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A Thesis.  
on  
The Physiology of Education,  
being mainly  
a study  
of  
Cerebral Physiology applied to Education,  
by  
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## On the Physiology of Education.

' The subject of the growth and  
' development of a human being in  
' body and mind from the period  
' of birth up to maturity is one  
' of the most interesting in the  
' whole range of knowledge. - Its  
' practical importance is at least  
' equal to its interest. - To all classes  
' of men and women it is of vast  
' importance. - The student of mind,  
' the student of body, the educa-  
' tionalist, the sociologist, the  
' statesman, the clergyman, the  
' brain-worker, the craftsman,  
' all should regard it as one about  
' which we cannot know too much,  
' and one in regard to which every  
' increase of our knowledge nec-  
' cessarily tends towards human  
' welfare and happiness'. (T.S. Clouston  
Ph.D. on "The Growth and Development  
of a Child in Body and Mind." - Edinburgh

Health Lectures - fourth series no. 9. p. 21.)

- If the above be true, the subject which takes into consideration the guidance and direction of this "growth and development", is surely of equal theoretical interest and greater practical importance. This subject is Education, for whatever definitions of the word may have been given or whatever conceptions of its meaning may have been formed or expressed, we may conclude that it now refers to "the science and the art which aim at the proper guidance and direction of the growth and development of a human being in body and mind from the period of birth up to maturity," - in order to secure the greatest happiness and well-being first for the individual and secondly for the race. - James Mill and other authorities have recognised the true scope of the word, and through others, including Bain (*Education as a Science*

sixth Ed; 1886. p. 3) prefer to attach to it a more limited meaning, there is at least ample and excellent precedent for accepting the word in its wider significance.

It is not very long since education was an art only whose methods were founded in empiricism and propagated from one generation to the next without question or opposition; but in later years there has arisen, with a view of reforming the art, a science of education, the subject being first taken up by metaphysicians who ~~also~~ tried to set it on a more or less rational psychological basis, and later by physiologists who have recognised the dependence of psychology on physiology, and have gone so far as to say that "education is really a branch of physiology, and to be studied by physiological methods." (*Education & the Nervous System* by Sir J. Creighton Browne M.D.; F.R.S. - *Book of Health*, 1884 p. 272.)

- Whether this be a strictly accurate statement or not matters but little, as I think a large majority of scientific men will agree that it is a subject so intimately connected with medical science and practice, as to make it very desirable that medical men should take up its serious consideration. - Indeed the connections which have been established between mind and brain, and between the brain and the rest of the body, along with the reactions of body on mind and mind on body, are sufficient to vindicate its physiological interest; while its effects if properly used in promoting health, and if abused as constituting a fertile source of disease, are sufficient to commend its careful study to the clinical physician. -

Hitherto a few medical scientists have turned their attention to this subject, but that it has

not got a good hold on the general  
 medical mind is evinced by the  
 fact that more than one prom-  
 inent member of the profession  
 has been led to express publicly  
 the crudest ideas on educational  
 matters, blindly advocating or con-  
 demning, for instance, what has been  
 called "the higher education of women",  
 whereas a study of the subject will  
 shew that there is no reason why  
 women may not be very highly  
 educated, provided the education be  
 properly conducted; and that, in  
 relation to the three accepted divi-  
 sions of the subject into Moral, Men-  
 tal, and Physical education, the  
 first must enter into and per-  
 meate all the methods and ex-  
 ercises of the other two, of which  
 two the physical must invariably  
 take the lead. - Whether we regard  
 physical superiority as equally des-  
 irable with mental superiority or  
 not, the dependence of growth of

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mind on growth of brain, and growth of brain on growth of body, is sufficient to make clear the necessity of placing the physical on a sure footing as taking precedence of the mental. —

That this necessary, as it seems to me, relation is not universally recognised we see on turning to Bain (op. cit. 1886. p. 3), when, in speaking of "physical education" and its place as set down by Herbert Spencer and others, he says "It seems to me, however, that this department may be kept quite separate important though it be"; and in a work of 453 pages on "Education as a Science", he devotes only three pages to "the bearings of physiology," and disposes of physical education in a paragraph, declaring that "the discussion of the subject" does not in any way help us in educational matters as so commonly understood." — It is true that he defines education as "the means of building up the acquired powers of human beings"; yet with

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this at first sight narrow meaning, and without pausing to enquire whether such a definition does not necessarily include much of physical education, I am prepared to maintain that the discussion of this subject and of the physiology of mental education, has already helped us much, and will do so more, as these subjects become more thoroughly and more widely studied, in relation to "educational matters as commonly understood."

There can be no possible doubt that, in the systems of education at present in vogue, schoolmasters, and more notably schoolmistresses are undermining the health of thousands of the rising generation by absurdities so glaring as to appear almost incredible in the present age of advanced enlightenment. Girls are made to work for ten or even more hours a day; Competitive and other examinations are introduced, the girls being thus induced

to work at the highest possible pressure; they are allowed to study during their few leisure hours, and even in some cases the pernicious habit of staying awake in bed or waking very early in the morning to work is winked at. - They are permitted, indeed compelled, to spend most of their spare time in the vitiated atmosphere of the same room in which they have been working, and are provided with only "one hour" of "exercise in the open air, in the shape of a formal walk often with lesson books in hand, and even this only when the weather is fine at the appointed time." (Sir John Forbes - quoted in Herbert Spencer's "Education" p. 159.) - They are, at their lessons and at their meals, made to sit in cramped and unnatural attitudes, and are encouraged in the fashionable follies of dress, which in so many respects are deleterious. - The author of "Macleod's Nature" quotes 97 different world conditions, giving the

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authority for each, which have been ascribed by "eminent medical men" to the use of stays alone. - Nothing could so effectually rationalise fashion as the teaching of the laws of health and beauty in girls' schools. - At present girls are kept in almost entire ignorance, sometimes designedly, of the structure and functions of their bodies. - Their food is uninteresting and monotonous and they are allowed to bolt it, when many of them require really judicious dieting. - No notice is taken of their menstrual periods, but rather they are encouraged in a false modesty which leads them not to complain of weakness, malaise, and headache, and to work on at high pressure at times when they should be provided with almost entire rest. - The action of the bowels is a function which many boarding-school mistresses seem to be unaware of; girls are hurried into the schoolroom immediately after

breakfast, and that habit of constipation, which is the bane of so many women's lives, is frequently established. -

No wonder that such a system should produce Anaemia, Debility, Languor, Dyspepsia, Myopia, spinal curvature, Phthisis (Sutton's Lectures on Med: Path: Ch: XXI), excessive nervousness, "school-headache", chorea, hysteria, epilepsy, insanity (Hilton's Rest and Pain, 3<sup>rd</sup> ed. p: 10), amenorrhoea, sterility &c. - No wonder that Dr: Down in his recent Lettsonian Lectures on Idiocy (Jan: 1887), should say "If there is one thing more certain than another about the production of idiocy, it is the danger which arises from the cultivation of only one side of woman's nature"

Happily the spirit which tends towards the above class of education is no longer universal. - The writings of Sir Henry Holland, Dr: Andrew Corrie, Charles Kingsley, Herbert Spencer, Professor Lawrie, Treichler, Sir J. Crichton Browne, and other scientific philanthropists

and social reformers have done much to remove some of the evils; but that such a spirit is still very prevalent may be ascertained by anyone who will take the trouble to enquire from any half dozen girls who have been at different boarding-schools.

The subject of physical education in girls schools is admirably though briefly discussed in a paper by Dr. Batten of Gloucester, published since the above was written (Brit. Med. Journ. March 19. 1887). - Speaking of recent enquiry he says "we find that throughout this country, in the girls elementary schools, whilst the government carefully tests the mental progress, not one word is said, and no official oversight of any kind is considered necessary, in the matter of the physical development of the children." - "America and the continent of Europe are not very much if at all in advance of ourselves." - Speaking next of schools for

the upper classes, he says that drill for twenty minutes twice a week, from which those preparing for examinations are exempted, "and the hour's walk, so 'insufferably dreary, and ranking neither 'as exercise nor recreation, is nearly 'all that is done to promote physical 'health in our college boarding houses 'during the greater part of the year: - "In Summer there may be tennis 'for the few, and at other times there 'may ~~be~~ also be an evening game 'or dance in the unwholesome at- 'mosphere of a gas-lit room".

Such being the case it is difficult to imagine why any rational individual should wish to underrate the value of physical education. - Reform is urgently needed, but is only likely to be effected when the medical profession as a body awakes to its responsibility in this connection. -

My object in the present paper is, however, not so much to dwell upon this side of physical education, nor on

the general relations between brain and body growth, as to enquire into what we know or have good reason to believe true of the brain as an organ of the mind and the nature of its action in acquisition and education in general, and to point out any practical conclusions arrived at. - Such an enquiry will hardly lead to such definite and valuable results as one based mainly on the relations between brain and body growth, or mental and bodily health. - These subjects have, however, been fairly though not exhaustively worked out, while, though much has been written which bears upon what I am about to discuss, I am not aware that any attempt has been made to collect it and apply it to educational problems.

"That the brain is the organ of the mind is a universally admitted axiom". (Ferrier - "The Func.

tion of the Brain". seventh edition 1886. (p. 424.)

"The Cerebral hemispheres are usually said to be the seat of all the psychological activities". - "Objection has been taken to the term "the seat of" the will and intelligence, and undoubted-ly it is more consistent with what we know, or rather do not know, to say that the existence of volition and intelligence is dependent on the connection of the cerebral cortex with the rest of the brain." (Laudon's Physiology - Stirling's Translation - II - 903.)

"The destruction of the Cerebral hemispheres annihilates sensation, idea-tion, volition, and intelligence in general," and there can be no pos-sible doubt that the brain is, to use a convenient if perhaps incorrect expression, "the seat" of all the in-tellectual operations. - We can trace mental activities to the cortex; we cannot trace them further; and whether the brain be really the ultimate seat or not, we are

justified I think in using that term without being regarded as necessarily materialistic in tendency.

Before ~~having~~ considering the brain as an intellectual organ, or rather as a preliminary to it, I propose to recall a few points as to its blood supply, which will both facilitate further inquiry, and furnish one or two indications as to the practice of education. -

The brain is much more richly supplied with blood than is any other organ of the body; indeed whereas the brain of man weighs about one fortieth ( $\frac{1}{40}$ ) of the total weight of the body, it gets between one sixth and one fifth ( $\frac{1}{6}$  -  $\frac{1}{5}$ ) of the total quantity of blood (Carpenter's Mental Physiology p. 39), and of this by far the largest part goes to the surface. - Sir J. C. Browne (op. cit. p. 290) states that the grey matter of the cortex is five times as vascular as the white substance. - Working upon the above figures we see that the

brain as a whole gets nearly seven times as much blood as it would do if the blood were distributed equally throughout the body, and that the cortex gets nearly thirty times as much as it would be entitled to under similar conditions. -

The brain, not having any restorative effect upon the blood, we are led to suppose that the otherwise excessive supply which we find coming to it is for the purpose of enabling it to carry on the various mental operations which we know to be so intimately connected with that organ.

"The liberation of nerve-force has been represented as an explosive action, and this implies the presence in the nerve cells of a substance ready, on the application of the proper stimulus, to combine instantly with the blood. - The formation of such a material, its maintenance at a given state of chemical tension, so to speak, is not paralleled by any other nutritive operation".

(Broadbent - Croonian Lectures - March 1887.) -  
 -Dr. Broadbent speaks here of "nerve force": mental force is not necessarily included, but our position is corroborated, if indeed not established, on considering the reaction between mental work and the blood supply of the brain. - In severe mental work we get what has been called a "determination of blood to the head", with throbbing carotid arteries, hot head, and cold extremities. - Just as, when a full meal has been taken, and the functional capacity of the stomach has been stretched, we get an extra supply of blood to that viscus with a contracted condition of the vessels supplying the cutis, so when the brain functions are severely taxed by mental work we get a noticeable increase in the total supply of blood to the brain. -

Further, Fritsch and Hitzig first observed in 1870 (Reichert and du Bois Reymond's Archiv. 1870), and their observation has

been abundantly confirmed by Ferrier (West Riding Lunatic Asylum Reports 1873), and others, that the circulation of certain areas of brain is similarly alterable, and that the electrical stimulation of a given, say a motor, area of the cortex, produces, besides muscular movements, intense hyperaemia of the part of the cortex stimulated, the increase in the size of the vessels being visible to the naked eye. - Ferrier found further that, after great haemorrhage, when there was not enough blood to produce the hyperaemia attendant on faradisation, electrical stimulation then failed to produce muscular action; and we have every reason to believe that, as is the case with other organs or parts of organs within the reach of examination, functional activity of any part of the brain is accompanied by a dilatation of the blood-vessels of the immediate neighbourhood.

- As we shall see later, we have good reason to believe that education

in any one line is accompanied by func-  
 tional activity, and consequently by-  
 perœmia, of certain areas of brain  
 tissue, and we must bear in mind  
 the danger "especially in the young"  
 (Sir J. Crichton Brown loc. cit. p: 291), if  
 education be pushed too far, of producing  
 vaso-motor paralysis of certain areas  
 and consequent permanent congestion.  
 - In this connection it is well to re-  
 member that the venous arrangement  
 of the brain is one which peculiarly  
 favours congestion. - "Elsewhere, as-  
 cending veins convey blood that  
 has been brought by descending ar-  
 teries, and the venous flow is favoured  
 by the liquid pressure, which, accord-  
 ing to the well-known law of hydro-  
 statics, tends to make the blood  
 rise in the veins. - But in the brain,  
 the blood from ascending arteries  
 passes into ascending veins. - The  
 openings of these veins into the lon-  
 gitudinal sinus being directed  
 forwards, the entering blood is op-

posed in direction to the current in the sinus, and the effect must be to retard the flow in both veins and sinus." (Gowers - "Diseases of the Brain" 1884, p. 42)

- That congestion of the brain on any part of it is a state of things to be guarded against rather than encouraged is a point requiring no argument, and that it must be especially pernicious in an immature and still actively growing organ is sufficiently obvious. - To me it also seems clear that, had the brain been intended for prolonged and severe exercise, in limited directions especially, the arrangements of its circulatory mechanism would have been such, in comparison with other parts, as to diminish rather than increase the risk of congestion. -

From the above considerations it seems plain that mental work, more especially in young persons, should never be excessive, and that education should be, in the first

instance, general, inducing a widely spread and wholesome hyperaemia with a consequent good supply of nutriment and evolution of activity in all parts; and that, only as the vascular and structural arrangements become gradually more perfected, should education become special. -

If from anatomical and physiological grounds we arrive at conclusions similar to those arrived at by workers in other departments, we have stronger reasons ~~reasons~~ for supposing our conclusions correct, and insisting that brain work should be moderate in the young especially, and that the mind should be helped to evolve, in accordance with the fundamental law of evolution, from the general to the special. -

Turning from the consideration of hyperaemia and congestion to the opposite condition we get further corroboration of the connection between

the blood supply of the brain and mental operations. - In sleep, when mental action is at its lowest, we find an anæmic condition of the brain. - Whether cerebral anæmia be a cause, a consequence, or only a concomitant of sleep, matters in this connection very little; all that concerns us is the fact that the two go together. -

Further, we know that any interference with the blood supply weakens mental action, whether that interference be as to quantity as from hæmorrhage or a weak heart, or quality from anæmia or poisoning by carbonic acid, urea, or alcohol. -

- Since I have, in connection with the blood supply of the brain alluded to congestion, I propose here to devote some space to the consideration of anæmia as effecting mental work and education. - The subject is one of especial importance in relation to the education of females,

and the movement which has sprung up within the last twenty-five years in favour of the higher education of women. -

"Anæmia produces feebleness of brain function from slight blunting of the faculties to complete imbecility." (Via J. C. Browne loc. cit. p. 291) -

"What are the morbid conditions that take away the easy working of the brain? - Let us first take Anæmia of the brain. - We mean by that the organ is not freely supplied with blood, and there are several ways in which anæmia of brain may come on. - One is from bleeding..... Another way is from valvular or other failure of heart's action. --- Another is loss of red corpuscles, as is commonly seen in chlorotic girls, and many other forms of anæmia. --- Now whatever way anæmia of the brain comes on, it is characterised by uneasiness in the head - increasing distress in the head; increasing pain - neuralgia so called;

'Mental power is diminished and dis-  
 'ordered; there is restlessness and that  
 'becomes daily more oppressive un-  
 'til it may pass into spasm, muscular  
 'twitchings, and convulsions. - Anaemia  
 'of brain is attended by so much loss  
 'of healthy feeling, that we are never  
 'surprised to find the mind become  
 'more or less "insane". - There is increasing  
 'difficulty in thinking and of percep-  
 'tion; the muscular activities become  
 'so irritable and may be uncon-  
 'trollable that many such patients have  
 'to be sent into an asylum. - In its  
 'extremest forms it ends in coma. -  
 Dr: Savage has often impressed upon  
 'me the great importance of recog-  
 'nising the relation between anaemia  
 'and insanity." (Lectures on Medical Pathology  
 by H.G. Sutton F.R.C.P. 1886. p. 190.) -

All know how common is anaemia,  
 especially among boarding-school girls. -  
 - It is produced or aided at these schools  
 by a combination of conditions already  
 alluded to. - Want of fresh air; want

of light; want of exercise; want of sleep; excess of brain work and worry attendant on preparation for examinations, which leads many not only to work excessively hard during the long school hours, but also to devote much of their leisure time to extra study, and to wake in the night and grind at their books instead of sleeping. -

Study requires brain change - Chemical processes going on in brain tissue; and for this we must have a good supply of blood. - When a girl becomes anæmic, especially when she is placed in such circumstances as the above, it is obvious that the sixth of the total blood of the body which goes to the brain must no longer be allowed to have its goodness used up by excessive functional activity of that organ; ~~must~~ must the brain be endangered by being made to work hard on poor food. -

- It is sufficiently clear in extreme cases of anaemia, unless we court insanity or other breakdown, that country air, sunshine, and gentle exercise, with light and pleasant-mental occupation, must be substituted for the conditions above mentioned. - as an examination approaches a girl is most likely to become rapidly more anaemic, and no doubt there is much temptation to both girl and mistress to continue working till the examination is over. - But consider the risk: - Malaise attendant on anaemia, with its neuralgia, disturbance of gastric, intestinal, and uterine functions, is bad enough to balance any good results likely to accrue from passing the examination; and when we contemplate the risk of insanity, phthisis, and similar catastrophes, the absolute necessity for taking precautionary measures becomes obvious. -

Short, however, of extreme anaemia, we may have all degrees of poverty of blood, and Sir J. C. Browne suggests (loc. cit. 291), that at no very distant period, we shall be able, by counting the red corpuscles, to say just to what extent mental work should be allowed, and when it should be, for a time, entirely discontinued. - I would suggest that more serviceable results are likely to be got from the use of the haemoglobinometer than from that of the haemocytometer, for the improvement in symptoms in anaemia bears a precise ratio to the increase of haemoglobin under ferruginous treatment, while the number of the red corpuscles may or may not increase with it. - Arsenic too, sometimes at least, increases the number of red corpuscles without affecting the haemoglobin percentage; the symptoms in these cases being but little modified. -

whichever method were finally approved, or by using both in combination if necessary, it is clear that a great boon would be conferred upon the rising generation of girls, their parents, their future husbands, and children, - in fact upon society, - if some easily determinable limit were fixed by a competent commission, below which mental work should be for a time abandoned, and for less profound cases, a scale of the number of hours of study and of outdoor amusement or exercise deemed necessary to arrest further downward progress and permit of gradual improvement under suitable treatment.

Having now spoken of the blood supply of the encephalon and its variations, I turn to a consideration of the brain as a mental organ, and ~~its~~ the probable nature of its action in education. - In so doing

I propose, for the sake of clearness, to consider, as much as possible, in order, (I.) hemispheres and areas, (II.) intimate structure, (III.) development, and (IV.) the differences in male and female brains. - In each of these departments we shall, I believe, find some practical bearings on educational matters.

I. The Brain considered in relation to its Hemispheres and Areas. -

- We have already concluded (p: 14.) that the brain is the organ of the mind, and that we may, for all practical purposes, say, that the mind is located in it; for if the mind only expresses itself through the brain, we cannot trace it beyond the cortex. - In carrying our enquiry a step further, three different positions present themselves. - We may adopt

- (1) Flourens's doctrine (Système Nerveux. 1840. p: 99 + 101.) that the whole of the cerebrum is concerned

ed in every intellectual act. -

(2) Vulpian's "Loi de suppléance" - law of functional substitution of parts. (Leçons sur la Physiologie du Système Nerveux, 1866.)

or (3) We may be inclined to believe that each intellectual acquisition and operation is definitely located in certain part or parts of the brain. -

- It is unnecessary here to take up each of these separately. - An impartial enquiry, taking into consideration the latest additions to our knowledge of cerebral physiology, leads us to adopt, it may be in a modified form, the third of these views. -

"Up to a comparatively recent date, if we except the cumbersome 'cross divisions and fanciful localisation of "faculties" of the phrenological system, the results of experimental physiology, and human pathology, may be considered as opposed to the localisation of special

'psychical functions in distinct re-  
'gions of the cerebral hemispheres'.

(Ferrier - "The Functions of the Brain, 2<sup>nd</sup> ed.  
Edit., 1886. p. 221.)

Modern physiological research, however, confirmed by clinical and pathological observation, has ever tended, and is still tending to map out the brain's surface into areas, each having a distinct function; and for some time past it has been pretty generally held that we had reason to suppose the prefrontal lobes to be mainly concerned in processes connected with volition, and the occipital lobes and adjoining convolutions in certain exercises of memory, emotion, idea-  
tion &c. —

It having been found that certain parts of the cortex had a motor, and certain other parts a sensory function, it was not unnatural to suppose that other regions were dedicated to intel-  
lectual operations, and that these were the parts in which a lesion might

exist without causing any motor or sensory symptoms.

In the prefrontal, the temporal, and the occipital lobes, a lesion may exist without causing sensory or motor disturbance. - "It is here", says Gowers, (*Diseases of the Brain* 1884, p: 34.), "that we must look for the higher intellectual operations." - "These parts, whatever other connections they may have, seem to be connected with each other through the ~~downward~~ Cerebellar hemisphere of the opposite side", by the downward path from the frontal region and the upward path to the temporal and occipital lobes. "This very curious fact revives the old idea, that the cerebellum is, in some way, connected with intellectual processes - an idea suggested by the proportion the cerebellar hemispheres bear to intellect as we ascend the scale of animals." (Gowers op: cit, p: 34.) - Here also, in the Cerebellar hemispheres, we may have a lesion without motor

or sensory symptoms, as has been shown by Nothnagel, provided there be no pressure on the middle lobe. -

- The same is true of the two parts of the Corpus Striatum, if no pressure be exercised on the Internal Capsule. - Moreover both parts have an extensive connection with the opposite cerebellar hemisphere, and none with the Cortex. (Gowers *op. cit.*, p. 36) - These points favour the idea that the Corpus Striatum also may have an intellectual function. - "It seems 'probable', says Gowers, "that the 'two parts of the Corpus Striatum' are central organs analagous to 'the cortex itself.'" - The case is somewhat different with the Optic Thalamus. - It has connections with all parts of the cortex, and is "probably concerned in some of 'the higher reflex processes,' and may also, as has been recently suggested by Hamilton, have an important function in connect.

ing the sense of sight with the other senses. -

We have been considering parts in which lesions may exist without giving rise to motor or sensory disturbance, and concluding therefrom that their functions were probably intellectual. - It is, however, to be noted that lesions may exist in these regions without causing any noticeable intellectual disturbance. - This at first sight grave difficulty is however lost when we remember that physiologists of the Nervous System have come to the conclusion that "the psychical activities appear to be located in both hemispheres, so that after the destruction of a considerable part of one of them, the other seems to act in place of the part destroyed." (Lauder's Physiology - Stirling - II. 903.) -

Returning to the fact that lesions may exist in these parts without causing any sensory or

motor symptoms, we note further that this state of things is not invariable, and that more recent experimentation finds that the occipital lobe has important functions in relation to the sense of sight; "in order to cause complete and permanent loss of vision in both eyes it is necessary to extirpate both angular gyri and both occipital lobes." (Ferrier op. cit: 272.)

- It is also found (Ferrier p: 396) that though, as a rule, "a total absence of discernible symptoms" has followed destruction of the prefrontal regions in monkeys, yet in one case, "in which the paralysis of the lateral movements of the eyes following (a partial p: 397) lesion of the postfrontal centres had completely disappeared, the destruction <sup>also</sup> of the prefrontal region caused symptoms which though transient were of great significance." "There were rapid oscillations of the head, apparent inability to turn the

'head, except in unison with the trunk  
'and drooping of the opposite (right) eye-  
'lid," "By the third day, however, all  
'these symptoms had disappeared, and  
'from this time onwards the animal  
'exhibited no defect either as re-  
'gards its powers of motion or sensation."

"These facts indicate that the  
'prefrontal regions belong to the same  
'centres as the postfrontal, just as  
'the occipital lobes belong to  
'the visual centres." (Ferrier *q. cit.*: 397.)

In addition, recent research  
has fixed an auditory centre in the  
superior temporo-sphenoidal region  
convolution (Ferrier 310), a tactile cen-  
tre in the hippocampal and inferior  
sphenoidal region (Ferrier 333), and also  
in the gyrus fornicatus (342), centres  
for the trunk muscles in the near-  
ginal convolutions (Horsley and Schäfer  
- Proceedings of Royal Society *No.*: 231. March 1884.)  
& *et.* - In fact, recent localisation  
goes far to show that there is prob-  
ably no part of the cortex which

is not either sensory or motor in function: "the conclusion has been 'arrived at' (Ferrier op. cit. p: 424) "that 'the hemispheres consist of a system 'of sensory and motor centres."

Ferrier in the first edition of his work (1876) comes to a similar conclusion (p: 255), - "that the brain is a complex system of centres of motion and centres of sensation". - Though this position can hardly be said to have been proved then, extensive experiments on animals and observations, clinical and pathological, on man in various parts of Europe since that time, have adduced abundance of evidence in support of, and none which contradicts, such a conclusion. -

This being the case, and it having been already admitted that the cortex is the organ (or "the seat") of the mind, we are led to conclude that mental operations, the higher as well as the lower, must be carried

on in areas which are either sensory or motor; and though it were possible to conceive a double set of cells all over the cortex, one set with a physical, the other with a psychological function, it is more satisfactory, more economical, and certainly quite as possible, to suppose that each cell has a mental as well as a physical function; that "as has been clearly enunciated by Hughlings Jackson", - "Mental operations in their last analysis must be merely the 'subjective' side of Sensory and Motor substrata". (Ferrer op. cit. p. 425-6.). -

Such an idea is by no means new. - Here is a quotation from Democritus (460 - 494 B.C.), which I take from Draper's "Intellectual Development of Europe" (Vol. I. p. 120); - "Sensation constitutes thought, and is at the same time but a change in the sentient being."

It is unnecessary to enter into other reasons which lead to the

adoption of this view, and for the argument which leads to the conclusion that sensation, emotion, and the greater part of recollection and ideation are mental processes represented physically in sensory areas, while motor areas are the physical bases of volition, self-control, and direction of thought, I must refer to Ferrier (op. cit.: Ch: III.) - The subject is too long for a parenthesis, and a full discussion would lead too far from my main theme. - This conclusion, it is interesting to note, confirms the older and more empirical ideas as to the functions of the prefrontal and occipital lobes. -

Without entering into argument, some explanation seems desirable. - With regard to the sensory areas, "each is the substratum of the consciousness of its own special sensory impressions, and each is the organic basis of the memory of such impressions, in the form of certain cell func-

ifications, the reinduction of which is the representation, or revival in idea of the individual sensory characters of the object." - "The organic cohesion of these elements by association, renders it possible for the re-excitation of the one set of characters to recall the whole". - "This organic memory is the physical basis of Retentiveness, and the property of re-excitability is the organic basis of Recollection and Ideation" (Ferrier op. cit: 427.) - Therefore "the organic basis of memory of sensory impressions is the fundamental basis of knowledge". - We have thus found a physiological foundation for the conclusion arrived at from other grounds by Bain (Mind and Body p. 89.), that "the renewed feeling occupies the very same parts, and in the same manner as the original feeling." - Herbert Spencer too, concludes that the renewal of the feeling is "the faint revivification of the same processes ~~processes~~ which are

'strongly excited by presentation of the object.'

-To find a "physiological foundation" for an opinion reached by these philosophers is, of course, a strong addition to their arguments; and though above we have confirmed Bain's views only, and not Spencer's in its fulness, Professor Draper of New York (Human Physiology - 2<sup>nd</sup> edit. 1858 - p. 401) believes that if, owing to abnormal excitability, the revivification of molecular disturbance be as strong as the original disturbance, hallucination, instead of natural recollection or ideation, results. -

-Turning now to the motor centres; they have an intellectual as well as a physical function, being the organic basis of motor acquisition, and of volition, apparent and also real. (Ferrier op. cit. 461.) -

- In the scale of animals we note that as volition predominates over conscious automatism, do the

powers of special motor acquisition become extended. - In the same proportion are the cortical motor centres developed, and are the powers of movement abolished by their destruction. - In the same proportion (Ferrier *op. cit.*: 435) "is education necessary to perfect the powers of movement."

In man all these points culminate. - In him apparent automation "is scarcely detachable from the centres of consciousness and volition," (Ferrier *op. cit.*: 435), - and is only arrived at by long and laborious education. - A special motor acquisition is at first difficult to acquire; repetition renders it easier; and eventually, volition, if not absent is no longer a recognisable factor: - destruction, however, of the motor centres involved reminds us of its true nature by abolishing it. - How different this from the case of a rabbit, where removal of the

lowly developed motor cortex "exercises but slight and transient disturbance of the ordinary modes of action" (Ferrier op. cit. 435). - The rabbits "ordinary modes of action" are automatic and remain, while its few voluntarily acquired motor acquisitions are destroyed; - in man the "ordinary modes of action" are voluntarily acquired, i. e. are the result of education, and all are lost.

Now, though the motor centres have an intellectual function, being the organic basis of volition, they have no subjective side apart from the sensory centres with which they are associated, and "we have no idea of movement apart from the sensory centres through which alone the activity of the motor centres is revealed in consciousness." - "The organic cohesion formed between the sensory and motor centres, persistently enduring in these centres, is then the physical basis of our intellectual and volitional acquisitions

'in all their manifold range and complexity' (Ferrer op: cit: 486). -

Thus the purely intellectual faculties, i.e Retentiveness, ideas of difference and of similarity (Brain-Mind and Body" p: 88.), have no circumscribed habitation in the brain, but, for example, a special "representation or idea" of an object, say an orange, "is the associated re-excitation of the permanent cell-modifications in each of the special sensory and motor centres primarily engaged in the act of cognition." - From this we see (Ferrer op: cit: p: 438), that "there is practically no limit to the number of associated combinations of sensory and motor elements, and this is the organic basis of all intellectual and volitional acquisitions."

Here then we have something tangible, for although it seems clear that there can be no volition unaccompanied, provided all connecting tracks are healthy, by muscular movement;

though motive for the exercise of volition may be induced by activity in the sensory centres; though attention is accompanied by, and intimately connected with, movements, especially of the head, eyes, and mouth, (the centres being in the prefrontal and postfrontal regions); yet we can voluntarily, "by adapted voluntary movements", "indirectly" call up sensations and ideas. - (Terrier op. cit. 461.) -

- Intellectual education is similar in its nature to motor acquisition - Speech, writing, + etc; are special motor acquisitions; by these and other voluntary movements the various senses are brought into contact with the subjects of education. - Thus, by an exercise of volition, the organic basis of knowledge is gradually built up, strengthened by repetition, and eventually, in matters in which the repetition has been sufficiently repeated, becomes apparently automatic. -

- From the above considerations we have physiological grounds for insisting on the thorough education of the senses and motor powers as being a most important factor in good intellectual education. -

Returning again to the localisation of functions, we have still some important considerations remaining, which for their explanation require more theorising than is altogether satisfactory. -

The physiological and psychological activities of the hemispheres we have seen to be very intimately connected. - They are "not however, altogether coextensive. - While consciousness cannot arise apart from the activity of the hemispheres, many cerebral processes can occur without 'revealing themselves in consciousness.' (Ferrier op. cit. p. 26.) - In consideration of the above explained apparent automaticity of the cerebral workings, and other matters to which it

would be irrelevant here to allude, very little difficulty is presented by this well-known fact. - The position is however altered with regard to the further difference already alluded to, that "the brain as an organ of motion and sensation, or presentative consciousness, is a single organ composed of two halves; whereas the brain as an organ of ideation or re-presentative consciousness, and we may here add of volition," is a dual organ, each hemisphere complete in itself. - When one hemisphere is removed or destroyed by disease, motion and sensation are abolished unilaterally, but mental operations are still capable of being carried on in their completeness through the agency of one hemisphere: - the individual can still feel and will and think and intelligently comprehend with the one hemisphere" - "If these functions are not carried on with the same vigour as before, they at least do not appear to suffer in respect

'of completeness' (Ferrier op. cit. p: 426.). -

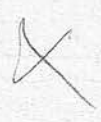
Although the above well authenticated condition seems at first sight to favour Flourens's doctrine that the brain as a mental organ acts always as a whole, and though it is undoubtedly a stumbling-block to the theory of universal localisation, it is not very difficult to see that, as we are provided with bilateral sensory organs which we use as a rule in conjunction with each other, we shall generally have a duplicate register in the brain, and that mental operations are carried on in both hemispheres simultaneously, partly perhaps by help of the Corpus Callosum. -

A further difficulty however presents itself in the fact that the same parts of both hemispheres have been removed without more than transient symptoms. - All seem to agree that removal of both prefrontal regions in dogs produces various

degrees of stupidity (Hitzig in *depos - archiv für Psychiatric Bd: XV - p: 271; - Goltz - Pflüger's Archiv Bd: XXXIV. 1884.*). - Horsley and Schäfer noticed signs of stupidity "for a time at least after the operation" in monkeys whose prefrontal lobes had been removed, but Ferrier (*op: cit: 402*) could not satisfy himself "as to the existence of any appreciable ~~de~~ mental deterioration" in cases in which the lesions were strictly limited (under antiseptic precautions) to the prefrontal regions, though he could where the frontal lobes as a whole were implicated. -

We have seen that for the complete abolition of sight we must remove both angular gyri and both occipital lobes; we have also concluded with Ferrier (*op: cit. p: 397*) that "the prefrontal regions belong to the same centres as the post-frontal, just as the occipital lobes belong to the visual centres." - Bearing this in mind it is perhaps not

too extravagant to assume that there may be on each side of the brain a double register both of sensory and motion acquisitions, and that the destruction of any limited area on both sides still leaves a bilateral register of the same acquisitions as those recorded in the parts destroyed. - Failing this, to which there are grave objections, it would seem that, for the present at any rate, we must still hold on to a modified acceptance of Pulpian's law of functional substitution; though whether, under certain circumstances, the Cerebellar lobes may play a part as supplementary organs to fall back upon, is a possibility not disproved. - The Cerebellum alone is no good as a mental organ, but there are various reasons to make us believe that it may have some intellectual function. - Returning from the hazy fields of theory, we must always remember that each piece of knowledge has been noted



and registered probably by several senses, and though the destruction of the sight centres on both sides would abolish the possibility of receiving the appearance of an object, say an orange, we should still have an idea of its taste, size, shape, consistence &c., through records left by impressions got through the other senses. -

- This gives a physiological explanation for the fact, long known though not usually acted upon, that, to insure the best chance of recollective power and ready reference to acquisitions, all study should be conducted through as many sensory channels as possible. -

- Now though the two halves of the Cerebrum act each as a complete psychical organ, we have reason to suppose that, in each individual, one hemisphere takes the lead. ~~xxxx~~ - The frequency with which aphasia follows lesion of the post-

erion end of the third left frontal convolution where it overlaps the island of Reil <sup>Reil</sup> indicates this at least, that ~~the~~ certain bilateral movements are, in some instances, presided over by cells in one side of the brain, and that in right-handed people the left hemisphere is the leader. -

- A very curious and interesting fact, which, from a wholly different point of view, tends to the same conclusion (that in most people the left hemisphere is the leading one) is noted by Bastian ("The Brain as an Organ of the Mind" 3<sup>d</sup> edit, 1885, p: 681), viz, "that the specific gravity of the cortical grey matter of the brain in the left frontal, parietal, and occipital regions is often distinctly, though slightly, higher than that from the corresponding region of the right hemisphere." -

- The subject of either handed education might be appropriately introduced here, but inasmuch as

its discussion involves certain points which have yet to be considered, I have resolved to postpone its discussion till later. - (p: 79.)

## II. Intimate Structure of Cortex.

Hitherto in looking at the brain as a psychical organ, we have considered it in relation to its hemispheres, which we have divided only into areas. - In the prosecution of our enquiry as to how the brain acts as an organ of the mind, and as to the changes effected in it by acquisition and education, it will now be necessary to look into its minute structure, and see, if we can, how the processes above alluded to are carried on. -

- all over the cortex we have the same elements which alone can be concerned with the psychical as well as the physical functions of the brain: - Cells, many of them branched by which they are joined to the branches or prolongations of other neighbouring

cells; some of these branches coalesce into fibrils, and these into fibres of which some go to the peripheral nerves, and some to other parts of the brain. - Our two nervous elements we may then set down as cells and fibres, and to these we may add, as being essential to their action, bloodvessels, -

If we apply electrodes to a motor area in the cortex, what follows? - (1.) Hyperaemia, and (2.) Muscular movement according to the area stimulated. - The hyperaemia is, as already noted (p:18.), essential; i.e. unless the electrical stimulation produces hyperaemia, neither does it produce muscular contraction. - What then is the nature of the activity produced in the cortex by this stimulation. - It is not electricity (Ferrier op: cit: p:227), but there is a liberation of nervous energy in the cells of the cortex which travels down by the

Corona Radiata, Internal Capsule &  $\pm$ : to the nerves and muscles, and this energy we believe to depend on chemical changes between the nervous tissue and the blood, and to be of the nature of a molecular disturbance originating in the branched nerve-cells. - Similar changes we believe to take place in the cells of the cortex in all sensory, motor, and mental processes. -

- Mental operation and association we believe to be effected through groups of nerve cells, each cell being connected by its processes with some or all of the cells of its group; the group being connected by fibrils and fibres with other groups in adjacent and more distant parts of the brain. - The molecular disturbance in cells which accompanies all sensory and motor impulses, and consequently (p: 37-8) all mental operations, passes along the processes, fibrils, and fibres to other cells and other groups. -

- Bain (Mind and Body p: 91) concludes

that the mechanism of retentiveness consists in cell-junctions. - "For every act of memory, every exercise of bodily aptitude, every habit, recollection, train of ideas, there is a specific grouping, or coordination, of sensations and movements, by virtue of specific growths in cell-junctions" - Bain estimates (op. cit: p: 107) that the cortex contains at least 1,200,000,000 cells, (this figure has been largely quoted, though Gowers [Diseases of the Brain p: 1] puts it at 800,000,000), and 4,800,000 fibre-junctions, and goes on to show that, "with a total of 50,000 acquisitions evenly spread over the whole of the hemispheres, there would be for each nervous grouping at the rate of 20,000 cells and 100,000 fibres", and that with a total of 200,000 acquisitions "which would certainly include the most retentive and richly endowed minds, there would be for each nervous grouping 5,000 cells and 25,000 fibres". -

Now though we have already seen that in most matters there is prob-

ably a ~~duplicate register~~ simultaneous register in each hemisphere, and possibly a duplicate register in each hemisphere, and though we may be inclined to think that large parts of the cortex have little or nothing to do with mental operations, we must all admit that there is at least ample provision for a mechanism of the nature indicated, as, if we take the parts of the cortex concerned in mental acts at only one tenth ( $\frac{1}{10}$ ) of the whole surface, we shall still have for each acquisition 500 cells and 2,500 fibres, and in less richly endowed minds, as of the first type cited, 2,000 cells and 10,000 fibres. -

When we examine an adult cortex with the microscope we find a large number of branched cells, but also many simple round ones; and when we examine the same part of the brain of an early foetus we find that all the cells are the simple ones of embryonic tissue, without junctions or

groupings. - If we look, between these two extremes, at the brain at birth, we find a very large proportion of the cells unbranched (See J.C. Browne loc. cit. p: 288), and again at the end of the seventh year "the inner and finer structural development of the organ is, in all its higher tracts, still in a comparatively embryonic condition." (Bastian "The Brain as an Organ of the Mind" 3<sup>d</sup>. edit. 1885 - p: 376). -

- We thus see that there takes place during growth from birth to maturity, and in all probability in a more active and specialised manner after the age of seven (see p: 73), an alteration in the form and shape of many of the cells, which become branched and form groupings with other cells. -

- Though some may be inclined to think that education consists largely in the establishment of "lines of least resistance" (Gowers - op. cit. p: 6) in nerve paths already formed, and though this may be an important factor, it seems probable, from the physiological grounds

just alluded to, as well as others which I shall adduce, that the theory of acquisition and retentiveness enunciated by Bain and quoted above, represents to a large extent the true manner in which the brain acts as the physical basis of these operations; i.e. that in the process of acquisition cells, as well as undergoing molecular disturbance, develop and shoot out processes which join those of other cells, and that further stimuli along the newly formed lines of physical association, are accompanied by a physical strengthening of the connection.

That, at the period of birth and for ten days subsequently the motor cortex of dogs is not stimulable by electricity though the medulla and nerves are (Soltmann - Jahrbuch für Kinderheilkunde 1876.); that, at the same period, as "all competent observers agree" (Clouston loc. cit. p. 37), a child is absolutely devoid of mind, for though

at this period the apparatus for several automatic or reflex acts such as crying, sucking, and breathing, is perfect or nearly so, we have no true evidence of sensation or any psychological phenomena whatever; that we can note by gradual degrees a growth of mental faculties, the earlier manifestations of which have been carefully worked out by Taine and by Darwin; that, at the same time, we can observe the above mentioned changes in the cortex; - all lead us to believe that mental acquisition is accompanied by physical growth in the cortex. -

- Probably the natural stimuli applied to the peripheral organs of sensory nerves from the period of birth onwards, gradually produce changes and junction-growth in a few of the cortical sensory cells, and following this natural stimulus to growth we get changes in groups of motor cells, thus forming a primitive sensori-motor chain. - New impressions and ac-

quisitions are tacked on to old ones by growth originating in, and proceeding from, already modified cells. - If this be true, we have a physiological reason for the well-known fact that, if in acquiring knowledge we wish it to be retained and well organised, we must be careful in teaching to supply along with the new knowledge, links connecting it with matter previously known, and that in proportion as knowledge is thus organised, will it be serviceable for future reference. - Our theory also explains how time allowed for learning and thorough consideration of the matter in hand, becomes an important factor in forming good associations, and how repetition strengthens such associations and facilitates their recall. -

- Two curious, though sufficiently familiar phenomena, neither of which have, so far as I am aware, received any very satisfactory explanation, may I think be explained

ly the views now under consideration, and if so certainly tend to strengthen the probability of its truth. -

(1.) a man walks along a street A, turns into another B, and then into another C, in which a slate falls onto his head and he is stunned. - When he recovers consciousness he can recollect all the events of the day up to his being in the street A, but nothing further. - Now for the growth of a physical connection, rapid though it may be in an organ specially adapted for rapid growth, as the brain is by being already stocked with cells ready to evolve, and by its unrivalled blood supply, a certain amount of time is necessary, and I assume that the shock producing concussion (probably a molecular alteration of structure which gradually rights itself when rest is afforded), suddenly arrests the growth in the cells and fibrils which had been most recently stimulated to growth, or

actually breaks the most newly formed and consequently most delicate connections.

(2.) Many, indeed most people have, at one time or another, experienced a curious sensation - a kind of indefinite recollection of having been placed at some period or other in circumstances and surroundings the precise parallels of the present, when on consideration it is evident that the present combination has in reality not been previously experienced. - It is to be noted that such recollections are always vague, and it will I believe be found, on looking carefully into the facts of such cases, that they occur on arousing from a somewhat listless condition to one of greater mental activity. - For instance, I was lying with a companion in the sunshine on a hillside in a somewhat drowsy condition; suddenly my companion came round from a similar mental attitude, and

said "Does it not strike you that you have been in exactly in this position before?" - It did not strike me, so he continued "It does me though - just this hill - the same sunshine and the same clouds - the same sound of water - the same cottage down there - and you here - some time or other, I don't know when." - as a matter of fact we never had been together in circumstances at all similar. - The explanation I offer is this: - while in a somewhat drowsy condition the various senses were taking cognisance automatically, cell modification was going on and cell-junctions being formed; but, owing to the general inactive state of the mind, time and other special localising points had not been noted; - then suddenly the attention is aroused to the surroundings, and by voluntary observation, we find a hazy record already formed, and attribute it to some remote period.

-This seems to me a more satisfactory explanation than that which attributes such feelings to an asynchronous recording in the two hemispheres. -

### III. Development of Brain.

I have already alluded to certain points in the development of the brain as evidence of the probable nature of the physical changes in that organ accompanying acquisition and education. - It is now desirable to consider certain others as tending to throw further light on the connection and relations between mind and brain. -

Looking at the brain of a six months old foetus, we find the surfaces smooth, but the fissures are appearing and mapping it out into lobes, though as yet there are no convolutions (Bastian op: cit. p: 342). -

-Thence onwards development is rapid, and at birth the brain is divided by all the principal fissures and sulci

into lobes and convolutions, but the secondary convolutions which differ in each individual, and which if more numerous and more tortuous than usual give rise to that high degree of convolutional complexity, indicating of course greater surface area, which has been found very commonly to be associated with high intellectual attainments (Bastian *op. cit.*: Ch. ~~XXI~~), "are formed during childhood and youth, but how late their development may go on we are as yet unable to say" (Dr J.C. Browne *op. cit.*: p: 287). -

This convolutional complexity, or as Ferrier puts it, the secondary differences of convolutions, occur mainly in the frontal lobes (Ferrier *op. cit.*: 466), but ~~to~~ when the frontal convolutions are very complex, the secondary convolutions are better developed all over. - Ferrier also ~~states~~ states that the frontal lobes are less highly convoluted in the female type of brain than in the male, though many recent brains

exhibit a female, and many women's brains a male type. -

- If, in thus examining the cortex from the more general to the more particular, we note that, as we get to smaller divisions, the differences between individual brains becomes more marked, we may with some confidence assume that, were we able to carry our examination further, and note the differences in the cell groupings of which the cortex is made up, we should find even greater differences, the groupings being both more numerous and more complex in brains belonging to more highly endowed minds; and that, in taking male and female types of brain, we should find more marked differences than are evident in examining merely the convolutions, between what we may regard as the physical bases of their intellectual capacities. -

-Gratiolet and Marshall, and others as Thurman, have shown how civilization and national education increase the size, weight, and convoluted complexity of the brain; and coming to the brains of individual adults, we find, though there are notable exceptions, that high degrees of education and mental attainment are, as a rule, accompanied by brains which are large, heavy, and rich in secondary convolutions, while brains which are notably small (under thirty-two ounces) belong to individuals whose mental powers are markedly deficient. -

- Much stress has been laid by some upon the inutilty of the weight of the brain as any indication of mental capacity unless compared with that of the body. - Though very light brains occur almost exclusively in idiots; though many men of great mental power have been found to have ~~had~~ unusually heavy brains;

though civilisation certainly increases the average brain weight of a nation; yet in view of what I have next to speak of viz: - the early development of the brain as regards its weight - it would seem that the mere weight of the brain, whether compared with that of the body or not, can at any rate only be taken as an indication of intellectual possibilities. - Such a view, while in itself entirely rational, easily explains all those anomalies which have thrown sand in the eyes of those who try to discover relationships between mental capacity and brain weight: - we must also bear in mind that we are neither able to thoroughly compare the thickness and weight of the cortex alone, nor to compare those minute differences of structure which, if we could compare them, would probably prove by far the most important item in gauging mental capacity from

## Examination of the brain. -

- I come now to a point in connection with cerebral development which should, I think, yield some pretty clear indications with regard to Education, and which is, in addition, a further argument as to the probable truth of the of the theories of brain change in education above advocated. -

- "It was believed by the earlier anatomists, and even by Tiedemann, and Sir William Hamilton, that the human brain attained its greatest development about the seventh year. - We now know this to be incorrect, yet from the extensive researches of Dr. Boyd as tabulated by Thurban (Journal of Mental Science 1866), it would appear that it does in the male actually reach about five sixths ( $\frac{5}{6}$ ) of its ultimate weight by the end of the seventh year, and in the female about ten elevenths ( $\frac{10}{11}$ ) of its ultimate weight by the same period." (Bas-

tion. op: cit: p: 867). -

- Thurham (Journal of Mental science 1886) in his conclusions, states, however, that "it may in general be admitted that the average weight of the brain undergoes a progressive increase to somewhere between the twentieth and fortieth year." - According to the tables at his command the greatest average weight of the male brain was between the ages of thirty and forty, and this as Broca observes, agrees perfectly with what we know of the continued growth of intelligence during the whole of this period." - "For women the full average size of the brain is perhaps attained between the ages of twenty and thirty, but the differences between the two sexes in this respect is not great."

- Here then we have a somewhat remarkable fact, which, if it were not carefully established, we should hardly be able to credit. - Judging from the size of childrens heads,

as indicated by their hats, as well as from their mental powers, we should certainly not conclude that their brains had, by the age of seven, reached five sixths or more of their eventual weight at maturity; a condition which could, I imagine, hardly be stated of any other important organ, while the body as a whole is at the age of seven seldom more than one third, and often much less than that, of its eventual weight. -

- This being, however, an established fact, we see that in later childhood and youth the blood supply to the brain, and especially to the cortex, is, in proportion to the rest of the body, much greater even than has already been shown to be the case in adults (p: 15). -

- I now turn to a point already quoted (p: 58), viz: that "at the age of seven the inner and finer structural development of the brain, is, in all its higher tracts, still in a con-

'paritively embryonic condition'. (Bastian op. cit. p: 375). - It could indeed scarcely be otherwise; development hitherto has been too rapid to be very complex. - We have seen that there is, after this age (seven), a gradual though slow addition to the weight of the encephalon, and that there is a continuing alteration in the shape of the cortex in the formation of secondary convolutions and sulci thus extending its area: there must be, then, after this age, great changes going on in the cells and their groupings. - It would seem that the general growth of the brain up to this time has been exceedingly rapid in order to allow a larger share of the splendid blood supply to be devoted after this to the formation of special groupings of cells corresponding to special acquisition and education generally, thus agreeing entirely with Bastian's idea that this acquisition and mental association,

- the extension and "recompounding" of elementary groupings which he believes to take place in all special acquirements, - is the most expressive of all the bodily functions. (Education as a Science p. 13.) - Practically we know that the periods of later childhood and youth are those when special acquisition is most easy. - It is curious to note that eight hundred years ago the great Arabian philosopher Algazzali fixed the age of seven as that at which "understanding" begins. -

- We have here what seems to me a pretty clear physiological indication as to Education: - as before the age of seven brain growth is mainly general and later special, our efforts to direct it should be in strict accordance with these facts; in other words that special Education should be commenced at seven years of age. -

- It is evident that during the

first seven years of life the ac-  
 tual growth of the brain must  
 be very active. - From birth to  
 two years of age the brain increas-  
 es two and a half times its own  
 weight. - In so rapidly growing  
 an organ, whose perfect growth  
 is so essential, it is clear that no  
 additional claim should be made  
 upon its blood supply by an attempt  
 at educational forcing, which, if  
 successful in any one direction, must  
 necessarily be at the expense of some  
 other or of the general growth. - More  
 especially when we remember that all  
 psychologists, educationalists, and physio-  
 logists agree that "intelligence and  
 mental power, as a whole, will  
 largely depend on the relative bal-  
 ance or development of one part as  
 compared with another" (Ferrier op.  
 cit. p. 468), does it become evident  
 that we should on no account  
 risk the stunting of general growth  
 by early special education. -

- If however, before the age of seven, we leave the brain largely to itself, merely giving it ample opportunity of having its sensory and motor centres exercised in as varied a manner as possible and cultivating the powers of observation and inference in the general, we may then with some confidence expect to find a fertile soil in every part for processes more purely educational. -

- We have seen already that development and growth appear to go on in the brain till between thirty and forty years of age, and if we agree that mental acquisition and association is always accompanied by physical growth in the brain, it is clear that there must be some growth, though perhaps no addition in weight, after the age of forty. - at the same time it is very probable that the weight of any given brain at forty five

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years of age is only very slightly greater than that of the same at twenty-five. - It is also certain, if we may judge from the blood-supply and the general economy with which the body is arranged, that, in common with other organs there is active growth in the brain between the ages of seven and maturity, and, as we have seen the increase in weight during this period to be insignificant, it is fair to assume that the early age at which the brain reaches five sixths of its ultimate weight is a special provision to allow of the blood supply being used between these ages in that "most expensive of all bodily processes", the forming and strengthening of the cell-connections which are the basis of our mental life. -

- The above facts tend to lessen even our previous estimate (p: 69) of brain weight as a measure of intellect. -

- Before leaving the subject of development, there is one point which must be alluded to. - It has been shown that the various motor centres, as well as the various intellectual faculties, have their own periods of evolution. - In cases of the congenital absence of a limb, the cerebral convolutions which represent its motor centres do not develop, whereas in amputations of the leg, though we get atrophy in the lumbar re-arrangement, we get more in its cerebral motor area. -

"These facts, that cerebral centres never properly exercised do not develop, and that once developed they are not so liable to waste on the withdrawal of their appropriate stimuli, or where they are cut off from their natural activities, strongly inculcate the importance of educating every centre at its nascent period, and the danger of postponing education till the nascent period is

'over.' (See J. C. Browne loc. cit. p. 329.) -

- I here take up the subject of ambidextrous education alluded to p. 52. -

- The development of knowledge regarding aphasia has naturally led many to contemplate the possibility of utilising apparently wasted areas of cortex on the right side of the brain, by educating both hands equally in writing and in other movements. - As a matter of fact those parts of the right cortex concerned are not lying dormant, though their functions are not so highly specialised as on the left side: - lesion in the third left frontal convolution gives motor aphasia but not loss of the power of mastication. - The left hand has two, as Lister has observed, functions especially its own, and is not more clumsy in the use of a knife than the right hand is in that of a fork. -

- Without entering into an

Exhaustive discussion of the ques-  
 tion, I cannot do better than quote  
 what Sir J. Crichton Browne says of  
 it in his essay on Education and  
 the Nervous System (Book of Health p:  
 331.) — "To undo right-handedness, we  
 'should have to alter the foundations  
 'of the brain architecture laid down  
 'at a remote period when a dif-  
 'ferentiation in the use of the two  
 'limbs first commenced. — And ev-  
 'en could we gradually retrace our  
 'steps, and by laborious efforts get  
 'rid of dextral preeminence, we should  
 'be working counter to true progress;  
 'for it is to be borne in mind that  
 'the two sides of the brain, which  
 'have their convolutions arranged  
 'with perfect symmetry in the lower  
 'animals, become more and more a-  
 'symmetrical as we advance in the  
 'scale of being, and that they are  
 'more asymmetrical in the civilised  
 'than in the barbarous races of man-  
 'kind, and in men of great intellect-

'ual attainments than in men of  
 'average mental power. - and it is  
 'also to be borne in mind that dex-  
 'trial preeminence, which is only faint-  
 'ly foreshadowed in some of the lower  
 'animals, becomes also more and more  
 'marked as we ascend in the scale  
 'of being, and is most marked of  
 'all in those races who have brought  
 'the arts to the highest perfection." -  
 - Either-handedness though common  
 to all children is "never" seen among  
 educated adults, "but is very gener-  
 'al among idiots, in whose training  
 'one of the great ~~est~~ difficulties is to  
 'get them to use one hand in prefer-  
 'ence to the other, in sewing, or in any  
 'manual occupation to which they may  
 'be set." -

-There can be little doubt that any  
 attempt at general ambidexterity is  
 a mistake, but this does not fully dis-  
 pose of the question. - Would a child  
 learning French and German, and  
 using the right hand for the French

exercises &c., and the left hand  
 for the German, be able to econom-  
 ize brain substance and so learn eas-  
 ier and have room for more acquire-  
 ments, and would a left-sided cere-  
 bral lesion in such a case have a  
 different effect as regards the two  
 languages? - Such a question I have  
 heard propounded, and am inclined  
 to think that in such a case the effect  
 produced by a left-sided lesion would  
 be much the same as regards both lan-  
 guages. - Both ears and both eyes would  
 be used in both cases, and there is,  
 I think, not much doubt that the her-  
 editary or other influences which tend  
 to locate articulatory and other cell-com-  
 binations in the left side of the brain,  
 though the sensory influences are mainly  
 bilateral, would not be much affected  
 by writing German exercises with  
 the left hand. - Cell-groupings for the  
 manual dexterity of the left hand  
 required would lie in the right brain,  
 but the impulses would there from the

left side. - Thus such an attempt would be wasting nerve force in making it travel further, and wasting force also in educating a part of the brain not specially susceptible, nor hereditarily adapted, to that class of special acquisition. - There is moreover every reason to believe that in the left side of the brain there is an ample provision of cells and group-forming power for all reasonable acquisitions. - Persons who learn languages easily can learn eight, nine, or even more without, so far as we know, employing unusual areas of cerebral tissue; and it is probable that in the brain of each of us there is room for more learning than we have time in our lives to acquire. - There is some reason to believe that only certain of the cortical cells are usually used in carrying on the cerebral functions, but less reason to believe that other layers might not be encroached upon if the functional capacity of these was exhausted. -

IV. Male and Female Brains.

- I have now reached the fourth and last division of my subject, but before turning to the brain it may be well to mention that the mental constitutions of the sexes differ, and progressively with civilisation. - There can be little doubt that this is the result of a natural law - some would perhaps say of a natural law in a spiritual world: - a spiritual law in a natural world would be, I fancy, here as elsewhere, a more correct expression. -

- "It has been said that women are 'more sensitive, impressionable, observant, intuitive, sympathetic; - less logical, reflective, persevering.'" (Lecture on the Education of Girls - by W. B. Hodgson L.L.D. 1864)

- Professor Rouanes, in a recent lecture at the Royal Institution (March 1887), comes to somewhat similar conclusions. - Perhaps the main drift of his lecture may be summed up by saying that women have a more ready and acute power of acquisition, but are less able to or-

iginate ideas. -

- Their habits of thought and mental characteristics may be largely due to the nature of the education given to their female ancestors. - Their brain has increased with civilisation along with that of men, but till lately their mental education has been, with a few exceptions, absurdly neglected and perverted into useless channels. - There is no doubt, looking at a nation, that its male and female mental characteristics are hereditary. -

- of late female education has received much attention, and the fear is that, even were the ills referred to in the early part of my paper removed, the tendency is too much to aim at mental similarity in the sexes, though the means used are sure to defeat that purpose. - Girls are guarded by such extreme barriers from any of that knowledge of the world which tends more than anything to form a man's general character. -

-little enough of the practical element is introduced into boys' education, but in ladies' schools and colleges education is almost wholly abstract. -

- Education always tends towards a neurotic constitution and its morbid tendencies: suicide varies *pari passu* with it. - Girls who go voluntarily, as most do, to our ladies' colleges, are probably neurotic already, and the form of education supplied tends to make them more so. - In a paper advocating the higher education of women, by Mrs. Fawcett, which appeared in the *Contemporary Review* for November 1886, there occurs the following astonishing passage. - "The student's life is a very happy one; there is no dullness in it; there is always an immediate definite object in view to work for; there is a reason on each day and almost on every hour of each day for work which calls out the strength of developing faculties and powers." - Neurotic girls, who have been rendered so largely

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at their schools, are provided with reasons for working hard "on almost every hour of each day". - The girls who find such a life "a very happy one" would certainly be better elsewhere. -

- This is not a paper on the higher education of women. - There is nothing to be said against it, everything for it, but much to be said against almost all the methods which have been hitherto devised for its furtherance. - It would be irrelevant to proceed, so without saying more of the mental differences of the sexes, their origin and desirability, I turn to the differences which have been noted in the brain, and very little space they take to record. - Most of them have already been alluded to, but it seems well to collect them.

- It is not surprising that the apparent differences are slight; we should expect the main ones to be in the cell groupings we are unable to investigate. -

- (1) (a) At seven years of age the female brain has reached  $\frac{10}{11}$  or  $\frac{60}{66}$  of its eventual

weight; the male brain only  $\frac{5}{6}$  or  $\frac{5.5}{6.6}$ . - (p: 70.)

(b) The maximum development of the female brain occurs between the ages of twenty and thirty; of the male between thirty and forty. - (p: 71.)

- Thus the female brain, like the body, grows quicker and arrives at maturity sooner, but has not quite the same scope of increase in weight between seven and maturity that the male brain has. - It is also a general law that the higher the type, the slower and more prolonged is the growth. -

(2) - The average weight of the female brain is of course less than that of the male, as we should expect from the total body weight being less. - But further, the female brain weighs less than would be thus indicated, it weighing ten percent (10%) less than that of the male, while the total body weight of the female is only eight percent (8%) less than that of the male (Bastian op: cit. p: 356). -

(3) - The frontal lobes in the average female brain are less highly convoluted than in the male; - also, in those brains where we find high convolutional complexity of the frontal lobes, the rest of the cerebral surface is pretty highly convoluted (Ferrier op: cit: p: 466). -

- Thus we see that in an average male and female brain of equal size, the male is the most highly convoluted, and has consequently the largest area of cortical grey matter, giving probably a cortex weight, compared with the female, still greater than that indicated by the total brain weights referred to above. -

(4) - I am not aware that any further definite points can be stated as to anatomical differences between the male and female brain. - All the above however point to the inferiority of the female, and by proceeding if we could to a more minute examination, we should not be surprised to find that further disclosures tended in the same direction. -

-In all enquiries as to brain structure, differences, but slight in large areas, become exaggerated as we proceed to more minute examination, and it is probable that this law extends further than we can trace it. - The average thickness of the cortex may be less in the female, and differences may be still more marked in the cell groupings: - it is unlikely that we should find the tables turned. - Further differences we should certainly expect to find in the brains of the sexes: - we have already found, and might find more, inferiority on the side of the female. -

It is to be remembered that these remarks apply to the "average" female or "female type" of brain. - Very possibly most of the ladies who become the subjects of "higher education" may have brains which, in many particulars exhibit a male type, but even without taking this into consideration we do not glean any very definite indications as to female education. -

- One point at least seems, however, worthy of notice. - We have seen how the frontal convolutions are concerned, <sup>in motor acquisition,</sup> and also how it is they that are chiefly concerned in will power, self-control, and direction of thought. - Now these are points in which the female mind is deficient compared with the male, and these the areas especially deficient in the female brain. - Surely here is another reason, besides the general health one so obvious, for insisting on girls being supplied with opportunity and motive for healthfully exercising their various muscles. -

Locke, long ago, in speaking of the education of a gentleman said "I would have him learn a trade - a manual trade", and it has been found recently in schools for the poor, that education in special motor acquisitions, i.e. the teaching of a more or less delicate handicraft, favours will power and self-control ("Manual Training in School Education" by Sir Philip Magnus - Contempt<sup>4</sup>: Rev. Nov. 1886; - see also Report of Roy. Commission on Depression of Trade.). -

- Girls are taught to play the piano, to sew, and to knit, but a more extended general and special motor education is on all grounds most desirable. -

- It is unnecessary to insist on education in extent and precision of all the senses. - Sight and hearing are the two through which girls now get nearly all their knowledge, and the main uses made of these senses are in reading and hearing lectures. -

- Good and thorough sensory and motor education is necessary to produce the best results; this applies to both sexes. - The former is lamentably deficient in the teaching of both; the latter also in the case of girls, while in that of boys it is not developed as it should be either in extent or precision. -

- To produce the highest minds we must aim at a well balanced brain. - To produce this we must educate all areas, sensory and motor, and in each area, as far as possible, some line of acquisition should be educated in precision. - Every

object should, as already stated, be studied through as many senses and manipulatory methods as possible, and time should be allowed for good physical association. -

- We may then hope for a brain which is able to make use of all information that comes in its way, to locate it in relation to former knowledge, compare it, estimate its value, and which knows how to pursue the subject further and to particularise upon it. -

- This paper cannot pretend to exhaust its title: to do so would require many times the space I have allowed myself. - I have endeavoured to treat as fully as seemed servicable the subject of cerebral physiology as applied to education, and have alluded to other branches in a less exhaustive manner. -

- The absurdity of forming classes or "standards" according to age; the value of pleasurable methods of study; the value and evils of examinations; the dangers of cramming: - these, and many other questions, can be discussed from physio-

logical as well as from other points of view. -

- Perhaps no prevalent educational custom is more easily met by physiological argument than that of making pupils do the hardest work of the day - "preparation" or the acquiring of new information - in the evening when they are tired and their nervous vigour is on the ebb, and without the assistance of a teacher. - Preparation should be undertaken in the morning, with those at hand who are able and willing to explain and help. - If evening work is to be done, revision is probably the most suitable form. -

If, in addition to indicating the age at which special education should commence, and the various other points which have, in the preceding pages, been alluded to, I have shown more clearly than has hitherto been done, that there are reasons beyond those of general health and consequently brain health, beyond too the conclusion from general considerations that education conducted

in the concrete is better where practical than in the abstract, for extending the education of the senses and muscles, I may hope to have added an argument which, were it to reach them, might tell on those who, in aiming at intellectual excellence, think physical education superfluous, and in so doing I might indirectly, while helping to render education more pleasurable and rational, at the same time influence favourably the health and happiness of posterity.

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Claude Wilson.  
Bath.  
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