yielded to persistent and devoted research and the solution has been found. There is every reason to hope for a similar outcome in this undertaking, and the universal rejoicing in this achievement will more than repay the labours of all those who have been privileged to have a part in it."

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BRAIN SIZE AND MENTALITY

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(A preliminary account of part of the work of the Burden Mental Research Trust)

In a previous and more technical communication¹ a preliminary account was given of some of the structural abnormalities presented by the brains of mental defectives. These observations have since been extended on more general medical grounds to include normal brains, defectives, and mongolians, while the technique has been improved by including cerebral breadth as well as height and length, from which can be calculated the brain product as an index of cerebral size. With this product of brain size comparisons are easily instituted between normals and abnormals, and it is thus possible to ascertain the relationship of brain size to average or defective mentality.

At the moment the available material comprises thirty-nine normal brains of both sexes and various ages, and seventy defectives, of whom sixteen are mongolians. The final analysis will, it is hoped, be made on an equal number of normals and defectives, both series to comprise not fewer than 100.

The technique is the same throughout. The left cerebral hemisphere having been removed and specially prepared for subsequent histological examination, the right half of the hardened brain is placed in a dioptrograph, and a life-size tracing is made of the external or lateral surface. On these tracings measurements, angles, and planimeter readings of size can be made with a high degree of accuracy. Cerebral breadth is measured by the diagraph. As this mode of recording the length, breadth, and height of the brain coincides with similar methods for measuring the dried skull or living head all three procedures are comparable, and permit an interchange of data.

Preliminary Considerations

Size of the Normal Adult Brain.—In view of the fact that there do not appear to be available any reliable figures of the three linear dimensions of the adult normal human brain, it may at once be stated that in this series the figures are as follows:

Cerebral length	...	...	...	...	170.67 mm.
Cerebral breadth	...	...	...	...	133.92 mm.
Cerebral height	...	...	...	...	108.25 mm.

¹ *Journ. Neurol. and Psychopathol.*, 1935, xvi, 54.

These dimensions are those of twenty-eight normal brains from persons of both sexes over 8 years old. As will be shown later, the normal human brain appears to attain its final adult dimensions between the eighth and eleventh years of life, though this does not apply to head growth.

Brain Products as an Indication of Brain Size.—A simple and reliable index of brain size may be obtained by multiplying together the figures for length, breadth, and height, and taking the first three figures of the calculation as the index product of brain size. Thus if a brain has the dimensions quoted above, then the product is 247, because if the figures for length, breadth, and height to the nearest whole numbers be multiplied together the answer is 2,474,712, and the first three figures, again to the nearest whole number, are 247, which thus becomes the index product of brain size. By this simple method it is possible to establish comparisons of brain size between individual normals, as also between normals and defectives. It is further possible to establish direct comparisons between brain size and living head size, and to estimate from the latter the probable size of brain of the living individual.

Brain Products as an Index of Normal Brain Growth.—Since the present series of normal brains includes infants and children as well as adults—although the former are not yet as numerous as could be wished—the effects of normal brain growth, as shown by the product method, are indicated by the following:

Chronological Age	Brain Product
3.6 weeks	70
3.6 months	148
2.6 years	204
2.11 "	227*
4.0 "	226
8.0 "	242
11.0 "	249
21.0 "	249

* Above average

The close agreement of this rate of growth with other known figures, as also with Donaldson's estimates, is sufficient evidence of the reliability of the method. In 1895 Donaldson wrote: "At birth the weight of the encephalon is nearly alike in both sexes, and in both growth during the first year, and indeed during the first four years, is rapid. By the seventh year the encephalon has reached approximately its full weight, the subsequent increase being comparatively small." That the defective brain departs altogether from these standards of normal growth may be shown by the fact that out of sixteen defectives between the ages of 4 and 10 years none attained to the normal 4-year-old brain product, and only four achieved a size of brain equal to that of a normal 2.6-year-old infant.

The Brain of the Defective

While neurologists would naturally expect the intellectual and moral deficiencies of defectives to be reflected in the size and make-up of the brain, it is not improbable that the pure psychologists would endeavour to explain the mental deficiency on temperamental, emotional, or, indeed, on any ground other than the materialistic, yet that there is a very definite physical basis for mental deficiency the following comparison of size alone will clearly prove:

Linear Dimensions			
	Cerebral Length	Cerebral Breadth	Cerebral Height
	mm.	mm.	mm.
28 normals above 8 years	170.67	133.92	108.25
55 defectives above 8 years	154.69	116.07	103.63

Brain Products			
28 normals above 8 years	...	...	247.64
55 defectives above 8 years	...	...	187.49

TOP ROW: Growth of the normal human brain.

From left to right—

1. Female, aged 3 weeks
2. Male, aged 3.6 months
3. Female, aged 2.6 years
4. Male, aged 4.0 years
5. Male, aged 8.0 years
6. Male, aged 21.0 years.

MIDDLE ROW: Normal human brains.

From left to right—

1. Female, aged 9.0 years ... 119 %
2. Male, aged 17.0 years... 103 %
3. Female, aged 19.0 years ... 100 %
4. Male, aged 45.0 years... 106 %
5. Male, aged 49.0 years... 95 %
6. Male, aged 55.0 years... 113 %

BOTTOM ROW: Brains of mental defectives.

From left to right—

1. Female, aged 9.7 years ... 55 %
2. Female, aged 11.7 years ... 67 %
3. Female, aged 16.1 years ... 62 %
4. Female, aged 18.3 years ... 65 %
5. Male, aged 21.2 years ... 68 %
6. Female, aged 12.7 years ... 77 %

The defective percentages are expressed in terms of Brain No. 3 of the middle row.

The proportion of the product of the defective brain to the normal is, after the cessation of brain growth, as 76 is to 100—that is to say, the majority of mental defectives are so because their brains are about one-quarter too small. This fact may also be shown on a percentage basis, the brain of the normal 8-year-old child being regarded as equal to 100 per cent., thus:

	Per cent.
Normal 8-year-old child	100
Normal 2.6-year-old child	85
28 mental defectives, average age 10.7 years	72
Normal 3.6-months-old infant	62
Normal 3-weeks-old infant	29
Gorilla	24

The mental defective over 10 years of age ranks, as regards brain size, at about the level of an 18 to 24 months normal human infant. Mental deficiency is thus seen to be characterized by the persistence of an infant's brain in the stunted body of an adult—that is to say, it is a departure from the normal standards of normal growth.

NORMALS, DEFECTIVES, AND MONGOLIAN DEFECTIVES

In view of the general interest taken in mongols, a similar analysis may now be made of their brain products to ascertain how far, if at all, they differ in brain size from other defectives. The series from which the present comparison will be drawn comprised thirty-nine normal persons, five of whom were below 8 years old; fifty-four defectives, including eight below 8 years of age; and sixteen mongols, of whom one-half were below 8 years of age, the oldest in the group being a female who died at the age of 30.10 years. The fifty-four defectives were in no way selected, but included even the most obviously pathological, such as pronounced hydrocephaly, porocephaly, microgyria, absence of the corpus callosum, tuberosclerosis, and under-developed opercula, to mention only a few.

The average ages and brain products of the three groups are as follows:

	Average Age	Average Brain Product
A. 39 normals	29.0 years	239
B. 54 defectives	18.0 ..	191
C. 16 mongols	13.2 ..	177

The mongolian is thus seen to be the most lacking of defectives in brain size.

Brain Proportions

In addition to an undue smallness of size and liability to structural developmental errors, defective brains display in some cases another important departure from normal standards, and that is in the relative proportions of pre-central (effector) area to post-central (receptor). On neurological grounds it would seem to be essential that the proportion of receptor to effector cerebral cortex should only vary within narrow limits, otherwise disturbed mental reactions would be commoner than they are. But these proportions do not appear to be known, so they were first worked out on the normal series of brains by recording the planimeter sums of cortical areas exposed on the surface of the dioptrographic tracings. These readings do not record the total amount of cortex, but only its exposed portions. As cortical sulci are more variable in the defective brain than in the normal, the comparison now to be established flatters the defective. These proportions were found to be as follows:

	Pre-central	Post-central
28 normals over 8 years old	38.71 %	61.29 %
55 defectives over 8 years old	37.54 %	62.46 %

Although the difference between the normal pre-central percentage (38.71) and the defective (37.54) may appear so slight as to be negligible, there is reason for believing that some neurological significance may attach to it, especially when it occurs in a brain already too small for

normal mental reactions. When this difference is still more pronounced it may be suggested that the "inhibiting" powers of the reduced pre-frontal area are insufficient to arrest or delay the stimulation of effector neurones by receptors. Such a cerebral construction would seem to suggest that such defectives should exhibit tendencies to exhaustion of effector neurones from non-inhibited stimuli (epilepsy), or even possibly some more or less permanent manifestation of diminished pyramidal tract control as in some of the so-called cerebral diplegias. Theoretical though the thesis is and was, it seemed worthy of further analysis, and was attempted on the following lines.

In delineating the frontiers of potential abnormality in relative proportions of pre- and post-central cortices, levels were selected one and a half and twice the standard deviations respectively. Among normal brains those that would fall outside these limits would be 14 per cent. and 4.5 per cent. respectively. Since several of these defectives were found to come into these categories, a re-examination was made of the clinical phenomena presented during life, and the interesting fact was revealed that they numbered some of the worst epileptics and "diplegias."

One of the last cases to be included in this series of defectives was a male aged 8.3 years, who died on March 17th, 1936, in "status epilepticus," having suffered from epilepsy all his life. This was obviously a test case. If, in this instance, the epilepsy was associated with a structural defect of disproportionate cerebral areas the theory could be maintained. Post-mortem examination showed that the pre-central area was indeed deficient by nearly twice the standard deviation. In this instance, then, the theory stood the test, and is, indeed, supported by other brains in the series.

Tentative Conclusions

These investigations, comprising as they do thirty-nine normals and seventy defectives, suggest that mental deficiency is in the great majority the result and consequence of a brain too small for its proper functions, and that this cerebral deficiency affects the whole central nervous system. That system should therefore display neurological clinical phenomena so closely resembling those produced by post-natal pathological lesions as to be mistaken for such—as indeed it actually does. Differently expressed, an underdeveloped central nervous system does not function properly, and this imperfect functioning resembles those disturbances produced in a previously normal nervous system which is the subject of diseased processes.

In addition to their mental state, the pronounced epileptic and diplegic phenomena presented by some, but not all, defectives may be due to, or aggravated by, abnormal proportions of the pre- and post-central cortices. Since most, if not all, these features of the defective brain are embryological in character and nature they are pre-natal in origin, and are not so commonly due to "birth injuries" as is generally supposed. If, therefore, mental deficiency be defined, as it now well may be, as a departure from the normal standards of normal growth, the genetic factors concerned would appear to be those associated with growth in general and not mentality in particular.

That the basal ganglia share, with the cortex, a diminution in size is only too probable, though the point has not yet been fully examined. Since the striate body is a derivative of the neopallium it is difficult to realize how it could fail to share in this reduction. If this be true it is not unlikely that some pathological states usually regarded as symptomatic of striatal disease may

really be indicative of a much broader and more widespread affection of the nervous system as a whole, especially of the neopallial cortex.

Microscopical Features

The microscopical features of these seventy defective brains are also under investigation by Drs. R. M. Norman and A. L. Taylor, but such inquiry is necessarily longer and more laborious, on account of its greater difficulties, than the simpler and informative macroscopical examination. It is, however, possible to give, under this head, a generalized conception of the results obtained up to date on this material by Dr. Norman and his colleague.

Notwithstanding that instances have been found where the defective supragranular cortex is thinner than normal, micrometric measurement of the cortical laminae shows, on the average, no significant difference in the mean between defectives and normals. In this respect these findings differ from some of those of the earlier observers. On the other hand, these investigations strongly support the view that a disorderly arrangement of the cells of the cortex is a feature of defective brains. In fact it is by these qualitative changes that the defective cortex may most easily be distinguished from the normal. The defective cortex shows many variations from the normal in its cellular construction, more especially in the supragranular layers. Thus in some there are very small supragranular neurones with a reduction in the amount of stainable cytoplasm in the third lamina. In others there are greatly increased numbers of pyramidal cells per unit of the count.

Again, a textbook normal cortex is commonly encountered in the normal controls but is not found in the defective range, and the latter tend to show abnormal cyto-architectonic features more frequently than the former. While the purely cytological approach to the detection of cortical differences between "poor" normals and "good" defectives can never be easy, and may, indeed, escape us altogether, it is nevertheless permissible to suggest, as does this investigation, that in the majority of defective brains there has been some inhibition or distortion of the factors making for normal neuron growth and organization, in consequence of which the defective neurone is less resistant to noxious influences than are those of more normally constructed cortices.

Relation of Brain Size to Head Size

The product method is as applicable to the living head as it is to the brain, since the procedure is precisely the same for both. That is to say, the length, breadth, and height are measured and multiplied together, the first three figures of the sum being taken as the "product."

It has already been shown that brain growth practically ceases in normal children between the eighth and eleventh years of life, whereas the head continues to show some slight increment in size for some years afterwards. During the period of brain growth there is therefore a distinct and measurable relationship between head size and brain size. It obviously becomes of clinical importance to know whether the child's brain is or is not keeping pace with its chronological years, and this fact may be ascertained, within the limits of our present knowledge, from head measurement.

What, then, is the proportion of brain size to head size? That the proportion can never be constant is obvious, because the size of head, though largely reflecting that of the brain, is disturbed by other factors, such as thickness of skull, thickness of integuments, temporal muscles, and even by unduly large sinus development over the glabellar region.

The Burden Mental Research Trust staff has worked out the head products of the 10,000 Australian children and young adults published some years ago by Berry and Porteus. It found so close a similarity between these figures and those it obtained by similar methods on a smaller group of English school children of comparable age as to justify their retention for the basal purposes of the comparison of brain size with head size. Taking the curve for brain products as ascertained from the thirty-nine normals of the present investigation as the standard of comparison, it has been found that an almost exactly synchronous curve is obtained by taking 35/48 of the Australian children's head products as an index of their brain size. This proportion would then seem to be a close approximation to the actual proportion of brain size to head size. Since such a degree of accuracy would not be required for clinical purposes, the proportion of brain size to head size may be roughly assessed at two-thirds.

A living defective, aged 8 years, was found to have a head product of 177 (length $\times$ breadth $\times$ height). Two-

thirds of that is 118, which is approximately the brain size of a normal human infant of 2 months old. As this child has already passed the age when brain growth ceases it would seem unreasonable to spend time, money, or labour endeavouring to "educate" such an imperfectly constructed individual. No educationist should waste his time endeavouring to teach the rudiments of the three R's to a 2-months-old infant; yet to make the attempt on older defectives of similar cerebral rating seems to be the rule rather than the exception. It thus seems probable that these facts, when sufficiently well established and appreciated, will enable a scientific separation to be made between the "educable" and the "ineducable"—and these classes are not confined to certified and segregated defectives—with a corresponding diversion of labour into more profitable channels.

The product method of estimating the probable size of brain from that of the head of the living individual would thus seem to have a wider applicability than the restricted fields of mental deficiency, for the latter is but a pointer to the larger world beyond.

THE MIRROR TEST IN PULMONARY TUBERCULOSIS

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Radiological advances have in recent years led to a neglect of sputum tests. This is partly because the finding of bacilli merely indicates the presence of disease while the skiagram indicates not only its presence but, within limits, its extent and character. But though radiographic appearances may be so characteristic that they seem only to admit of one interpretation, probability rather than certainty is all that we can gauge from the average skiagram, and the last word remains with the bacteriologist.

The collection of sputum for examination is often a matter of difficulty. The patient who suffers from an only too well founded phthisiophobia may show small desire to supply a rope to hang himself. He may forget to return the sputum outfit or send back a sample of saliva. On the other hand the eagerness of the phthisiophilic to prove himself a suitable subject for compensation may induce him to fill his sputum bottle with sputum bought or borrowed from a consumptive friend, an artifice said to have been frequently adopted in military hospitals during the world war. A further disadvantage attaching to the sputum test as usually carried out is that it causes a delay in diagnosis that may be embarrassing to the practitioner and distressing to the patient. Nor is sputum always available, for it may be negligible in amount or unconsciously swallowed. As a short cough may spray a mirror with tubercle bacilli at a stage of disease when expectoration is absent, it is evident that portions of the air-way may be teeming with bacilli which will remain undetected if the usual vehicle for their discovery is lacking. This is perhaps especially so when expectoration has been abolished by collapse therapy, a method of treatment which also prevents radiographic exploration of the lung fields.

Laryngeal Mirror Method

A device which permits the immediate examination of secretion obtained directly from the air passages and which is more accurate than the ordinary sputum test

seems worthy of consideration. It is many years since Sir James Dundas-Grant pointed out that the ejection of pulmonary secretion may be provoked by the sudden inhalation of volatile mustard oil and that secretion may often be obtained by this means in apparently "unproductive" cases. In describing this method he mentioned that a laryngeal mirror might also be used to obtain samples, but his advice has been strangely neglected and the more elaborate and less reliable method of bacteriological examination of the faeces is usually recommended when sputum cannot be obtained. This method is only suitable for use in institutions and is not practicable for dispensary or surgery work. Apart from the difficulty of collecting suitable samples the isolation of organisms from stools demands much time and special skill and, even if acid-fast bacilli are at length demonstrated, some doubt as to their origin and significance must remain. Having lately employed the laryngeal mirror method and found it satisfactory, we feel that a short note on the results of our experience may be helpful to others.

The technique is simple. The test should, when possible, be carried out in the early morning. The patient and examiner sit as for ordinary indirect laryngoscopy and a large-size mirror—for example No. 6—is held with its surface horizontally above the larynx. The patient is instructed to give several short barking coughs, and the mirror is thus sprayed with bronchial secretion. It is then withdrawn along the roof of the mouth, care being taken to avoid brushing its surface against the tongue. Flecks of yellowish secretion of pin-head size are characteristic though not typical of tuberculous expectoration. Mucoïd or watery secretion usually but not invariably yields a negative result. The flat of the mirror is now applied to one end of a slide and drawn along it, leaving a thin film which is dried and stained in the usual manner. The possibility that the slide may be contaminated when the mirror has been used in a previous test is remote, but careful sterilization of the mirrors is essential. Dr. Hebert has suggested to us that the use of the all-metal mirrors now sometimes employed for indirect laryngoscopy might be a useful safeguard.

Comparative Results

The results obtained from a small series of mirror tests will show the usefulness of the method, and though statistical significance cannot be claimed for a limited number of tests it seems probable that a more exhaustive trial would prove that this method is more accurate than sputum examinations as ordinarily carried out.

The patients supplying the material were women suffering from pulmonary tuberculosis. Most belonged to the adolescent and early adult group, and the disease was