangrenous cavity in right lung; slight recent pleurisy. *Brain much congested;* dura abnormally adherent anteriorly; extreme thickening and opacity of arachnoid on either side of middle line; considerable increase of sub-arachnoid fluid; membranes stripped freely from convolutions; increase of fluid in ventricles; fornix almost diffluent.	R. *a.* 1·029 *b.* 1·031 *c.* 1·029 to 1·030 L. *a.* 1·029 *b.* 1·031 *c.* 1·031 to 1·032	R. 1·041 L. 1·041	1·027	R. *a.* 1·033 L. *a.* 1·033	R. 1·043 L. 1·043	R. 1·040 L. 1·040	1·043	1·039
XXXIX.	70	M.	26	Chronic mania, with delusions; extensive pneumonia of right lung; long continued diarrhœa; slight recent pleurisy and peritonitis; medium vascularity of brain; arachnoid much thickened and opaque, adherent to dura in some parts anteriorly; portions of gray matter removed, with membranes from anterior convolutions; sub-arachnoid fluid small in quantity; ventricles filled with fluid.	R. *b.* 1·034 L. *b.* 1·034	R. 1·038 L. 1·038	1·024	R. *a.* 1·034 L. *a.* 1·034	R. 1·044 L. 1·044	R. 1·038 L. 1·038	1·044	—
XL.	83	F.	26	Chronic mania and senile dementia: diarrhœa; *great congestion of brain;* general opacity of arachnoid, especially over middle and post. lobes, slight increase of fluid beneath; convolutions, not much wasted; membranes stripped off easily; ventricles filled with fluid.	R. *b.* 1·033 L. *b.* 1·033	R. 1·041 L. 1·041	1·031	R. *a.* 1·033 L. *a.* 1·033	R. 1·043 L. 1·043	R. 1·041 L. 1·041	1·041	—

ANALYSIS OF TABLES.

A mere glance at the tables will show remarkable variations, not only in the specific gravities of the several parts in each brain, but also in the amount of relative variation in the specific gravities of the several parts, when different brains are compared with one another. The number of cases examined by myself is as yet too small to justify my attempting to make anything like an elaborate analysis of results at present, and, therefore, I shall content myself with pointing out, under each head, a few of what appear to be the most constant and noteworthy facts observed, as well as comparing the results of others, so far as they have gone, with my own. The observations on the specific gravity of the gray matter will, however, require to be entered into pretty fully.

Gray Matter.

Sane.—Some of the most interesting facts that I have ascertained from my experiments upon the specific gravity of the different parts of the brain are:—that the gray matter of the convolutions has not a uniform density throughout; that its average specific weight is less on the upper frontal convolutions than it is on the ascending parietal convolutions, and less here than it is on the upper occipital convolutions; that the amount of difference between the convolutions on the same side is more constant than the amount of variation found to exist between the specific gravities of corresponding convolutions on the two sides of the brain; that, as far as observations have yet gone, the convolutions on the left side of the brain appear very frequently to have a higher specific gravity than those of the right; and also that these variations in specific gravity seem to depend very slightly, if at all, upon differences in amount of congestion or quantity of blood in the part, but rather to be dependent upon some intrinsic differences in the intimate structure of the gray matter itself in these various regions. The evidence on which these conclusions rest will be found in the following results, obtained from an analysis of the numbers recorded in the tables.

Averages and Extremes
of
Gray Matter.

Left Hemisphere	1·026 **1·0291** 1·035	Frontal	1·025 **1·0276** 1·035	Right Hemisphere.
	1·027 **1·0300** 1·035	Parietal	1·027 **1·0296** 1·035	
	1·029 **1·0320** 1·037	Occipital	1·029 **1·0316** 1·037	

The above table seems at once to reveal two principal facts:—(*a*), that the specific gravity of the gray matter differs in various regions of the cerebrum; and (*b*), that the average specific gravity in all three regions is higher on the left than the right side.

a.—On both sides of the brain, gray matter of the lowest average specific gravity is met with when taken from the upper frontal convolutions, whilst it is a little higher with gray matter from the ascending parietal, and higher still from the upper occipital convolutions. The average increment of increase is exactly ·002 in each case, with the exception of that between the left frontal and parietal where it is less.

Although the *average* specific gravity of gray matter from the ascending parietal convolutions is intermediate between that of the frontal and occipital convolutions it is by no means always so in the individual cases, as a glance at the tables will show. In 27* cases its relations were as follows:

Parietal same as frontal.		Parietal intermediate.		Parietal same as occipital.	
Left side.	Right side.	Left side.	Right side.	Left side.	Right side.
12	13	6	8	9	6

Thus in nearly one half of the total number of cases the specific gravity of the parietal convolutions has been found—on one side or another—sometimes on both, the same as that of the frontal convolutions.

In two cases (xvi and xx) the specific gravity of the gray matter of the convolutions was the same not only in all these different regions of the brain, but also on the two sides, whilst in three other cases (iv, ix, xxix) there was this uniformity on one side

* Adding to the twenty-five Nos. I and II.

only. In four other cases (III, XV, XVII, XXIX) the specific gravity of the frontal gray matter was *less* on one side of the brain than that from the parietal convolutions of the same side. And lastly, in some cases the *amount* of difference between the gray matter of the frontal and occipital convolutions was very remarkable; in two cases (XIII and XIX) this difference on one side was as much as 0·1, and in another (XII) there was a difference on both sides of ·007.

It might perhaps be imagined that this different specific gravity of the gray matter from the three regions in question could be accounted for by varying amounts of blood in the tissues due to mechanical congestion, or gravitation of this fluid after death. But it does not seem to me that this will afford a sufficient explanation of the facts; and after a due consideration of the points to which I will now call attention, I am inclined to believe that this variation is rather dependent upon some intrinsic differences in histological structures and composition than upon the mere accident of amount of blood contained in the part. The points which have influenced me in forming this opinion are the following:—that we find there are great differences in the specific gravity of gray matter generally, in different persons, which cannot be accounted for merely by differences in vascularity; that the kind and extent of variation, in specific gravity, met with in the same person, not only between the two sides but also on the same side of the cerebrum, seems opposed to this method of causation, for, as before stated, in just one half of the cases, the specific gravity of the frontal gray matter is found to coincide with that of the parietal, and, frequently, the specific gravities differ notably on the two sides of the brain, when no corresponding changes can be detected in the amount of congestion; and lastly, there is not that amount of concomitant variation met with which we should expect to find if degree of vascularity was the real cause of the difference.* For, in illustration of this latter point, we do not find that the greatest differences have been met with in cases of extreme congestion, and the greatest uniformity in those in which the brain has been anæmic. In the three cases cited above as those in which the greatest amount of difference was met with, in that in

* Since this was written, I have made two post-mortem examinations of persons who were laid in the *prone* instead of the supine position, almost immediately after death, and so allowed to remain during the interval of more than twenty-four hours intervening between the death and autopsy. Notwithstanding this reversal of important conditions, differences of a similar kind were met with between the specific gravity of the frontal and occipital gray matter. In these particular instances, in fact, the discrepancy happened to be very great, since in one case the specific gravity of the occipital gray matter exceeded that of the frontal by ·004, and in the other (a case of general paralysis) by as much as ·009.

This seems pretty conclusive evidence that the difference is for the most part independent of the degree of congestion, and due rather to histological structure, even were this not also rendered still more probable by recent observations of Mr. Lockhart Clarke. ('Proceed. of Roy. Soc.,' vol. xii (1863), p. 716.)

which this condition was most marked, there was only a medium state of vascularity, in another the brain was actually anæmic, whilst in the third (xix), though the brain was congested, the great increase in the specific gravity was met with only on one side, and even then only in some parts of the occipital convolution. Whilst an inspection of the results obtained from those cases in which the congestion was sufficiently pronounced to be noted (i, vi, ix, x, xv, xvi, xix, xxi, xxix), will not show that they were remarkable also for differences in the specific gravity of the gray matter—in four or five of them, indeed, it is quite the reverse, and in one especially (xvi), although the brain is noted as being "considerably congested," an uniform density of gray matter was found in all three situations, and on both hemispheres.*

There is one other condition which may well be supposed to exercise an influence upon the specific gravity of the gray matter, and that is the amount of sub-arachnoid fluid met with after death. Owing to the recumbent position of the body the occipital and parietal convolutions would be most frequently exposed to its influence, and the effects of contact most likely to be produced would be a diminution in the specific gravity of the gray matter of these parts from an absorption of a fluid specifically lighter than itself. Of course it is extremely difficult in any particular cases to say that such a change has been produced, because we can have no knowledge of what the density of the gray matter was before its exposure to this influence.† The cases in which I have noted a marked increase in the amount of this sub-arachnoid fluid are Nos. xxix, xx, xxvi, xi, xxiii; but they are too few to enable us to form any opinion upon this subject, and the evidence they afford cannot be said to point in any definite direction.

b.—An inspection of the table before given of the specific gravities of the gray matter shows, that in each region the average density is greater on the left than on the right hemisphere, and curiously enough, the amount of difference in the averages is almost the same in each region; thus, the average density of gray matter from the upper frontal convolution of the left side is heavier by ·0015 than of that from the right side, whilst, in both parietal and occipital convolutions, the excess in favour of left side is ·0014. Although the averages are higher on the left side, the specific gravity is only actually so in a certain proportion of individual brains; in the majority, indeed,

* I may again state here that in removing the gray matter from the occipital convolutions, it was always done with a knowledge of the fact of its lesser depth in this region, and that, accordingly, I always took extra care, and removed thinner slices in order to estimate its specific gravity in this situation.

† It may well be that during the life of the individual, and the active nutritive changes going on in the part, that no absorption may take place, whilst such an effect may follow after death when there is nothing to interfere with or modify the ordinary physical laws.

there is an equality between one or more regions of the two sides, whilst in a few cases (and more especially in the occipital region) the density has been greater on the right side. The following table, illustrating these points, shows the results of an analysis of twenty-seven cases:—

Regions.	Density greatest on right side.	Density greatest on left side.	Density equal on two sides.
Frontal	1	7	19
Parietal	2	12	13
Occipital	4	9	14

In one case (IV) all the specific gravities on the left side exceeded those on the right; in seven, all the numbers were respectively equal to one another on the two sides, but in no case did all the numbers of the right side exceed those of the left.

In connection with this higher average specific gravity of gray matter on the left side, it is well to bear in mind the fact that Dr. Boyd,* in his extensive investigations upon the weight of the cerebrum has almost invariably found the left hemisphere heavier, by about one eighth of an ounce, than the right.

Insane.—My observations have been so few and incomplete on this subject, that I have little to say concerning it. So far as they have gone, however, they seem to bear out the conclusions of Skae and Bucknill, that the specific gravity of the gray matter is higher in the insane than in the sane. It will be interesting, hereafter, to see the results of an investigation of the specific gravity of the gray matter in the insane, when taken from different regions, in a large number of cases.

In the eleven cases which I have yet examined, I have found the mean specific gravity of gray matter from the parietal convolutions to be 1·0325, the extremes being 1·029 and 1·037.

Comparison of Method and Results of Preceding Observers with my own.

The great discrepancies between the results arrived at by previous observers and myself, as to the specific gravity of gray matter in both sane and insane, make it desirable that some definite statements should be made concerning our respective methods.

* 'Philos. Trans.,' 1861, and 'Med.-Chir. Trans.,' vol. xxxix.

It does not appear that either Sankey, Skae, or Bucknill were very particular as to the precise convolutions from which they selected gray matter for examination. In reply to a question on this subject, Dr. Sankey writes: "I generally (I believe I may say always) took the cerebral substance from the part opposite the parietal protuberance." Dr. Skae answers, "I regret to state that I made no distinction, as to the particular part of the brain from which I selected portions in order to ascertain the specific gravity of the gray matter. Nor did I restrict myself to any particular thickness of the portion taken;" whilst, as Dr. Bucknill made no reply to this particular query, I can only presume that it was not a point to which he particularly attended. The fairest way will be, therefore, to compare the mean results which I have obtained from an examination of the gray matter of the *parietal* convolutions with those obtained by other observers. These results I will now place side by side.

	Sane.	Insane.
Sankey	1·028 **1·0346*** 1·046	
Skae		1·030 **1·0391** 1·049
Bucknill		1·030 **1·037** 1·048
Bastian	1·027 **1·0300**† 1·035	1·029 **1·0325** 1·037

An examination of these numbers will show that mine, both for sane and insane, are between five and six degrees lower than those of other observers, and after careful inquiries on this subject, I think that these discrepancies may be accounted for, for the most part, from a difference in our method of operating, though to a less extent owing to differences in the relative proportions of acute and chronic cases examined.

With regard to method, Dr. Skae states, as we have just seen, that he restricted himself to no particular depth of the gray matter taken for examination; Dr. Bucknill writes, "I always took the

* There seems reason to believe that this is not the correct average of the seventy-three cases in which Dr. Sankey investigated the specific gravity of the gray matter—there must either have been a misprint, or some slight mistake made in estimating the average. At p. 242 (Brit. and For. Rev., 1853) he states the average of gray matter in the thirty-six males to have been 1·0353, and of the thirty-seven females 1·0349. The mean of these two numbers would give 1·0351 as the general average, and an examination of his table (1), p. 250, also makes it probable that this is the more correct average.

† These numbers refer to the left side; the average on the right is even lower, being 1·0296.

whole thickness of the gray substance, shaving it, with a sharp thin knife, from the cerebral convolution;" whilst Dr. Sankey says, "I usually slice off a long strip from the top of a convolution, and divide it into pieces for the experiment." The method which I adopted was this:—having stripped off the membranes from the particular convolution that I was about to examine, I carefully sliced off with a sharp knife a *small*, somewhat elliptical portion of gray matter from the surface of the convolution, taking particular care not to include the deepest layers of the gray matter, so as to do away with every possible chance of including even the slightest admixture of white substance. From transverse sections of the convolution afterwards made at the spot, I have ascertained that my slices, at the farthest, penetrate as far as the upper two thirds of the depth of the gray matter, and sometimes have been even rather less in depth than this. A short time since, as soon as I became aware of the exact method adopted by Dr. Bucknill, I procured a brain, in order to make some comparative experiments upon the specific gravity of its gray matter by our respective methods. I found that it was only by the exercise of the very greatest caution that I could accurately separate the whole of the gray matter from the white without including some small portion of this latter substance, and that, too, when I had operated under the most favorable conditions, by cutting a portion of a separated convolution in such a manner as to leave only a small cubical or rectangular piece of gray matter to be shaved off from the white substance—the brain fragment at the time lying on a smooth, flat surface. I always examined the surface of the gray matter, and frequently found some minute laminæ of white substance at one or other corner of the section which had been removed with the gray matter. Of course, if one attempted to slice off the whole of the gray matter from the convolutions still *in situ*, this would be a matter of still greater difficulty, since we could not so accurately lay the edge of the knife upon the line of junction of the two substances as we are able to do with small separated fragments of brain.* When, however, cubical fragments consisting of nothing but gray matter, and including its whole depth, were taken for examination, I almost invariably found that the specific gravity of such a portion was ·004 higher than that of a portion taken, as I have been in the habit of doing, from a contiguous portion of the

* In ascertaining the specific gravity of the gray matter by taking portions including its whole depth, to ensure accurate results capable of comparison with others, it is absolutely necessary that the gray matter should be cut off in little cubical blocks, or of some symmetrical form, so as in all cases to take the same superficial area of surface and deep strata. A portion removed from a convolution *in situ*, with shelving edges, would necessarily include an undue proportion of the specifically lighter superficial strata. Seeing that the difference between these upper and lower strata is as much as ·004, inattention to this point would considerably modify the correctness of the results.

same convolution. If even a minute portion of white substance had been removed with the total thickness of gray matter, this difference was still further increased. As on former occasions, I had no difficulty in obtaining uniform results, with any number of small pieces, removed by my method from the same convolutions. So that it would appear that there are no particular differences in the density of the upper strata of gray matter, although that of the lowest strata is considerably higher, owing, probably, to the large intermixture of tubular fibres entering them perpendicularly from the central white substance of the cerebrum.

In the brains of both sane and insane persons I have found the specific gravity of the gray matter from the parietal convolutions varying, at the most, only by a difference of ·008, whilst Drs. Bucknill, Sankey, and Skae have each found a difference of ·018 between their highest and lowest specific gravities of gray matter. Seeing that my minimum coincides almost exactly with theirs, I think that their high numbers must be due, in great part at least, to their having included, in these cases, the deepest as well as the more superficial portions of gray matter, and I cannot help thinking that the very great difference between their maxima and minima may be accounted for to a certain extent by differences in the thickness of gray matter taken for examination in the various cases.

Another reason of some importance accounting for the differences in our observations, is the fact that, amongst Dr. Sankey's cases, a larger proportion were acute, dying with cerebral symptoms, than existed in the number that I examined. And in these cases he has almost invariably found a higher specific gravity of the gray matter. It must be borne in mind, also, that the great bulk of his observations were made upon the brains of persons who had died from typhus or typhoid fever, one of the tendencies of both of which diseases seems also to be the production of a high specific gravity of the cerebral substance. In the insane cases of Bucknill and Skae, also, there were a certain number who died in the acute stages of their cerebral disease, whilst the few that I have as yet examined were all chronic cases.

White Matter.

We meet with far greater uniformity of results when we compare the observations of different investigators, upon the specific gravity of the white matter of the cerebrum, as may be seen by the numbers given below.

	Sane.	Insane.
Sankey	1·032 **1·0412** 1·048	
Bucknill	1·033 **1·039** 1·046	
Skae	1·034 **1·0424** 1·053	
Bastian	1·031 **1·0404** 1·043	1·026 **1·0405** 1·042

The average specific gravity of the white substance of the cerebral hemispheres seems to correspond pretty closely, in both sane and insane brains. The very low numbers correspond, in my own observations, with portions of brain-substance which were obviously in a condition of *ramolissement,* or white softening (III, XXIII, XXXVII), and I have no doubt this was also found to be the case by the other observers. It is only when the specific gravity of the gray matter sinks below 1·035, that the softening becomes very obvious to the unaided senses. In No. XXVI, where there had been right hemiplegia of four days' duration, a sinking of the specific gravity of the white substance of the opposite hemisphere to 1·035 was recognised by means of the specific gravity apparatus, though no appreciable softening had been detected at the ordinary post-mortem examination. The *prevailing* specific gravities of the white substance of the cerebrum, are 1·039, 1·040, or 1·041, and the very high numbers reported by Sankey, Skae, and Bucknill, have mostly been met with in acute cases, and doubtless were obtained from portions of brain in a distinctly indurated condition.

In no instance have I found the specific gravity of the gray matter higher than that of the white in the same brain, and in one case only have I met with it of the same specific gravity. In this case (XIII), in which the death was sudden, and the cause rather obscure, the occipital gray matter on the left side, and the white substance of both hemispheres had each a specific gravity of 1·037; in this same case, also, the maximum difference between the specific gravity of frontal and occipital gray matter was met with.

The density of the white substance of the two hemispheres seems to be normally the same.

Fornix.

The specific gravity of the fornix, as originally indicated by Dr. Sankey, seems to be normally less than that of the white substance of the hemispheres. It varies much in its density in different individuals, and the numbers I have met with have been the following :—

Sane.	Insane.
1·025	1·024
1·032	**1·0302**
1·039	1·037

The highest specific gravity, 1·039, was found in a case of epilepsy (XVI), and the lowest in a case of chronic mania (XXXIX), the subject of which died at an advanced age from an exhausting disease, in a condition of extreme emaciation.

The specific gravity of the fornix seems to be generally lower in the insane than in the sane, and its density seems to be, to a certain extent, independent of the amount of fluid in the ventricles. Thus in Cases XXXIX, XL, so far similar, that both, being at an advanced age, and having the lateral ventricles "*filled with fluid*," were examined the same number of hours after death, still the specific gravity of the fornix in one was 1·024, and in the other 1·031.

Corpora Striata.

No observations have, I believe, been hitherto recorded concerning the specific gravities of the corpora striata apart from the optic thalami; and it was not till just at the commencement of my observations upon the specific gravity of the sane brain, that I became aware of the different densities of its intra- and extra-ventricular portions. In the insane cases, therefore, observations have only been made concerning the specific gravity of the intra-ventricular portions of these bodies, the pieces for examination being taken in the manner indicated at p. 475. The averages and extreme numbers met with, have been as follows:—

	Sane.	Insane.
a. Intra-ventrical portion ...	1·031	1·033
	1·0350	**1·0354**
	1·041	1·039
b. Extra-ventrical portion ...	1·039	
	1·0416	
	1·043	

The observations upon the insane have, as yet, been too incomplete and few in number to make a comparison of results derived from them, and from the sane respectively, of much value. So far as they have gone, however, there seems to be no particular difference in the two classes.

Normally, the corresponding parts of these bodies seem to be of the same specific gravity on the two sides of the brain. The *prevailing* specific gravities—in fact, those met with in one half of the sane cases, have been 1·035 for the intra-ventricular portions, and 1·041 for the deep extra-ventricular portions.*

* From some experiments which I have made, it would appear that the difference in density of these two portions depends to a great extent upon the different

This gives a difference of ·006, but in one fifth of the cases there has been a difference of ·01, whilst in two of the cases in which the maximum specific gravity (1·043) of the deep portion has been met with, that of the superficial portion has been as high as 1·041, therefore presenting a difference of only ·002. One of these cases (XV), was that of a drunkard, of middle age, who died from delirium tremens and pleuro-pneumonia; whilst the other (XX), was that of a female, æt. 55, who died of phthisis, but concerning whose habits there is no record.

In Case XXXI, a softened patch in the deep portion of the corpus striatum had a specific gravity of 1·031, which is about the same number as we have seen belongs to the softened white matter of the hemispheres.

There is no evidence at present to show whether the amount of ventricular fluid would have any influence upon the specific gravity of the superficial portions of the corpora striata, since in only one of the sane cases (XXV) were the lateral ventricles found filled with fluid. In this case, it is true, the minimum specific gravity was met with, but then in the same brain, some of the other numbers were unusually low. And although amongst the insane in each of the five cases XXXVI—XL, inclusive, the ventricles were filled with fluid, and at the same time presented the ordinary specific gravities of these parts—in one case, indeed, notably above the average—still, since from the data before us, we cannot be said to know what is the ordinary specific weight of these bodies in the insane, it may possibly be that they are usually denser in them than in sane individuals, and that the numbers in the above cases represent only their specific gravity, after this has been lowered by an absorption of ventricular fluid.

Optic Thalami.

As with the corpora striata, there has not been, hitherto, any separate estimation of the specific gravities of the optic thalami.

amounts of fluid which respectively enter into their composition. Thus, a slice about ¼″ thick of a corpus striatum, including both superficial and deep portions, having been exposed on a tray for two hours to the influence of the atmosphere at a temperature of 71° Fahr. (20¾° C.), whilst another similar portion was immersed in water for the same time, the alterations in density were these—

Before experiment.	After experiment. (Air.)	After experiment. (Water.)
a. 1·035	*a.* 1·043	*a.* 1·029
b. 1·043	*b.* 1·047	*b.* 1·031

Thus, the superficial portion increased in density twice as much as the deep by evaporation from exposure to the atmosphere, whilst by immersion in water the deep portion diminished in density twice as much as the superficial owing to an increased absorption of fluid. Of course, a part of this lowering of the specific gravity with both portions may have been due to an exosmosis of saline matter.

The averages and extremes of specific gravity of these bodies found by myself in sane and insane, are as follows :—

Sane	Insane.
1·039	1·039
1·0422	**1·044**
1·045	1·045

The extremes are seen to be the same in both classes, though the average is higher in the insane; the number of cases is, however, too small to justify us in coming to any positive conclusion with regard to their proportionate density in the two classes.

The *prevailing* number in the sane is 1·043, this being met with in fifteen out of the twenty-five cases. The minimum number was met with several times, but the maximum only once, and that in a drunkard (xv), who died of delirium tremens and pleuro-pneumonia. The same high number was met with amongst the insane in a case of epilepsy (xxxiv), and both, being men of the same age, presented also a rather high specific gravity of the fornix.

Normally, the specific gravities of these bodies seems to be the same on the two sides of the brain. In three cases only has a slight difference been met with in this respect.

Of the six cases in which the specific gravity of the corpus striatum and optic thalamus, taken together, was estimated on each side by Professor Aitken, in the brains of sane individuals, there was one notable case of chorea, in which the specific gravity of these bodies on the left side was 1·031, and on the right only 1·025. The difference is remarkable, but in addition to that, even the highest of these numbers is very considerably below the average, and in fact corresponds to what I have met with as the specific gravity of a softened patch of the corpus striatum, and of the white matter of the cerebral hemispheres, when a notable degree of *ramolissement* has taken place. In two other cases, the specific gravities were unusually high on both sides. The one in which the numbers were highest was a case of typhus fever, the man having died on the twenty-first day of the disease. In this case, the specific gravity of the cerebrum and the cerebellum were also very high, and so far this is in harmony with the fact, that, in two cases of this disease, Dr. Sankey found the specific gravity of the white matter of the cerebrum remarkably high.*

Cerebellum.

The specific gravity of the cerebellum has frequently been made a subject of investigation, as may be seen by reference to the table at p. 471. Dr. Bucknill has directed his attention to the specific gravity of the whole organ in the insane, and Drs. Aitken and

* Loc. cit., p. 254.

Peacock to the same in the sane. There is, however, the objection to the method employed by Dr. Bucknill and Dr. Aitken, that they did not strictly ascertain the specific gravity of the whole organ, but of parts including both gray and white substance, which they considered representative. This objection, however, has not nearly so much force in the case of the cerebellum, as it has in that of the cerebrum, owing to the identity, or slight difference only, in the separate specific gravities of the gray and white substance in the former organ. Dr. Skae's observations, of a more analytical kind, made upon the separate specific gravities of the gray and white substance in both sane and insane, are the only ones with which I can compare my own observations. Unfortunately, however, I did not ascertain the specific gravity of the white matter in any of my insane cases, and in only about three-fifths of the brains of sane persons. Our results were as follows :—

Observers.	Sane.			Insane.		
	No. of cases.	Gray.	White.	No. of cases.	Gray.	White.
Skae	5	**1·042**	**1·0433**	27	1·036 **1·040** 1·044	1·0430 **1·0438** 1·0444
Bastian	25	1·035 **1·0395** 1·043	1·037 **1·0399** 1·043	11	1·038 **1·0396** 1·044	

These numbers are too small to draw anything like satisfactory conclusions from, but so far as they go, Dr. Skae's figures show a greater discrepancy between the specific gravity of the gray and white matter of the cerebellum in the insane than in the sane, with an absolutely less specific gravity of the gray matter in the former than in the latter. His numbers are also, as with the cerebrum, all higher than mine. A comparison of my own numbers, shows even a closer approximation between the specific gravity of the gray and the white matter in the sane than in Dr. Skae's observations, whilst the specific gravity of the gray matter in the insane is almost equal to that of the sane in mine, rather than less, as in Dr. Skae's cases. Whether the same discrepancy would have been met with between the white and gray matter of the cerebellum in my insane cases, as was found by Dr. Skae, I am unfortunately unable to say. Taking into consideration, therefore, these results of Dr. Skae and myself, from an examination of the white and gray matter separately, in conjunction with the results of the examination of the whole cerebellum, as given in the table at p. 471, it does not appear that as yet we have evidence to show that any definite difference exists between

the specific gravity of the cerebellum in the sane and the insane, and that therefore we must look upon the conclusion of Dr. Skae, "that the specific gravity of the cerebellum is increased in insanity," as one which more recent observations have shown to have no sufficient foundation.

An examination of my sane cases will show that in ten out of the sixteen in which the specific gravity of the white matter was estimated, this was found to be precisely the same as that of the gray, whilst of the six remaining cases, it was slightly less in two (xii, and xiii), and slightly higher in four (x, xxiv, xxv, xxviii).

This different proportion between the specific gravity of the gray and white matter in the cerebrum and cerebellum, respectively, is due to a change in the density of the gray matter, which is much greater in the cerebellum than in the cerebrum, whilst the specific gravity of the white matter is almost identical in both.

The minimum number for the specific gravity of the gray matter 1·035, has been met with three times (iii, xxv, xxvi), and the maximum number, 1·043, just as often (ix, xvi, xxii).

The specific gravity of the gray matter on the two sides of the cerebellum has always been found the same, with one exception—that being in a case of general paralysis.

Pons Varolii.

The specific gravity of the pons alone has not, I believe, hitherto been made the subject of investigation, therefore there are no numbers with which to compare my own results. The following are the averages and extreme numbers met with, from an examination of the brains of twenty-five sane, and of nine insane individuals :—

Sane.	Insane.
1·039	1·041
1·0424	**1·0444**
1·045	1·045

The average is slightly higher here in the insane than in the sane, but then the number of cases examined has been very small.

The *prevailing* specific gravity in both sane and insane, is 1·043; this number was met with in 13 of the 25 cases in the former category, and in 4 out of the 9 belonging to the latter. The maximum numbers have been the same in each class. The minimum number of the sane, 1·039, has been met with only in two cases (vii, xiii).

The average specific gravity of the pons seems higher than that of the white matter of the cerebellum, and corresponds almost exactly with that of the optic thalami, but, in individual brains, the actual numbers do not correspond in more than about one half of the total number of cases, whilst in the others they differ by ·001—·003, from one another.

In one brain of an insane man (XXXIII), the specific gravity of the pons was as much as ·005 higher than that of the optic thalami, and ·006 higher than that of the white matter of the cerebellum.

The pons varolii and optic thalami have a higher mean specific gravity than any other part of the encephalon.

Medulla Oblongata.

I have been able to find no record of the specific gravity of the medulla alone. From an examination of twenty-four sane cases, I obtained an average specific gravity for this portion of the encephalon, of 1·0360, the extremes being 1·035 and 1·039. As yet, I have only ascertained its specific gravity in the brains of three persons dying insane, and in these cases the numbers were 1·038, 1·039, and 1·041—the last being met with in a case of general paralysis (XXXVII).

The *prevailing* number met with in two thirds of the sane cases was 1·035.

Dr. Peacock's observations give 1·0403 as the mean specific gravity of the combined pons and medulla; but seeing that the specific gravities of these two parts differ so much from one another, and are liable to vary independently, it does not seem desirable that observations on their combined specific gravity should be continued.

Principal circumstances influencing the specific gravity of the different parts of the Encephalon.

This is a subject of the utmost difficulty, and could only be handled satisfactorily after the examination of a very large number of cases. The main difficulty arises from the fact, that we are unable to see the *uncomplicated* effects of almost any one possible cause of modification, because in every case in which the one condition, whose influence we wish to ascertain exists, it is almost sure to be complicated with one or more other conditions, each of which is in itself either a known or possible cause of change. How very difficult, if not impossible, therefore, is it to deduce trustworthy conclusions, from a limited series of cases, as to the influence of any one condition existing in all the numbers of this series, when, in each case, this condition in question is associated with one or more others (in all possible combinations) some of which may be more potent for the production of change even than that whose influence it is desired to ascertain; whilst these other potencies, whether superior or inferior, are acting sometimes with and sometimes against, the one in question. These, surely, are not the conditions for legitimate experimentation, and conclusions thus

derived must be received with the very greatest caution, as being little else than mere gropings in the dark. I shall, therefore, have little to say on this subject, and shall confine myself principally to an inquiry, as to how far my own observations would seem to bear out the conclusions of Dr. Sankey.

Influence of Sex.—My data are altogether too limited to permit me to say anything under this head, since in my twenty-five cases there were only five females.

Dr. Sankey thought his numbers tended to show "that there is a great similarity in the density of the white substance in the two sexes," and that, "while the mean density is slightly higher in males than in females, * * * * the most frequent density in females is higher than that which is most frequent in males."

Influence of Age.—Dr. Sankey thinks his table "appears to show that the density of the gray matter is highest between the ages of fifteen and thirty years in males, and twenty and thirty in females, or between twenty and thirty, sex not considered;" and also, "that there is very little variation in the density of the white matter at different ages."

No confirmation whatever of this conclusion concerning the gray matter is to be found from an inspection of my own cases (arranged in order of age); and from the fact of the numbers referring to the specific gravity of the gray matter of two children (I and II), each two years old, being nearly all of them above the averages obtained from other twenty-five cases, it would appear that even at this early age, when the brain is admitted by all observers to be in an immature condition, that the gray matter, nevertheless, has attained pretty nearly its mean density, unless we are to credit the diseases from which they had been suffering with an unusual amount of influence in raising the specific gravity of the gray matter. In only three out of the eight cases,* whose ages are included within this period of maximum density, are the specific gravities of the gray matter higher than those met with in the two very young children just alluded to; and in two of the remaining five cases, one a man, æt. twenty-four, dying in the third week of typhoid fever; and the other, a man of the same age, dying after a very short illness from the effects of a surgical operation, the numbers were actually lower than those found in the two children only two years old. It cannot be said either that an inspection of my cases seems to indicate any alteration of the specific gravity of the gray matter in old age. At all events, no approach to a regular increase or decrease is to be seen; and it would seem that the irregular variations met with must be dependent upon other causes more potential than simple variations in age. I think that at present, therefore, there is no evidence to show that age has a modi-

* And the total number of males and females examined by Dr. Sankey, between the ages of twenty and thirty, was only *nine*.

fying influence upon the specific gravity of the gray matter of the cerebrum.

Neither is there any evidence to be gathered from my list of cases tending to show that age has any influence whatever in modifying the specific gravity of other parts of the encephalon. The only fact which it seems desirable to call attention to, is, that in both of these children, only two years of age, the white matter of the cerebrum had a very low specific gravity, as well as the deep portions of the corpora striata, and, in one case also, the specific gravity of the medulla oblongata was below the average, whilst in both, the specific gravity of the gray matter and the pons was fully up to the average. Although the specific gravities of the optic thalami and cerebellum were below the average, still the same numbers that were found in these children have been met with in many adults.

Influence of Post-mortem Changes.—Dr. Sankey thinks it appears, from a table which he gives, "that the mean density of the gray matter is less the longer the post-mortem examination was deferred, while, with the white matter, no such effect is apparent;" and also that "there is a pretty regular decrease of density equal to about ·001 for every twenty-four hours that intervenes between the death and the autopsy." We must say, after due consideration, that Dr. Sankey's facts scarcely seem to warrant his conclusions.

He seems to have been influenced a good deal in drawing these conclusions from the fact that in six cases, in which the post-mortem examination was made in less than twelve hours after death, he found the *average* specific gravity greater by ·0036 than that obtained from twenty-six cases which were examined at periods a little less than twenty-four hours after death. But then he states that "of the six patients, the post-mortem examination of whom was made thus early, *two had severe cerebral symptoms*, two slight delirium, and two died sensible." Surely, at the very least, these first two cases should have been omitted from such a calculation; and, if this were done, the discrepancy would be much diminished, so that the fact of the average of four cases, made at a certain period after death, being slightly less than the average of twenty-six made at a certain other period, could have no real weight in determining the influence which the duration of time between the death and the autopsy exercises upon the specific gravity of the gray matter. And more especially is this so when out of these four cases the specific gravity in one was only 1·036, and in another 1·033 (actually a low specific gravity rather than a high one). Neither is there a regular decrease in the remaining three series, since whilst the average specific gravity of nine cases, examined at a mean period of twenty-nine hours after death, was 1·0340, that of nineteen cases, examined at a mean period of forty-four hours after death, instead of being less, as it should have been according to this view, was 1·0347. The "direct experiment,"

also, which Dr. Sankey introduces to show that the supposed diminution in density is due "to changes in the brain after death," appears to us to throw no light whatever upon the question. For how is it possible to judge from the change taking place in the gray matter of a portion of brain, which "was simply wrapped in paper during the time that elapsed between the first and second examination, and lay uncovered in the dead-house on a plate, between the second and third experiments—the weather being cold and wet," as to what would be the changes taking place in a brain still within the unopened cranium.

It appears to me, therefore, that there is no satisfactory evidence to show either what, or whether any, influence is exercised upon the specific gravity of the brain by the length of time intervening between death and the post-mortem examination.

Connection between absolute weight of brain and the specific gravity of its white and gray matter.—There seems to be no correspondence whatever between these conditions, and we can quite agree with Dr. Sankey in his conclusion that, "the heaviest brain neither has the lightest specific gravity, nor the contrary; nor has the lightest brain the lowest specific gravity of either white or gray matter."

Influence of the duration of the last illness on the specific gravity.—From an examination of one of his tables, Dr. Sankey is inclined to believe that there is "a general tendency in the gray matter to decrease in density as the length of the last illness increases, but the decrease proceeds much less rapidly after the seventh day than it appears to do up to that date." A consideration of the nature of the five cases, in which the examination took place before the seventh day, in conjunction with the fact that a *regular* diminution does not take place in the average specific gravities, given in Dr. Sankey's table, of the gray matter in persons dying after successively longer periods of illness, would of itself be sufficient to show the very unsatisfactory nature of the evidence upon which this conclusion is based. Dr. Sankey admits that the evidence is very slight, but still he seems disposed to attach more weight to it than might have been expected. He seems to think that "in active health the density of the gray matter is usually high," but this seems to be little else than a mere supposition, since it receives no neeessary support whatever from the fact that, in many cases of acute disease where the individual dies after a short illness, the specific gravity of the gray matter is found to be high. This high specific gravity may simply be a product of the acute disorder itself, so that it is just as likely that the antecedent specific gravity had been increased by the disease, as to suppose that there was no time to lower the initial high specific gravity of health owing to rapidity of death.

The influence of the nature of last illness, and of symptoms pre-

ceding death.—This is the influence which it appears to me Dr. Sankey has shown most conclusively to affect the specific gravity of both the gray and white matter of the cerebrum. His observations, as well as those of other observers upon the specific gravity of the brain in the insane, seem to show that in most cases of cerebral disease the specific gravity of the gray matter is above the mean, whilst with regard to the white substance, it may also be either above the mean, or greatly below it, the substance itself being, in the latter case, in a condition of white softening. Dr. Sankey's observations tend to show also that, in granular disease of the kidneys, the specific gravity of the gray matter is generally above the average, though it is not so much affected as it is by cerebral disease.

The mode of death also—whether leading to an anæmic, or a congested condition of the brain—seems to produce some effect upon the specific gravity of the gray matter, but I am inclined to think that this influence is less than it has been represented, and that such as it is, it is principally seen in a slight increase in the specific gravity of the gray matter, whilst it does not appear to affect that of the other parts of the encephalon.

What are the other conditions most influential in producing alterations upon the specific gravity of the brain, is a matter which may, perhaps, be determined in the future; certainly at present the variations met with in the specific gravity of corresponding parts in different brains can be accounted for only to a very slight extent; and, what is even more inexplicable still is, the amount of variation in the relative proportions between the specific gravities of the several parts of the same encephalon. How far some of these differences may be looked upon as mere individual peculiarities, and so far independent of all pathological change, is a question of the utmost interest, but one also upon which it is quite impossible to come to any conclusion at present. At all events, it seems highly desirable that the specific gravity of the different parts of the encephalon should be ascertained in as large a number of sane individuals as possible, so as to learn the kind and amount of variation which could be met with in the brains of persons displaying no anomalous mental symptoms—the amount of change, in fact, compatible with healthy mental action.

It is only after this has been done that we shall be able better to estimate the value of any particular deviation from the normal standard met with in the insane.

After what has been said in the earlier portion of this paper, it would appear almost needless to enforce the necessity of the most zealous attention to every detail tending to increase the accuracy of the results. The investigation is of such a delicate nature that unless it is conducted with a due attention to all the necessary pre-

cautions, the results would be quite valueless. It is of the utmost importance, also, in order that different workers may compare their observations, that they should each take the portions of cerebral substance as nearly as possible from the same situations. And since so large a share of the interest of these investigations attaches to the examination of the gray matter of the convolutions, it is above all things desirable that a uniform method should be adopted for the determination of its specific gravity. Although it would be more desirable, if it could be done with equal facility, and with an equal chance of uniformity, to ascertain the specific gravity of the whole depth of gray matter, still the dangers of error, and the sources of fallacy to be guarded against, are so much greater when this is done, that I think the method I have adopted of taking not more than the upper two thirds in depths to be the more desirable process. I shall continue to make my observations in this way, since in addition to the fact that it gives such a much smaller field for possible error, they can be effected with so much greater ease and rapidity, owing to the precautions necessary for ensuring accuracy being fewer and simpler. It is not likely that changes in the deep strata of the gray matter would be absolutely confined to this portion, and, therefore, its upper and middle strata may be almost as representative of the degree of change in the specific gravity of the gray matter, as if its whole depth were taken.

Estimations of the specific gravity of the different parts of the brain can, however, be considered as only the first steps towards a more thorough knowledge of the pathology of this organ. These investigations will serve to supply us only with the most convenient and trustworthy beacons, indicating the situations where pathological and histological changes are most likely to be found, but as to the nature of such changes this method can reveal little. Recourse must then be had to the aid of chemistry, and this again be supported and abetted by the microscope, in the hands of one who has already made himself thoroughly conversant with the healthy structure and appearances of the different portions of the encephalon. Investigations pursued in this triple method would surely be productive of good results. At all events, the pathology of the brain in the very many obscure forms of cerebral disease, has hitherto so effectually eluded all ordinary methods of research—inquiries into the nature of the changes have been so baffling and confusing—that it behoves us to deviate somewhat from the beaten path, and to bestir ourselves, calling to our aid, if need be, either new means or more effective combinations of old methods, that we may do our utmost to solve this riddle of the Sphinx, and so rid ourselves of an incubus and a cloud now darkening the fields of knowledge.

On the 1st of January, 1866, No. XX, New Series, price 2s. 6d.

THE JOURNAL OF MENTAL SCIENCE.

Published by authority of the Medico-Psychological Association. Edited by C. L. Robertson, M.D. Cantab., and Henry Maudsley, M.D. Lond.

CONTENTS.

John Churchill and Sons, New Burlington Street.