and whooping-cough would be followed by similar if not equal success?

At the beginning of the present year the compulsory Infectious Disease (Notification) Act has been adopted here as in most other places, resulting in a more complete knowledge of cases and increase of power for good in dealing with them. I am pleased to bear testimony to the general smoothness with which the Act works, owing to the nearly unexceptional loyalty with which the medical profession so honourably assists in carrying it out, and being for years a strenuous advocate of the measure, I am gratified to find that the social and professional objections to the Act, which always appeared to me to be of the weakest possible kind—unworthy of either the professional spirit or the intelligence of medical men—are proved to have had no foundation whatever. The distrust and friction between the practitioner and the medical officer of health, which were predicted, do not appear. The concealment of disease, which was to have happened, is equally absent, and on the contrary many more cases now are reported than before. The sacred confidence between patient and doctor, which was to have been destroyed with most disastrous results, remains inviolate, and so every theoretical objection which timidity, selfishness, or inexperience could find or invent has been refuted by practical experience.

One of the objections put forward, and which deserves special remark, was that notification would be useless in the absence of isolation hospitals. Without stopping to refute this assertion, which, however, would not be difficult, I may remark that notification to an authority of cases of infectious disease which ought to be isolated constitutes one of the strongest inducements to make provision of such hospitals. They follow as a natural consequence. The Birmingham infectious disease hospital has over 380 beds, and I think it is fair to conclude that every town should make similar provision in the proportion of at least one bed to every thousand of its population.

If asked what have been the principal agencies by which the past triumphs of preventive medicine have been achieved, there would be little hesitation in answering that the majority of the scourges which have afflicted mankind and been overcome have yielded to cleanliness. Ague and small-pox—possibly hydrophobia may soon be added to the list—have yielded to different and special influences, but the plague and the mediæval and early epidemics were banished by cleanliness. Typhus, thanks to the labours of Howard, was influenced by cleanliness as if by magic. Cholera, so fatal in its first visitations before its favouring conditions were understood, wrought terrible havoc where filth conditions prevailed. I am just old enough to remember the cholera epidemic of 1831-2 as it existed in the neighbouring town of Bilston more particularly, where it horrified and paralysed the population and surrounding towns by the alarming suddenness and extent of its devastations. From the different parts of the kingdom no fewer than 52,000 deaths were reported; they were not registered; for until 1837 there were no civil registration and vital statistics, so that the number of deaths stated was probably only an approximation to the truth. In the next visitation of cholera in 1849, over 52,000 deaths by cholera were registered, probably less than in the first visitation. The first public work I ever undertook was to attend during my studentship the victims of this particular epidemic in Birmingham; they were very few in number, and consisted mostly of imported cases; for in Birmingham cholera has never been able to establish itself. The next visitation was in 1854, when, with a purer state of towns, the number of deaths in England and Wales amounted to only about 20,000, for it had become known that filth of air and water and soil was the great promoter of this disease; and Dr. Snow had previously shown that sewage-polluted water, whether of rivers or wells, was one of the principal agents of its dissemination; and yet there are people living in this present year who object to the closure of wells whose water is proved to be polluted by sewage, more particularly when the wells are their own.

In the year 1866, the fourth visitation caused the smaller number of 14,378 deaths. Since then there have been several slight visitations, which were unable to make any permanent settlement in the country, or to cause any serious destruction of life. Greater cleanliness, that is, purer water, purer soil, purer air, appear to have changed the conditions which are necessary to constitute a *habitat* for the disease.

To a less extent, the occurrence of typhoid has become generally less common, and, though it does not appear that filth conditions give rise to the poisons of measles, whooping-cough, and scarlet

fever, there can be no doubt that they seriously aggravate their severity. And yet the old lesson of thousands of years ago is still unlearned. The sanitarian has still to go forth and try to teach that, without cleanliness, health is impossible, and that though much has been done in this direction, very much indeed still remains to be done. In order to effect the required amelioration, we must in the first place secure, as far as possible, cleanliness and purity of air, water, soil, and food. This is the object to which human effort has been directed more or less from the earliest historic times. The Jewish code of laws clearly provides for such conditions with a precision and detail which strike the modern mind as over-elaborate, while the Romans had a system of sanitation which, as regards its baths, its aqueducts, and its gymnasia, magnificent evidences of which, after more than 2,000 years, remain to bear witness of it, excites wonder and admiration. The fact that cleanliness and purity, so much inculcated and practised thousands of years ago, should have been almost entirely neglected in modern times, is not only incredible but for the indisputable proof of it, but is absolutely humiliating. After the fall of the Roman Empire, Europe lapsed into social conditions of filth which became habitual, and some religious orders actually inculcated it as a virtue. Not only have individuals to be taught, but sanitary authorities also require educating on this point. Much remains to be done in the direction of pure water supplies and the preservation of rivers from pollution; the air is still rendered filthy and injurious by overcrowding, want of ventilation, intra- or juxta-mural burial grounds, offensive trades, badly constructed or improperly managed sewers and drains, the keeping of animals near to dwellings, and conservancy systems of refuse disposal which, by retaining in the midst of the living what Nature distinctly tells us should be instantly removed, violate in the most direct and in the most offensive manner one of her greatest and most legible laws, with the inevitable result of exacting the payment of a frightful penalty for the infraction. The surface of the earth has to be rid of cesspools and surface filth of every kind, whether specific or non-specific, and the highest standard of purity aimed at with never-failing persistency. It is difficult to over-estimate the ultimate advantages of such a policy, but we are assured already by past experience that they must be very great to humanity, and will prove the truth of the old dictum that "cleanliness is next to Godliness."

AN ADDRESS

DELIVERED AT THE OPENING OF

THE SECTION OF ANATOMY AND PHYSIOLOGY.

At the Annual Meeting of the British Medical Association, held in Birmingham, July, 1890.

By D. J. CUNNINGHAM, M.D., F.R.C.S.I.,

Professor of Anatomy and Surgery, Trinity College, Dublin.

ON CEREBRAL ANATOMY.

Ontogeny and Phylogeny.—The Relation of Convolution to Body Weight.—Homogenetic and Homoplastic Agreements.—The Early Development of the Primate Brain.—The Brain of the Ape and of Man.—Annectant Gyri.—The Development of the Principle Fissures.—The Influences which Produce the Fissures and Convolutions.—The Blood Vessel Theory.—The Influence of "Pulsatory Concussions."—The Influence of the Form of the Head.—The Influence of Varying Rates of Growth.—Jelgersma's Theory.

BEFORE entering upon the subject-matter of my address, I think that it would be only right to congratulate Professor Windle and Professor Allen on having organised a Section of Anatomy and Physiology in connection with this meeting of the British Medical Association in Birmingham. The last few years have been unquestionably a time of marked activity in the domain of both of these subjects. Prior to the foundation of the Anatomical Society, a certain amount of lethargy had crept over anatomists. Individual work and good work was no doubt done, but there was no cohesion—no combined effort.

The Section which we now open I regard as an expression of

this renewed activity; and I am glad that physiology is associated with anatomy. Notwithstanding the many new and important developments of physiology, bringing it into close touch, on the one hand, with chemistry, and, on the other hand, with physics, the link which binds it to anatomy is not thereby lessened in its strength, and it must always be profitable for the workers in the two fields to meet on the same platform, and to discuss the problems which are engaging their thoughts from the functional as well as from the morphological standpoint.

I have selected as the subject of my address the field in which I have been most recently occupied, and to which my thoughts have been chiefly directed for the last two or three years. I refer to the fissures and convolutions of the cerebral hemispheres. It is, indeed, strange that this ground, apparently so limited and circumscribed, should still be capable of yielding rich results to anyone who devotes himself earnestly to the work. But such is, indeed, the case, notwithstanding the great advance that has been made in cerebral anatomy during the present century, and more especially during the last forty-five years.

It is true that we no longer look upon the cerebral convolutions as being disposed in an unmeaning disorder; we no longer compare them to the coils of the small intestine. The labours of Leuret, Gratiolet, and Broca in France, Huschka, Bischoff, and Ecker, in Germany, and Huxley, Turner, and Flower in this country have taken us many stages beyond this. The descriptive anatomy of the human cerebrum is now very nearly complete; what still remains to be done is the establishment of our knowledge upon a proper morphological basis.

In approaching the subject from the phylogenetic side, there is an overwhelming amount of material ready to hand. The brain of the ape is nearly as well known as that of man, and it has likewise been studied with an equal amount of care in almost every animal group.

Further, the facts acquired in this manner have been compared and checked by the evidence afforded by ontogeny, or by the study of the developing brain. It must be admitted, however, that in the case of the primate brain this evidence is somewhat one-sided. Little or nothing is known of the manner in which the fissures and convolutions appear in the foetal ape. In so far as the human brain is concerned, the material is very abundant, but the picture afforded is so variable, that very different interpretations may be arrived at by different observers. Certainly it cannot be too strongly insisted on that it is only from large numbers of developing brains in each stage of growth that correct and trustworthy information can be gathered; and seeing that the development of the permanent fissures is compressed into the last four months of intrauterine growth, there should be little difficulty in meeting this requirement.

The law that ontogeny is a brief recapitulation of phylogeny, or, in other words, that the germ-development is a compressed and shortened repetition of the stem-development, is a generalisation which is now within certain limits universally admitted, and what is true for the organism as a whole is also true for the various parts which build it up; but when we apply this rule to the study of the cerebral convolutions, we are met with the difficulty that the two lines of evidence in many cases yield us what appear to be contradictory results.

There is a general consensus of opinion amongst anatomists that the fissures and convolutions of the primate brain are arranged according to a pattern which can be compared with the arched fissures and convolutions of the carnivore brain, and yet it must be admitted that the ontogeny of the human brain affords us no assistance in our endeavours to detect in what particulars the carnivore pattern is repeated in the primate cerebrum. The ontogenetic and phylogenetic evidence are apparently at variance with each other; the whole chapter before the primate stage (if, indeed, such a chapter ever existed) is as it were entirely effaced, or at least so blurred and shortened, that it is impossible to recognise the any trace of it. Where, for instance, can we perceive the least degree of resemblance between the three radial "Primärfurche" of Bischoff and Pansch, so conspicuous in the human foetal brain, and the convolution type of the carnivora? Indeed, it is in the adult brain, and not in the foetal brain, that what correspondence there is can be most easily followed.

But are we sure that the phylogenetic chapter which we expect to be repeated in the ontogeny of the primate brain had ever really any existence? Are we right in trying to compare all convoluted brains with each other, seeing that an increase in the body weight of an animal produces a stronger development of the

furrows and convolutions without necessarily giving rise to a higher brain organisation? In some of the smaller forms of apes, for example, the brains are smooth, and yet on account of this we do not give them a lower place in the organic scale. Further, before we seek to detect homologies between the furrows and convolutions of two different animals, should we not in the first instance hold it as an essential that the animals under consideration be descended from a stem-form or common ancestor with a more or less convoluted brain? But this is not the case with the primates and the carnivora. These two groups have in all probability been derived from a stem-form with a smooth brain, and the furrows and convolutions in the brain of each are the product of an after-development. Might we not fairly ask whether the different convolution type in each is not the result of this? Jelligerson, of Meerenberg,¹ has recently advocated these views with great ability, and there cannot be a doubt but that a great deal can be said in support of them.

It appears to me, however, that the physiologist will have something to say on the other side. In a smooth cerebrum the same leading functional areas are doubtless present as in a convoluted cerebrum, and, although similarity of function is altogether inadmissible as a factor to be considered in the determination of homologies, it is not unlikely that these areas are really in a certain sense homologous in both. Later on, when I come to speak of the influences at work in producing the convolutions, I shall endeavour to show that they probably take origin by the outgrowth of areas of functional activity. If this be the case, there is every likelihood of a somewhat similar surface pattern of the brain being produced, even in animals whose only connection lies in a smooth-brained ancestor. Such convolutions and fissures cannot be regarded as homogenetic, because they have no genetic relation; but Professor Ray Lankester² has suggested a term which meets the requirements of the case. I refer to the word homoplastic, which "includes all cases of close resemblance of form which are not traceable to homogeny, all details of agreement not homogenous, in structures which are broadly homogenous, as well as in structures having no genetic affinity."

About the third month in the development of the primate brain, when the cerebral wall is little thicker than the skull capsule which encloses it, a rich series of transitory fissures make their appearance. In six weeks these furrows, with two, or it may be three, exceptions, are completely obliterated, and the cerebral

Fig. 1.—Outer surface of a cerebrum of a fetus between the third and fourth month of development. The transitory infoldings are well marked. All these disappear at a subsequent stage of growth and the cerebral surface becomes smooth.

Fig. 2.—Inner or mesial surface of a cerebrum of a fetus in the early part of the fourth month. Transitory infoldings and the complete permanent fissures are seen. h, Hippocampal fissure; c, calcarine fissure; p.o., parieto-occipital fissure.

surface again becomes smooth preparatory to the formation of the permanent sulci. For a short time I thought that it might be possible to establish a connection between these temporary fissures and the convolution type of the lower mammals, but in this I was completely deceived. They have an altogether different significance, and in all probability they are peculiar to the primate brain, in which they mark a distinctive and curious stage of growth.³

¹ *Morphologisches Jahrbuch*, June, 1889.

² "On the Use of the term Homology in Modern Zoology, and the Distinction between Homogenetic and Homoplastic Agreements," *Annals and Magazine of Natural History*, 1870.

³ "The Complete Fissures of the Human Cerebrum and their Significance in Connection with the Growth of the Hemisphere." By D. J. Cunningham *Journ. Anat. and Phys.*, vol. xxiv.

But to pass from the lower mammals, and to confine our attention to the primates, let us consider how far the convolution type of the ape's brain corresponds with that of man, and how far the differences which exist can be cleared up by the light which is thrown on the question by ontogeny.

Putting aside the great advance in the development of the lower part of the frontal lobes in the human brain, a development which leads to the complete formation of the speech centre, we find that all the principal fissures and convolutions in the primate brain show a more or less precise homology with each other. The differences which do exist are of a twofold nature—namely, (1) a greater richness of secondary furrows and convolutions in man, and (2) a marked tendency in the human cerebrum towards the breaking up of the principal fissures into two or more component parts by the formation of deep or superficial annectant gyri.

The secondary furrows of the human brain do not make their appearance until the last month of intrauterine development, and are only completed in the first month of infancy. This would seem to indicate that they are, comparatively speaking, a recent acquisition by the stem-form.

The disruption of the principal fissures, however, by annectant gyri shows itself in the earliest stages of the development of these sulci, and is therefore to be regarded as a deep-seated and important distinctive character of the human cerebrum. Such being the case, I may be allowed to develop this aspect of the subject a little more fully, and for this purpose we shall choose as examples two of the radial "Primärfurche," namely, the fissure of Rolando and the intraparietal sulcus of Turner.

If the lips of the fissure of Rolando be widely separated from each other a distinct deep annectant gyrus will in many cases be observed to cross its bottom, and thus partially cut off its upper third. In certain rare instances this gyrus has been observed to come to the surface and completely break up the fissure of Rolando into two portions. Such a condition, for example, was present in the cerebrum of the celebrated physician Fuchs. In no ape, with the exception of the chimpanzee, and to a less extent the orang, can this deep annectant gyrus be seen.⁴

But the intraparietal sulcus affords us a more striking example of the disruption of a primary fissure. In the ape this is a long continuous sharply-cut fissure, whilst in man it is broken up into two, three, or even four pieces by the development of deep, or in many cases superficial, gyri.

Wernicke⁵ held that these deep annectant gyri were peculiar to man, but this is not the case. Even in the baboon I have noticed one in the bottom of the intraparietal sulcus at the point where in man the ramus occipitalis becomes cut off; and in the chimpanzee one or even two are not infrequently found in the same fissure at points similar to those in which they are developed in the human brain.

I have said that this is a deep-rooted distinction between man and the man-like apes on the one hand, and the lower apes on the other hand, and one which is not bridged over by the condition present in the fetus. But upon this point it is impossible to speak too cautiously. As I have mentioned, we have little or no information regarding the manner of appearance of the fissures in the foetal ape, and it is naturally in the earlier conditions of the two forms that we would expect the greater degree of approximation. Still, anyone who studies closely the material at present at our disposal must come to the conclusion that the difference between the human and the ape brain, in so far as the primary fissures are concerned, is distinctly emphasised in the foetal condition, or, in other words, that the developing human brain is further removed in this respect from the ape type than that of the adult.

The more usual mode of development of the principal fissures of the human brain, and more particularly the intraparietal, is not in the form of a long continuous groove, or a groove which lengthens out from one or other or both ends, and in the bottom of which annectant gyri make their appearance later on, but in the form of distinct and isolated pieces. Indeed, it is not infrequent for the two most distant parts of a fissure to show first, and for the intermediate portions to develop later. All this has a most important bearing upon the development of the annectant gyri, which are so distinctive of the higher brain organisation. The bridges of brain cortex which intervene between the isolated portions of a developing fissure are ultimately borne down as the pieces run into each other; but they are not, as a rule, completely

obliterated. In the bottom of the fissure they still show as deep annectant gyri. In some cases, indeed, they prove an efficient barrier to the junction of two adjacent portions of a developing fissure, and then they form superficial gyri.

I do not say that this is the way in which these interrupting gyri invariably arise, although I believe it to be the chief and most important mode of development.

It is a dangerous thing to draw conclusions regarding development from the condition present in the adult; still I cannot help entertaining the idea that were the ontogeny of the ape's brain known, we should find in the chimpanzee and orang, and probably also in the gorilla, a tendency exhibited towards the interrupted or human mode of development, whilst amongst the lower apes the continuous method would hold good. The straight continuous fissures of the latter, with their smooth walls and uniform depth, all point to this.

The development of the fissure of Rolando offers some points of considerable interest and importance. In many cases it arises, no doubt as is usually described, in the form of a continuous groove, which is steadily deepened by the upheaval of its bounding banks. But very frequently it takes origin in two portions. Of these the lower and the longer part makes its appearance first as a continuous groove. The upper part has an independent origin. It first shows as a slight depression, which widens and deepens and is separated from the lower part of the furrow by a high bridge of cortex. A faint groove then runs over the surface of this bridge, and connects the two parts. In course of time the bridge disappears from the surface as the connecting groove cuts deeper and deeper into it, but in the after-growth of the brain it is retained in the form of the annectant gyrus to which I have referred.

This does not coincide with the account which is given by Krause⁶ of the development of the fissure of Rolando. This author holds that it is caused by a constricting vein, which stretches from the superior longitudinal sinus to the Sylvian fossa, and cuts into the cerebral surface. If this were the case it would be impossible for the fissure to appear in two detached portions. In all cases the middle or most projecting part of the convex surface of the cerebrum would be affected first, and from this the furrow would extend uniformly upwards and downwards.

I might pursue this aspect of the question further, but it is needless to do so. I have pointed out elsewhere in the parieto-occipital and calcarine fissures an apparent contradiction in the phylogenetic and ontogenetic evidence,⁷ but in all cases it is

Fig. 3.—Cerebral hemisphere in the early part of the sixth month of development. The interrupted mode of fissural formation is well seen. *r*, two parts of the fissure of Rolando; *p.c.*¹, sulcus præcentralis superior; *f.*¹, sulcus frontalis superior; *f.*², sulcus frontalis inferior; *f.m.*, sulcus frontalis medius (See Eberstaller's *Das Störnhirn*); *p.*³ ramus horizontalis (of the intraparietal); *p.l.*, parallel sulcus; *e.c.*, external calcarine.

necessary not to lose sight of the fact that if we had the developing brain of the ape before us such difficulties and discrepancies would, no doubt, in most cases melt away, and differences would be reconciled.

But I have set myself another task in this address, and that is to discuss the influences at work in producing the furrows and convolutions on the surface of the cerebrum. Many theories have

⁴ I have not had an opportunity of studying the brain of the gorilla.

⁵ "Das Urwindungs-system des menschlichen Gehirns," *Archiv für Psychiatrie*, Band vi, Heft 1, 1875.

⁶ *Handbuch der menschlichen Anatomie*, Zweiter Band, p. 813.

⁷ "The Complete Fissures of the Human Cerebrum, etc.," *Journal of Anat. and Phys.*, vol. xiv.

been advanced to account for these. By some observers they have been regarded as being due to the influence of mechanical forces operating on the brain from without; by others they have been considered to be the effect of different degrees of growth tension acting on the surface of the cerebrum from within.

Two widely different forces have been thought to exercise a mechanical influence upon the surface of the growing cerebrum, namely, the blood vessels and the enclosing skull capsule. But the advocates of these views are by no means agreed as to the precise manner in which the external influence is applied.

It has been my experience that most anatomists, in reflecting upon this question, are in the first instance attracted by the "blood-vessel" theory, but as they enter more deeply into the study of cerebral growth, they find that it has no solid basis of support. Further, there appears to be a prevalent belief that Reichert was the leading exponent of this view, but anyone who reads his remarkable book upon *The Structure of the Human Brain*,⁸ will see that this is not the case. He calls attention to it is true to the striking agreement which exists between the type of branching of the cerebral arteries and the arrangement of the furrows and convolutions. He leads one to infer that the radial sulci of the island of Reil are caused by the pressure of the branches of the middle cerebral artery, but he nowhere distinctly commits himself to this opinion. Indeed he states that the convolutions are chiefly formed by the growth energy of penetrating processes of the vascular pia mater. In the blood supply of the brain it is an absolute necessity that the blood vessels which enter should be exceedingly fine, and this requires a corresponding increase in the extent of the surface. Johann Seitz,⁹ who in the main follows Reichert, applies to the fissures of the cerebrum the name of "Nährschlitz" or nutritive slit.

So far as I am aware, there is no anatomist who maintains that the entire fissural system is the result of the pressure exercised by blood vessels on the surface of the growing cerebrum. Mihal-kovics¹⁰ considers that the larger blood vessels must have some influence upon the formation of the cortical furrows, and Krause,¹¹ who entertains a similar view, specially singles out the fissure of Rolando, the callosal-marginal, and several of the secondary sulci as being produced in this way, while he even hints at a similar origin for the parieto-occipital and calcarine fissures.

It is true that there is a general correspondence to be noted between the course of the blood vessels and the fissures of the cerebrum, but the former have absolutely nothing to do in determining the existence of the latter. Were this the case, the largest vessels would always occupy the deepest furrows, and in all cases they would lie at the bottom of the furrows. As we very well know, however, neither of these conditions is present. Again, if we follow the branches of the middle cerebral artery we perceive that they are placed sometimes between the lips of a fissure, whilst at other times they pass across the surface of the convolutions. But, as Schwalbe has pointed out, the strongest argument against the theory is to be found in the cerebellum. There cannot be a doubt that the same causes which are responsible for the production of the cerebral sulci must also be responsible for the formation of the cerebellar fissures, and yet, in the case of the cerebellum, the larger vessels do not occupy the fissures, but are placed on the surface of the organ.

But have we no markings on the surface of the cerebrum which are due to vascular pressure? Certainly we have, but not in the shape of fissures. If a brain be carefully hardened *in situ*, or if it be successfully removed when perfectly fresh, and at once plunged into a chloride of zinc bath, a deep wide groove will usually be observed curving downwards and outwards over the occipital pole of the right hemisphere. The right lateral sinus is responsible for this impression, and the forked posterior extremity of the calcarine fissure occupies the bottom of the groove. Again, if the blood vessels have been injected beforehand it will be seen that where they cross the surface of a convolution their course is marked by shallow but sharply cut grooves. Another example is to be found in the so-called præoccipital notch which indents the lower border of the hemisphere and marks the anterior limit of the occipital lobe below. Schwalbe would seem to indicate that this notch is the representative of the fissura præoccipitalis of Meynert in the ape's brain. It is true that the bottom of the notch is often traversed by a fissure, but this is merely related to it in

the same way that the extremity of the calcarine fissure is related to the lateral sinus groove on the occipital pole of the cerebral hemisphere.

The præoccipital notch is formed at a point which very nearly corresponds with the middle of the parieto-mastoid suture. Here three veins, converging towards each other from the outer surface of the hemisphere, open into the lateral sinus which lies immediately below the under border of this part of the cerebrum. Tension of these veins produced by cranial growth at the suture line is the usual cause of the præoccipital notch. In many cases, however, where the notch is strongly marked, another factor comes into play. Immediately behind is the asterion—the star-like sutural meeting of the occipital, mastoid, and parietal bones. The attachment of the tentorium with the enclosed lateral sinus crosses the deep surface of the asterion, and the growth of the skull capsule which takes place here as from a centre drags upon the dura mater, and raises it into more or less salient folds. One of these, opposite the middle of the parieto-mastoid suture, is usually more marked than the others, and, cutting deeply into the lower border of the hemisphere, co-operates with the veins already mentioned in producing the notch. Anyone who makes a cast of the interior of the growing cranium of a child, in which the dura mater and the tentorium are undisturbed, can readily prove the truth of my statement.

None of these markings produced on the surface of the cerebrum by blood vessels can be classed as true cerebral sulci, and therefore we dismiss the constricting influence of vessels as being altogether outside the sphere of the causes which operate on the brain in the production of the convolutions.

But quite recently the vascular theory has received a new and important development in a totally different direction at the hands of Dr. Richter,¹² of Daildorf. This author argues with much ingenuity that the furrows on the surface of the cerebral hemispheres are produced by the movements of the foetal brain. During the heart systole the passage of the blood into the minute twigs of all the blood vessels causes the brain to swell up from the base of the cranium in a centrifugal direction by squeezing out the cerebrospinal fluid from the interior of the ventricles. The borders of the brain are thus pressed into all the recesses of the skull cavity, and the organ receives a concussion which travels in an inward direction upon the surface of the hemispheres. Richter compares this concussion to the waves or ripples which may be generated at the borders of a vessel filled with water. In such a case, however, the waves are raised towards the outer surface, and each draws itself further away, whilst in the case of the brain the influences produced by the molecular concussions of the brain deviate inwards, and along their lines of meeting they become broken and annulled. Richter believes that a disturbance of the surface growth of the cerebrum is the result. He argues that in the stable existence of these interference lines the cells of the ganglionic layer are not all placed in equally favourable circumstances in so far as their growth tendencies are concerned. Those which lie in the lines of interference, or in other words in the lines in which the molecular concussions are broken, will suffer a check to their growth. Through this arrest the furrows arise.

It is impossible to do justice to this theory in the short notice which I am able to give it, but as an illustration I may briefly point out the manner in which Richter believes the fissure of Rolando to be formed. He regards this fissure as being, as a rule, the "first expression of the collective pulsatory concussions of the lateral surface of the cerebral hemisphere." Its oblique direction is due to the fact that the concussions, which travel along the medial border and which give rise to the upper end of the sulcus, are not interfered with until they reach the parieto-occipital and calcarine infoldings, whilst below they are early called to a halt by the fore part of the Sylvian fossa. Richter asserts that if we were to obliterate the parieto-occipital fissure and the Sylvian depression, the fissure of Rolando would proceed perpendicularly downwards from the mid-point of the medial border of the hemisphere.

The same author further contends that as the hemispheres present a greater antero-posterior than a vertical diameter, the furrows which pursue a sagittal direction must be more numerous than those which run in a coronal direction, and in this manner he explains, without calling in to his aid the influence of the en-

⁸ *Der Bau des menschlichen Gehirns*, Leipzig, 1861.

⁹ *Ueber die Bedeutung der Hirnfurchung*, Leipzig und Wien, 1887.

¹⁰ *Entwicklungsgeschichte des Gehirns*, p. 151, Leipzig, 1887.

¹¹ *Handbuch der menschlichen Anatomie*, Zweiter Band, p. 813. Hannover, 1879.

¹² "Ueber die Entstehung der Grosshirnwindungen," *Virchow's Archiv*, Berlin, 1887.

closing skull capsule, why it is that in brachycephalic brains the coronal fissural type predominates, whilst in dolichocephalic heads the sagittal fissural type is obvious. Richter's views, therefore, may be briefly stated thus. On the cerebral surface there are different degrees of growth energy. Along the lines of interference or breakage of the pulsatory molecular concussions there is a check to surface growth, and by reason of this furrows are induced. In the areas between these furrows there is an exuberance of growth which leads to the formation of the convolutions.

I shall not pause at this stage to criticise this theory at any length. It is open to an unanswerable objection which affects it in common with all other explanations which represent the fissures and convolutions as the product of mechanical influences operating upon the brain surface. As bearing specially on this view, however, I would urge that if the interference lines of the concussions are so stable as Richter would seem to imply, the various furrows should make their appearance in regular sequence, and always in the same manner. This we know to be very far from the case. There is the greatest variability in the order in which the furrows appear, and in general also they do not follow a uniform plan of development. The character and the direction of the concussions must, further, to some extent be influenced by variations in the arrangement of the main blood vessels at the base of the brain. Anomalies of this kind are by no means rare, and yet it has never been pointed out that they are associated with any disturbance of the convolutionary type.

Somewhere about the beginning of the third month of development the thin cerebral wall is thrown into a series of deep infoldings involving its entire thickness. These are undoubtedly the result of a want of harmony between the growth of the cerebrum and the enclosing skull capsule. Later on, as the cranial cavity expands, the majority of these deep fissures become unfolded, and the surface of the brain becomes smooth. In this condition it remains until the permanent cortical furrows make their appearance.

Fig. 4.—Section through the frontal region of an early cerebral hemisphere to show the infolding of the wall produced by a transitory fissure, *f.i.*

Now, several observers are of opinion that the permanent furrows owe their origin to the same causes that determine the transitory infoldings and the complete fissures. Henle¹³ is chiefly responsible for this view, but it has also been enunciated by Meynert,¹⁴ Meyer,¹⁵ and others. According to these authorities, therefore, the convolutions and furrows are called into existence by a growth antagonism between the brain and the skull. The cerebral surface grows more rapidly than the cranial cavity within which it is enclosed, and as a natural result of this growth restraint the cerebral surface becomes folded along lines which run at right angles to the axis of the growth energy. Horizontal convolutions would therefore arise in cases where growth is restrained in the vertical direction, and coronal convolutions where it is resisted in the sagittal direction.

Meynert shows that the form of the head in different mammals

exercises a marked influence upon the direction assumed by the convolutions of the brain. To render this clear, I may be allowed to quote the results which he obtained for the fox, the lion, and the elephant. In the fox the cranial cavity is more elongated than in the others. It presents a cephalic index of 77, and in accordance with this the cerebral fissures run more distinctly in a longitudinal direction than in the lion, which presents a cephalic index of 98.7. The elephant shows a striking degree of hyperbrachycephaly; its cephalic index amounts to 123.3 in the adult animal and 128.3 in the young animal, and in its cerebrum the convolutions and furrows assume an almost vertical direction.

Further, Calori,¹⁶ Meyer, and Rüdinger¹⁷ have called attention to the fact that even in the human brain a relation between the form of the head and the direction of the cerebral furrows may be traced. This is indeed an undoubted fact, and one which can be readily established by anyone who examines the brain *in situ*. The fissure of Rolando lends itself specially to such an investigation. In brachycephalic heads the angle which it forms with the mesial plane opens up, whilst in dolichocephalic heads it becomes more acute. More recently Zuckerkandl¹⁸ has endeavoured to prove that early synostosis produces a change in the arrangement of the furrows, and that not only the skull and its several segments, but also the cranial sutures, have an influence in this direction.

That the initial cause of the formation of the cerebral furrows is to be sought for in a restraint upon the surface growth of the cerebrum, I would deny in the strongest terms. At the time when the first permanent cortical fissures appear, the cerebrum lies loose within the cranial cavity, and does not completely fill it. Ecker¹⁹ pointed this out in his classical memoir upon the development of the cerebral fissures; and it is a fact which I have had many opportunities of verifying. The question as to whether the cranial wall, after the formation of the convolutions, exercises any influence upon their direction is a more difficult one to solve. Is the brachycephalic brain moulded into shape by the brachycephalic skull? or are both the result of the same hereditary influence, and, therefore, in perfect harmony with each other as to their growth? I am inclined to adopt the latter view; and, such being the case, I do not believe that, in normal conditions, the direction of the furrows and convolutions are affected by a restraint placed upon the growth of the cerebrum by the skull capsule. Rüdinger insists strongly that the anatomical peculiarities of brachycephalic and dolichocephalic heads are determined prior to birth.

But certain observers have endeavoured to explain the formation of the cerebral convolutions by influences operating upon the surface of the hemispheres from within. The theory advocated by Wundt²⁰ is one of the most notable of these. Different intensities of growth in stated directions, leading to surface tension of the cerebrum, is the explanation which he offers. To illustrate this view, let us suppose that the smooth surface of the foetal brain is growing more rapidly in the sagittal than in the transverse direction. Tension of the surface in a transverse direction is thereby induced, and the cerebrum becomes transversely folded in accordance with the direction of strongest tension. Longitudinal furrows, on the other hand, arise if the transverse surface growth outstrips the longitudinal growth, and, as a consequence of this, the surface tension assumes a sagittal direction.

According to Wundt, therefore, the direction of the developing furrows coincides with the direction of the most acute surface tension, or, in other words, stands at right angles to the axis of the greatest growth energy. Schwalbe is not too severe in his criticism of these deductions when he says that they are founded upon no positive proof, and, further, that they are directly contradicted by the fact that in dolichocephalic heads we have a preponderating tendency towards the formation of longitudinal furrows, and in brachycephalic heads a distinct tendency towards the formation of transverse furrows. If Wundt's views were correct, we would expect to find exactly the opposite.

¹³ "Del cervello nei due tipi brachicephalo e dolicocephalo Italiani, *Memorie dell'Accad. delle Sc. di Bologna*, 2 ser., t. x, Fasc. i, 1871.

¹⁴ *Ueber die Unterschiede der Grosshirnwindungen nach den Geschlecht beim Fetus und Neugeborenen*, München, 1877.

¹⁵ "Beweise dass die Näfte auf die Richtung der Windungen Einfluss nehmen," *Wiener medicinische Jahrbücher*, 1883.

¹⁶ *Archiv für Anthropologie*, Drittes Band, Drittes und Viertes Heft, 1889.

²⁰ *Grundzüge der physiologischen Psychologie*, 2. Aufl., Leipzig, 1880, 1. Bd. I have not had an opportunity of studying Wundt's views at first hand. An admirable account of the hypothesis is given by Schwalbe in his *Lehrbuch der Neurologie*, p. 576.

¹⁷ *Handbuch der Nervenlehre des Menschen*, 2. Aufl., pp. 177, 183, and 185. Braunschweig, 1879.

¹⁸ "Vorläufige Mittheilung über die Ursachen des Zustandekommens der Grosshirnwindungen," *Anzeiger der k. k. Gesellschaft der Aerzte in Wien*, 1876, No. 29, S. 162 (*Medicinische Jahrbücher*).

¹⁹ "Ueber den Einfluss der Schädelform auf die Richtung der Grosshirnwindungen," *Centralblatt für die medicinischen Wissenschaften*, October 21st, 1876, No. 43.

We have now discussed several of the leading theories which have been advanced to explain the initial causation of the cerebral convolutions, and we have noted certain points in each which are open to objection. But further it is impossible to show by means of any of them how it comes about that small animals have smooth brains and large animals convoluted brains; how, in short, we should find in the beaver, an animal remarkable for its intelligence, a cerebrum almost entirely smooth; and in the sheep, an animal—shall we say, remarkable for its dulness—a high convoluted system. Or, to take a still more striking instance, why in a cetacean we should encounter a cerebrum perfectly bewildering in the complexity of its convolutions and in the little marmoset monkey a brain that is practically without gyri. It was Dastre who first called attention to this striking contrast between the brains of small and large animals, and he showed that it was quite independent of class relationships.

Within the last year Jelgersma²¹, of Meerenberg, has developed a theory which appears to meet the difficulty. Not only does it afford a reasonable explanation of the forces at work in calling the convolutions into existence, but the apparent discrepancies in the case of animals of different bulk is made its strongest pedestal of support. The importance and interest attached to Jelgersma's views are such that they are the best excuse I can offer for dealing with them in some detail.

The grey cortex of the brain, which in members of the same species maintains a tolerably constant thickness, increases by surface extension. Further, with every advance in the growth of the grey matter there must be a proportionate increase of the subjacent white matter, the conducting fibres with which it stands in connection. Now if we extend the surface of a smooth-brained animal say four times, and at the same time desire to keep the surface even, we must provide eight times as much white matter to fill the interior of the grey capsule; or, to put it in different terms, if we lengthen out the radius of the cerebrum say ten times, we acquire a surface extension 100 times greater, and an internal capacity 1,000 times greater. The geometrical law involved is simply this—that in the growth of a body the surface increases with the second, but the interior with the third, power of the radius.

From this it is evident, seeing that the proportion of internal white matter and external grey matter is in all cases a uniform one, that in the evolution of a large animal out of a small animal a disproportion between the grey capsule and the white core of the cerebrum must result. This is compensated for by the extended cortex placing itself in folds or puckers, and thereby reducing the capacity of the capsule to a degree which brings it into correspondence with the white contents; consequently "the formation of the convolutions and furrows is simply the result of the tendency on the part of the superficial layer to increase by surface extension, and of a mutual space accommodation (*Raum-accommodation*) of the grey substance and of the white conducting paths."

It is but right that I should state—although, indeed, Jelgersma appears to be ignorant of the fact—that many years ago Baillarger arrived at very similar conclusions; and, further, that the theory in question has received independent testimony in its favour at the hands of my colleague, Professor George F. Fitzgerald. Some months ago, having constantly had occasion to appreciate the unsatisfactory nature of the current explanations as to the origin of the convolutions, I detailed to Professor Fitzgerald, as far as I could, the conditions of cerebral growth, and asked if he could account for the presence of the cortical furrows upon geometrical principles. The views which he advanced were identical with those of Baillarger and Jelgersma.²²

But Jelgersma brings forward some additional facts, which are well worthy of our consideration. He points out that the extent of the cerebral surface depends upon two factors, namely, (1) the absolute quantity of the grey matter, and (2) the thickness with which this is spread over the surface. The absolute quantity of grey matter present is determined by the bulk or by the psychical endowments of the animal, or by both of these factors together. On the other hand, although the thickness of the grey cortex is very much the same in the same species; it differs considerably in different animal groups, and it follows from the theory which he has advanced that the more sparsely the grey substance is spread over the surface of the white matter the

richer will be the convolution type. In the cetacean cerebrum the grey cortex is exceedingly thin, and it is due to this that the surface shows such an extreme condition of complexity.

But there is another way of looking at this question, and it is this: Anything which diminishes the quantity of internal white matter will of necessity tend to increase the folding of the external grey capsule; and in a short additional paper, published last March, Jelgersma²³ discusses in this light the effect produced by total or partial suppression of the corpus callosum on the convoluted type of the cerebrum. The question is a difficult one, because defects in the corpus callosum are very frequently associated with dilatation of the ventricular system, which of course would compensate fully for any deficiency in the white central core of the hemisphere.

A profound convolutionary disturbance accompanies the non-development of the corpus callosum. In a recent paper²⁴ I have shown that there appears to be present in such cases a marked tendency towards the retention of certain of the primitive transitory fissures, and sometimes also there is in addition an intricacy of pattern produced which presents a superficial resemblance to that seen in the cetacean cerebrum. Hans Virchow²⁵ has figured and described a brain of this kind.

The same law by which we account for the formation of the cerebral convolutions likewise explains the development of the cerebellar folia. Jelgersma is wrong, however, when he states that no one prior to himself has attempted to place the cerebellar and cerebral convolutions on the same footing. Kölliker²⁶ distinctly rejects certain theories which have been applied to the cerebrum because they will not suit the cerebellum, and Schwabbe²⁷ indirectly does the same. The enormous extension of the cerebellar surface by its complicated subdivision into folia is due to the thinness of the grey cortex, and more especially—as, indeed, Jelgersma has pointed out—to the fact that the most important constituents of this layer, the arborescent cells of Purkinje, are arranged in a single row. Still further, the wavy crenated outline of the corpora dentata of the cerebellum and the olivary bodies is produced by the same cause, namely, an extension of the grey capsule and an accommodation of this to its contents by a puckering of its walls.

Jelgersma confesses that he is unable to explain why the furrows and convolutions of the cerebrum, always within certain limits, assume a corresponding arrangement in different members of the animal group. It appears to me, however, that if the theory of cerebral localisation be true, the cortex must grow in accordance with the functional activity which is displayed in its different parts. It is true that these functional areas overlap each other to a considerable extent, but districts of especial functional intensity can always be detected. In its growth, therefore, the surface extension of the cerebrum cannot be uniform. In all probability the bulgings out in the form of convolutions are connected with the functions which the areas involved have to perform. It is absolutely necessary that the areas so extended should assume the form of outward puckerings unless an undue quantity of white matter grows all over the inside, and this, of course, is an impossibility.

It may be said that the explanation which we have given is merely another way of stating what has so often been urged in regard to the surface of the brain, namely, that the furrows are produced by linear arrests of growth, and that the convolutions are formed by exuberant growth in the intervening districts. In a certain sense this is perfectly true, but I think that it will be admitted that two very essential points are added. In the first place a reason has been given which indicates the influences at work in determining the convolutions; and, in the second place, an argument has been advanced with the view of showing that the pattern sketched out has, in all probability, a deep physiological significance.

Mr. Hill, in his masterly translation of Obersteiner's work, *On the Anatomy of the Central Nervous Organs*, gives expression to a similar opinion upon the functional value of the furrows and convolutions. He puts the matter in such an admirable manner that I feel constrained to quote the passage. He says: "No question in the comparative anatomy of the brain concerns the

²¹ "Das Gehirn ohne Balken: ein Beitrag zur Windungstheorie," *Neurologisches Centralblatt*, March, 1890.

²² "The Complete Fissures of the Human Cerebrum," *Journ. Anat. and Phys.*, vol. xxiv, 1890.

²³ "Ein Fall von angeborenem Hydrocephalus internus," *Albert von Kölliker's Festschrift*, p. 307, Tafel xiii and xiv, 1887.

²⁶ *Entwicklungsgeschichte des Menschen und der höheren Thiere*, 1879.

²⁷ *Lehrbuch der Neurologie*, 1831.

²¹ Ueber den Bau des Säugethiiergehirns. *Morphologisches Jahrbuch*, June, 1889.

²² I am also informed by Mr. John Marshall, F.R.S., that the same doctrine was taught by Dr. Sharpey in University College, London.

neurologist more closely than the question as to the morphological value of the fissures. Are they merely plaitings of a shifting surface, or are they boundaries of morphologically distinct organs? A study of the development of the fissures in the brains of animals which stand far apart in phylogeny teaches that they appear with such regularity as to sequence and progress in extension and obey such definite rules as to depth as would, in the case of other parts of the body, justify us in considering them as the divisions between structures of separate function."

REVIEWS AND NOTICES.

THE BIRMINGHAM SCHOOL OF MEDICINE. By B. C. A. WINDLE, M.A., M.D., and W. HILLHOUSE, M.A., F.L.S. Birmingham: Hall and English. 1890.

THIS small volume, written primarily for the information of members of the British Medical Association attending the annual meeting this year, yet possesses a permanent interest. It contains the history of the foundation, the vicissitudes, and the final establishment on a firm basis of the Birmingham Medical School, from the pen of Dr. B. C. A. WINDLE, Professor of Anatomy, together with an account of the foundation and present position of Mason College, by Mr. W. HILLHOUSE, Professor of Botany and Vegetable Physiology.

The Queen's College appears to have owed its origin to the enthusiasm and perseverance of Mr. William Sands Cox, who commenced a course of anatomical lectures with physiological and surgical observations in December, 1825. Even before this date, however, instruction had been given in the general hospital, one of the earliest pupils having been the present Sir William Bowman. Courses of lectures on materia medica and botany, chemistry, medicine, surgery, and midwifery were organised in 1828, and in 1829 the school acquired premises in Snow Hill. About this time Mr. Sands Cox succeeded in interesting the Rev. Dr. Warneford, the wealthy rector of Bourton-on-the-Water, in the medical school, which had just received the title of the Royal School of Medicine and Surgery of Birmingham, from William IV. Men then dreamt of the early foundation of a midland university. But for various reasons the school did not prosper, Dr. Warneford was a very liberal benefactor, but he held very rigid theological views which appear to have been out of harmony with those of many of the most influential citizens. In 1845, however, a new charter was obtained, the medical school became the Queen's College, and its governors proceeded to the constitution of new faculties of arts, law, engineering, and architecture. This ambitious effort was not attended with success. The financial position of the college went from bad to worse, and the success of Sydenham College, established in 1851, drew away from it many medical students. Finally, in 1867, a new scheme for Queen's College, drawn up by the Charity Commissioners, was adopted, and in the following year an amalgamation with Sydenham College was effected. Since then the history of Queen's College has been one of great and increasing prosperity.

The foundation of Mason College very greatly increased the facilities for higher education in Birmingham. In 1875, on his 80th birthday, Josiah Mason, the son of a Kidderminster artisan (a carpet weaver) laid the foundation stone of the College which bears his name, and to which he had already given more than a hundred thousand pounds. The building was opened in October, 1880, and since then has achieved the most remarkable success. This is largely due to the completeness with which the various teaching departments have been organised, and to the admirable laboratories provided. The chemical department and laboratories are under the direction of Professor Tilden, F.R.S.; the physics department under that of Professor J. H. Poynting, F.R.S.; the physiological of Professor F. J. Allen, M.B.; the zoological of Professor T. W. Bridge; and the botanical of Professor W. Hillhouse. There are also fully equipped arts, geological, and engineering departments, and a fine library, containing more than twenty thousand volumes, which is especially rich in serials. The Chairs of Chemistry, Physiology, Botany, Physics, and Comparative Anatomy, in Queen's College, have been amalgamated with those in Mason Science College, and the medical students of the former attend the classes in the latter. Queen's College possesses excellent museums of anatomy, pathology, and materia medica, to

which very numerous additions have been made in recent years. A well-designed dissecting room has been erected, and more recently a pathological laboratory, which it has already been found necessary to enlarge.

Altogether it will be seen that the Birmingham Medical School is thoroughly well provided in its science departments, and its great hospitals, served by many distinguished physicians and surgeons, who give systematic and clinical instruction, afford opportunities for acquiring a practical acquaintance with medicine, surgery, midwifery, and the various special departments, equalled perhaps, but not surpassed, by any city in Great Britain.

The volume is illustrated by reproductions of photographs of the Colleges, of the library, Mason College, and of some of the laboratories.

NOTES ON BOOKS.

Rhinoplasty. Being a Short Description of One Hundred Cases treated by TRILHOVANDAS MOTICHAND SHAH, L.M., Assistant-Surgeon and Chief Medical Officer, Junagadh, at the Junagadh Hospital. With Illustrations and Remarks. (Printed at the Junagadh Sarkari Press. 1889).—This book, written by an Indian surgeon and printed at a native press, deals with the operative treatment of mutilation of the face involving more or less destruction of the nose. The author has had exceptional experience of rhinoplastic operations, which were performed for the relief of disfigurement caused, not as is usually the case in this country, by the ravages of disease, but by wilful wounding committed either out of spite or in revenge for injury, or as an outrage inflicted on innocent individuals by miscreants known in Junagadh State as Makrani outlaws. The main bulk of the volume is made up of notes of one hundred cases in which the author, in the comparatively short period of four years, performed some form or other of rhinoplasty. Some of these cases are illustrated by photographs, which show very clearly the extent of the mutilation and the improvement subsequently effected by surgical treatment. In his early trials of rhinoplasty, the author formed the new nose of flaps taken from the cheeks, but after the tenth operation, not feeling satisfied with the results, he was led to resort to the old procedure in which the flap is dissected up from the forehead. There can be no doubt, as is pointed out in this work, that the latter operation compares very favourably in many respects with that of the lateral cheek flaps. It takes much less time to perform, a much more sightly nasal organ is thus formed, and the subsequent cicatricial disfigurement is less apparent, particularly in natives of the East, on whom the scar on the forehead may be readily concealed by the turban or some other head covering. In his concluding remarks Dr. Tribhovandas Motichand Shah discusses the best mode of dealing with the root of the flap, and points out how certain difficulties in rhinoplasty, as, for instance, the absence of the nasal septum, and the tendency to contraction of the nasal apertures, may be best overcome. The author has certainly worked at his subject with much zeal and success, and the results of his labour, as shown by the illustrations in this book, prove how much can be done by careful study and large experience to relieve a most distressing disfigurement.

THE Alvarenga Prize of the College of Physicians of Philadelphia, consisting of one year's income of the bequest of the late Dr. Alvarenga, of Lisbon, has been awarded to Dr. R. W. Philip, of the Victoria Dispensary for Consumption and Diseases of the Chest, Edinburgh, for his essay on pulmonary tuberculosis, which will be published by the college.

THE SHIPLEY AND WINDHILL JOINT HOSPITAL.—The erection of an infectious diseases hospital for the districts of Shipley and Windhill has been commenced, and on July 19th, two corner stones were laid by the chairmen of the Shipley and Windhill Local Boards. There will be three blocks of buildings divided into separate sections for males and females, each section containing two wards, with a nurses' duty room placed between the two wards in each case. A separate block will be devoted to the administrative department, and a third block will consist of mortuary, etc. The entire cost, including site, buildings, furnishings, and fittings, is estimated at £3,800. The Local Government Board has sanctioned the borrowing of £3,000 for the expenses of building the hospital.