# THE GROWTH OF THE BRAIN OF THE AUSTRALIAN ABORIGINAL

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In a previous paper I described the fissures of the brain of the Australian aboriginal and also determined the ratio of the grey matter to the white.

In the present paper an attempt is made to determine by the measurement of the fissures what areas of the brain are most affected by their development. The results so obtained are compared with similar studies on white brains. Further by comparison with the brain of the new-born aboriginal, using the same methods, a study of the fissures of each area during post-natal growth is made and an estimate of their relative development attempted. Finally some observations on the histology of the principal cortical areas are offered.

The material which forms the basis of the present study consists only of the brain of an aboriginal woman and that of her new-born son. Both died during the process of parturition and it was through the kindness and interest of Dr J. B. Dawson and Prof. Cleland that I obtained the brains. The rarity of such material and the slight prospect of obtaining more must excuse the slender basis of this enquiry. The brains were fixed in 10 per cent. formalin and so suspended that they hardened without deformation.

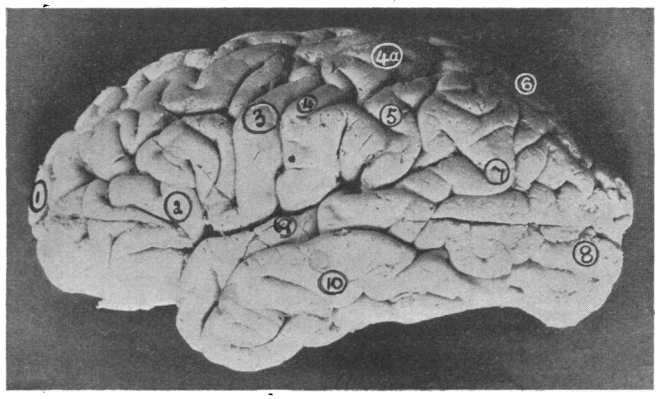
## BRAIN OF THE MOTHER

The mother was very stout, about five feet three inches in height, and aged about 43 at the time of her death. Her brain has a total length of 164 mm. and its greatest height is 96 mm., giving a height/length index of 58·5 per cent. It is noticeable that the frontal pole slopes sharply backwards, not having the fullness which is present in the European brain. The temporal pole is elongated and narrow. The superior margin of the parietal lobe is nearly straight, while the occipital lobe appears large and rectangular in form.

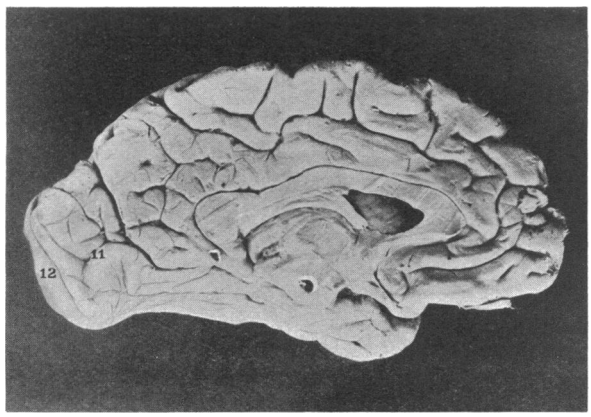
As pointed out in a previous paper, these general appearances are in a large measure the result of the extreme dolichocephaly. An inspection of the stable fissures and gyri calls for brief comment. There is no sulcus lunatus present and the superior temporal convolution appears extremely narrow. This latter feature was noted in the previous study referred to.

## BRAIN OF THE INFANT

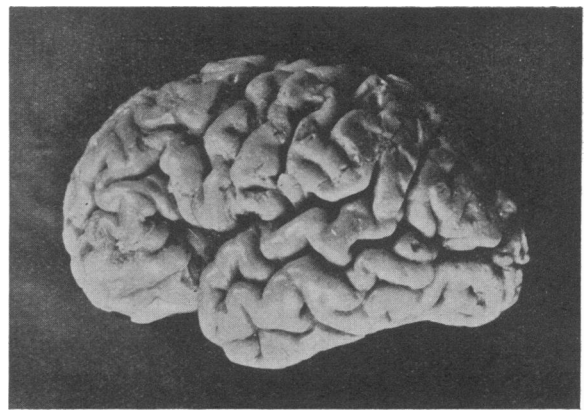
The new-born infant was extremely large, weighing about 12 lb., and the catastrophe at birth was due to this. Though damaged owing to the measures used in delivery, there was no doubt that it was perfectly healthy. It has been established by Spitzka and Karplus that the convolutional patterns have a



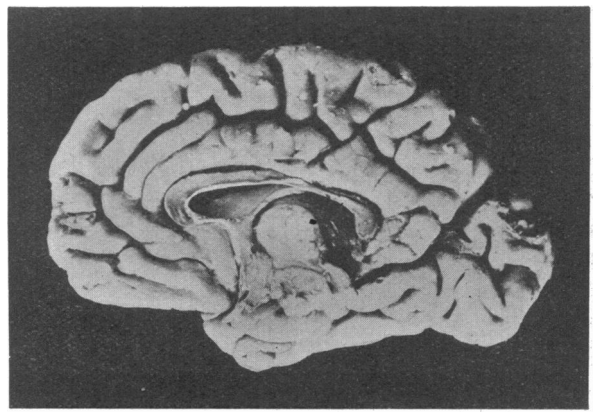

Text-fig. 1. Lateral view of the left cerebral hemisphere of the Australian aboriginal woman. The numbers refer to the actual areas from which the sections of the cortex were taken.




Text-fig. 2. Mesial view of the left cerebral hemisphere of the Australian aboriginal woman. The numbers again refer to the actual areas from which the sections of the cortex were taken.



Text-fig. 3. Lateral view of the left cerebral hemisphere of the full term Australian aboriginal foetus.



Text-fig. 4. Mesial view of the right cerebral hemisphere of the Australian aboriginal foetus.

hereditary tendency to repeat themselves. The present enquiry gains something by being based on the comparison of the mother's brain with that of her son. The maximum length of this foetal brain is 112 mm., while the greatest height is 78 mm., thus giving a height/length index of 70 per cent. Two brains of white foetuses taken at random gave indices respectively of 70 per cent. and 71·5 per cent. The aboriginal foetus, then, exhibits a height/length ratio of the same order as in European brains, and the extreme dolichocephaly is a departure that occurs during the later growth of the brain. Kappers, from a study of brachycephalic brains, concluded that in these the brachycephaly is far less evident in the foetus then in the adult. Perhaps we may therefore surmise that a moderate degree of dolichocephaly is the standard of the human species, and that brachycephaly and extreme dolichocephaly are due to later differential rates of growth.

The degree of exposure of the insula is of the same order as in the white foetal brain. The direction and curvature of the temporal pole is in all respects similar to the white, and the same is true of the parietal area. The occipital pole is drawn out into a slender projection in the aboriginal, but is blunt and rounded in the white foetal brain. In both the white and aboriginal foetus the frontal pole is blunt and rounded.

A comparison of the white and aboriginal foetal fissural pattern discloses no significant differences. Again the superior temporal convolution is definitely smaller than in the white, but the disparity between them is less than in the adult brains.

The superior temporal sulcus resembles the same sulcus in the white foetal brain except that in this instance the fissure is continued into a very well-developed lateral occipital sulcus. This latter is an isolated sulcus in the white brains used for comparison. The central sulcus appeared to be situated more anteriorly in the aboriginal foetus than in the white. A line drawn from the middle of the central sulcus to the frontal pole and to the occipital pole gave in the white and aboriginal foetal brains the following ratios. Taking the distance to the frontal pole as unity the occipital pole distance from the same point in the aboriginal brain is equivalent to 1·2, while in the white brain of the same height/length index the ratio is unity to 0·9. Since broadly it may be stated that the cortical area in front of the central sulcus is concerned predominantly with movement and the area behind and below with sensation these ratios are not without interest.

A detailed comparison of all the principal fissures between the foetuses of both races discloses no differences other than those mentioned. It is to be remarked, however, that there is no sulcus lunatus in this aboriginal foetus.

When the aboriginal foetal brain is compared with the mother's brain, the points noticed may be summarised as follows:

(1) The great proportionate increase in the length of the adult brain as shown by the height/length index, which changes from 70 in the foetus to 58 in the adult.

(2) The occipital pole, which looks like a slender projection in the baby, still retains its protuberant aspect in the mother, though becoming more of a rectangular block.

(3) The frontal pole, which is full and rounded in the foetus, becomes more pointed and less rounded in the mother.

(4) When compared with the white brain it was pointed out that in the aboriginal foetus relatively more of the cerebral hemisphere was contained in the posterior half of the brain behind the central sulcus. If the amount in front be represented by unity 0·9 is caudal to the central sulcus in the white foetus, 1·2 in the aboriginal foetus, and 1·3 in the aboriginal woman. Thus it would appear as if growth were more marked towards the occipital pole than towards the frontal pole.

(5) The superior temporal gyrus tends to be pinched out in both the mother and the child. In the mother the lateral occipital sulcus is almost cut off from the superior temporal sulcus. They were continuous in the child.

In general it may be said that the foetal brain exhibits only slight differences from the white foetal brain, but during growth it departs from the common form mainly by a disproportionate growth in length which gives to the adult brain a very low height/length index. The growth would appear to follow the general law of polar growth, but there is some evidence to be obtained from changes which occur in the interval between birth and maturity that the growth is greater towards the occipital pole and less towards the frontal pole.

*General Data on the Aboriginal Brains*

| | |
|---|---|
| Height of woman | 5 ft. 3 in. |
| Total brain weight with membranes | 1050 gm. |
| Weight of cerebellum with membranes separated at the level of the fifth nerve | 118·2 „ |
| Brain stem and cerebellum divided at interval between corpora quadrigemina | 137·3 „ |
| Weight of right hemisphere, membranes removed, ventricles empty | 442 „ |
| Same, with membranes | 449·5 „ |
| Weight of left hemisphere, as above | 453 „ |
| Same, with membranes | 460·7 „ |
| Ratio of weight of cerebellum to cerebrum | 11 % |
| Length of mother's brain | 164 mm.* |
| Greatest height | 96 mm.* |
| Height/length index = | 58·5 |
| *Foetal brain* | |
| Weight of infant at birth | 11·8 lb. |
| A. *With membranes* | |
| Total brain weight | 444 gm. |
| Cerebellum | 24 „ |
| Right hemisphere | 204·6 „ |
| Left hemisphere | 206·3 „ |
| B. *Without membranes* | |
| Right hemisphere | 184·8 „ |
| Left hemisphere | 187·8 „ |
| Cerebellum | 20·7 „ |
| Weight of spinal cord | 5·3 „ |
| Ratio of cerebellum to cerebrum | 11·4 % |
| Greatest length of foetal brain | 112 mm. |
| Greatest height | 78 mm. |
| Height/length index = | 70 % |

* Right hemisphere measured in each case.

### THE LENGTH AND DEPTH OF SELECTED SULCI

This aspect of the present investigation was suggested by Donaldson's article on the brains of three scholars.

The growth of the fissures appears to be, if not completely, at any rate relatively, independent of other cerebral features. The fissures appear in an orderly sequence which is always the same in all human brains. Their successive development leads to the production of a stable pattern which can always be identified and compared. True there is a later production of secondary diversified unstable fissures which cannot readily be reduced to any appreciable system.

The measurement by Donaldson of the length and depth of selected fissures in the four principal areas (the frontal, the parietal, temporal and occipital) of the brain disclosed several interesting facts. The area obtained by the product of the two measurements length and depth, which is about equal to one-fifth of the whole cortex, varies independently of the mass of the brain. This fact shows very well the independence of the development and growth of the fissures, since in all other respects the brain exhibits the most constant relation in the proportional weights of its various parts. In addition there is also a constant ratio of the amount of grey matter to white. This was established for a variety of brains by Kappers and the same holds in the aboriginal brain.

Donaldson compared the fissural dimensions of the two hemispheres and discovered that a reduction in one part of the fissural dimensions was compensated by an increase in another part, and therefore concluded that the cortical area so measured bore a constant ratio to the total cortex available for function.

If we can regard the fissures as having a growth characteristic peculiar to themselves and independent of other cerebral characters it becomes of some moment to enquire what meaning can be attached to the fissures. There is no evidence to suggest that any particular kind of mental performance is associated with the length and depth of the sulci in any particular area. Study of the pattern of the fissures has so far been fruitless in suggesting any relation with the level of mental performance. It is perhaps most probable that the fissures represent the segregation of neurons according to functional groups. Indeed of some we know this to be the case, but in others the meaning still escapes us. At the moment then the most that can be asserted is that the fissures represent a relatively independent growth capacity of the cerebral cortex. It has been argued that good fissural growth would represent the existence of favourable nutritional conditions, and to that extent would supply some measure of the physiological factors that must co-operate in mental performance, but it is difficult to see why this should apply to fissural growth more than to any other feature that might be chosen. Since the growth of the fissures must influence the extent of cortex in the several areas of the brain the data derived from their length and depth enable us to institute comparisons between the principal areas of different brains.

The following data have been prepared of the brains of the mother and the foetus:

| | Left hemisphere | | | Right hemisphere | | |
|---|---|---|---|---|---|---|
| | Length | Depth | Area of cortex | Length | Depth | Area of cortex |
| | | | MOTHER | | | |
| *Frontal area* | mm. | mm. | mm. | mm. | mm. | mm. |
| S. front. mesialis ... ... | 89 | 8 | 713 | 92 | 9 | 828 |
| superior ... ... | 155 | 14 | 2170 | 126 | 15 | 1890 |
| medius ... ... | — | — | — | 20 | 4 | 809 |
| inferior ... ... | 83 | 13 | 1079 | 48 | 14 | 570 |
| S. precentr. superior ... | 41 | 15 | 615 | 30 | 10 | 300 |
| S. rostralia ... ... ... | 48 | 7 | 336 | 31 | 4 | 124 |
| S. cinguli ... ... ... | 92 | 7 | 644 | 68 | 4 | 272 |
| S. pars marg. cing. ... | 52 | 11 | 572 | 50 | 9 | 450 |
| S. ramus ant. horiz. ... | 16 | 9 | 144 | 19 | 7 | 133 |
| desc. diag. ... | 33 | 7 | 231 | 28 | 13 | 364 |
| S. precentr. inf. ... ... | 44 | 12 | 528 | 64 | 13 | 832 |
| *Parietal area* | | | | | | |
| S. centralis ... ... ... | 120 | 13 | 1560 | 103 | 16 | 1648 |
| S. postcentr. inf. ... ... | 42 | 12 | 504 | 44 | 14 | 616 |
| sup. ... ... | 39 | 14 | 546 | 48 | 13 | 624 |
| S. intrapariet. ... ... | 51 | 20 | 1020 | 29 | 16 | 464 |
| S. pariet. sup. ... ... | 48 | 13 | 624 | 38 | 11 | 418 |
| S. parieto-occip. ... ... | 57 | 14 | 798 | 51 | 16 | 816 |
| S. ramus post. Sylvian fiss. | 145 | 18 | 2610 | 126 | 20 | 2520 |
| *Temporal area* | | | | | | |
| S. temp. sup. ... ... | 95 | 14 | 1274 | 81 | 16 | 1296 |
| med. ... ... | 58 | 8 | 464 | 137 | 7 | 959 |
| *Occipital area* | | | | | | |
| S. calcarinus ... ... | 74 | 12 | 888 | 79 | 10 | 790 |
| S. occip. trans. ... ... | 40 | 13 | 520 | 33 | 13 | 429 |
| lat. ... ... | 41 | 8 | 328 | 35 | 7 | 245 |
| | | | FOETUS | | | |
| *Frontal area* | | | | | | |
| S. front. mesialis ... ... | 60 | 6 | 360 | 60 | 6 | 360 |
| medius ... ... | 25 | 10 | 250 | 74 | 8 | 592 |
| superior ... ... | 54 | 11 | 594 | 58 | 9 | 522 |
| inferior ... ... | 59 | 11 | 549 | 30 | 7 | 210 |
| S. cinguli ... ... ... | 84 | 7 | 586 | 64 | 6 | 384 |
| S. pars marg. ... ... | 34 | 7 | 238 | 41 | 7 | 287 |
| S. rostralia ... ... ... | 34 | 6 | 204 | 26 | 4 | 104 |
| S. precentr. superior ... | 34 | 10 | 340 | 31 | 6 | 248 |
| mes. ... ... | 12 | 5 | 60 | — | — | — |
| inf. ... ... | 29 | 11 | 319 | 42 | 10 | 420 |
| S. ramus ant. horiz. ... | 11 | 10 | 110 | 10 | 5 | 50 |
| ascend. diag. ... | 13 | 3 | 39 | 14 | 6 | 84 |
| *Parietal area* | | | | | | |
| S. centralis ... ... ... | 63 | 11 | 693 | 66 | 10 | 660 |
| S. postcentr. inf. ... ... | 33 | 14 | 462 | 37 | 13 | 481 |
| S. parieto-occip. ... ... | 35 | 12 | 420 | 38 | 11 | 378 |
| sup. ... ... | 16 | 10 | 160 | 25 | 6 | 150 |
| S. intrapariet. ... ... | 30 | 17 | 510 | 36 | 14 | 504 |
| S. Sylvian post. ... ... | 74 | 13 | 962 | 60 | 15 | 900 |
| S. postcentr. sup. ... ... | 22 | 9 | 198 | 24 | 9 | 216 |
| *Temporal area* | | | | | | |
| S. temp. sup. ... ... | 80 | 10 | 800 | 78 | 13 | 1014 |
| med. ... ... | 49 | 6 | 144 | 50 | 7 | 350 |
| *Occipital area* | | | | | | |
| S. calcarinus ... ... | 54 | 12 | 648 | 52 | 11 | 572 |
| S. occip. trans. ... ... | 25 | 8 | 200 | 29 | 8 | 232 |
| lat. ... ... | 24 | 11 | 264 | 16 | 11 | 176 |

*Average Length of Sulci in mm.*

| | Frontal | Parietal | Temp. | Occip. | Total |
|---|---|---|---|---|---|
| Mother | 639 | 471 | 184 | 151 | 1445 |
| Foetus | 366 | 281 | 166 | 100 | 913 |

*Average Depth of Sulci in mm.*

| | | | | | |
|---|---|---|---|---|---|
| Mother | 10 | 15 | 11 | 10·5 | 46·5 |
| Foetus | 8 | 12 | 9 | 10 | 39 |

*Average Extent of Cortex in mm.*

| | | | | | |
|---|---|---|---|---|---|
| Mother | 6390 | 8706·5 | 2024 | 1585·5 | 18706 |
| Foetus | 2919 | 3347 | 1154 | 1046 | 8466 |

*Average Extent of Cortex in percentages*

| | | | | |
|---|---|---|---|---|
| Mother | | | | |
| Length | 44 | 32·6 | 13·4 | 10·4 |
| Extent of cortex | 37·4 | 41·4 | 11·2 | 9·2 |
| Foetus | | | | |
| Extent of cortex | 34·4 | 39·6 | 13·6 | 12 |

*Comparison of the Hemispheres. Extent of Cortex and Length of Sulci in mm.*

| | Frontal | | Parietal | | Temporal | | Occipital | |
|---|---|---|---|---|---|---|---|---|
| | Length | Extent of cortex | Length | Extent of cortex | Length | Extent of cortex | Length | Extent of cortex |
| Woman, Right | 586 | 5835 | 439 | 7106 | 149 | 2255 | 147 | 1464 |
| Left | 692 | 7559 | 502 | 7762 | 218 | 1738 | 155 | 1736 |
| Foetus, Right | 452 | 2901 | 276 | 3289 | 126 | 1364 | 97 | 980 |
| Left | 450 | 3291 | 286 | 3405 | 104 | 944 | 103 | 1112 |

The total length of the sulci in the adult aboriginal female brain herein measured is 1445 mm. This figure may be compared with the female in Donaldson's series O.W.S. This brain weighed just over 500 gr., while the aboriginal hemisphere was approximately 450. The length of the sulci in O.W.S. is given as 1850, a difference of some 400 mm. This is the more significant when it is remembered that the aboriginal brain is extremely dolichocephalic and therefore favourable to growth in length of sulci. Turning to the depth of the sulci O.W.S. gives an average total depth of 51·95, while the aboriginal woman gives an average depth of 46·5. If we divide the total length of the sulci into the total area of measured cortex an average depth is obtained for O.W.S. of 13·8, and for the aboriginal woman of 11·8. In general the white woman has 20 per cent. advantage in length of sulci, and 14·5 per cent. in depth of sulci.

O.W.S. gives an average extent of cortex of 25,528, while the aboriginal woman gives 18,706. Again the comparison is to the disadvantage of the aboriginal woman and amounts to 33 per cent. In this connection it is to be observed that the extent of the cortex obtained by this method for E.E.S., who is described as an eminent neurologist, is given as 16,409, a quantity actually less than in the aboriginal woman, while that of E.S.M., one of the scholars, only amounts to 19,653.

If we now turn to the distribution of the extent of cortex in the different areas, we find that in the parietal areas the measured cortex in the aboriginal

woman is 41·4 per cent. of the whole measured cortex, while in the white woman O.W.S. it is 35·9 per cent. In the frontal area they are respectively 37·4 per cent. and 38·3 per cent., in the occipital 9·2 per cent. and 6·6 per cent., and in the temporal area 11·2 per cent. and 19·2 per cent. From the figures given by Donaldson it appears that in the aboriginal brain the percentage area of measured cortex was lower in the frontal region than the six brains studied by him; higher in the parietal areas in all cases; approaches the scholars' brains, and exceeds the three Southard brains, in the occipital area; and is particularly unfavourable in the temporal region. The lowest value given in Donaldson's series is 18 per cent., while in the aboriginal woman 11·2 per cent. is the relative proportion of the temporal area.

It seems as if some significant aspect of the aboriginal brain has been here brought to light. It has been recorded in the previous study that the temporal area appeared as if the convolutions had been pinched out, and the same thing has been noticed here in the mother's and infant's brain. It now appears that not only are the convolutions reduced but also that the growth in length and depth of the sulci is deficient. The disparity is seen to some extent in depth, but particularly in length. If the length, depth, and extent of the measured cortex of the temporal area in foetus and mother be compared it will be seen that two areas, the occipital and the temporal, relatively diminish as the brain grows. The occipital still retains the same proportions as in the white brains, while the temporal falls far behind.

Thus by observation and measurement the conclusion emerges that the relative failure of the growth of the temporal area is an important feature of the aboriginal brain.

The comparison in growth of the length and depth of selected sulci between mother and foetus shows that the length has increased most in the frontal and parietal regions, least in the occipital and temporal regions. The occipital increase, however, exceeds that of the temporal. The amount of increase is practically the same in the frontal and parietal regions, while in the temporal region it is only half as great as in these two. The occipital growth is intermediate between these two. Expressed as the natural logarithms the amounts of increase in length are: frontal 5·61 (75 per cent.), parietal 5·24 (67·6 per cent.), occipital 3·93 (51 per cent.) and temporal 2·89 (10 per cent.). In regard to the depth the increase is more regularly distributed, except in the occipital area where the increase is slight.

In regard to the extent of cortex measured by the length and depth of selected sulci in the four principal areas, the amount of growth in extent follows very much the increase in length except that the temporal shows a greater increase than the occipital. The relative amounts can perhaps be best expressed by tabulating the square roots of the differences of the extent between mother and foetus in the four principal areas. This gives the frontal 58, the parietal 58, the temporal 29·5, and the occipital 23·2. Thus the frontal and parietal areas exhibit the same amount of increase. It would appear from

Donaldson's results and those of other observers that much greater growth occurs in the frontal than in the parietal area in the European brain. In general the law of brain growth has been formulated as a polar growth continuing longest at the frontal and occipital poles. The above analysis then shows a difference in the aboriginal brain, for the parietal area has grown almost to the same extent as the frontal region. The amount of growth in the occipital region is little, yet we have seen that its percentage area of the total measured cortex places it among the best of the European brains. This percentage of the total area of measured cortex is still greater in the foetal brain. We conclude then that the growth of the occipital area is peculiarly precocious in the aboriginal brain. In addition to the poor growth of the occipital region from birth onwards the relatively slight growth of the temporal region reduces the percentages of this measured area. Thus it seems that the occipital region is precocious in growth, while the temporal is poorly developed at all ages.

## THE SIGNIFICANCE OF THE TEMPORAL REGION

It is but natural to enquire if any special significance attaches to this failure of the temporal region, a failure which appears to be established both by development of its sulci and by observation of the convolutions.

An enquiry into the mental achievement of the aboriginal might betray wherein his deficiency resided. However, great difficulties are encountered in making any analysis. It is customary to refer to him as the most primitive member of the human species. The craniometrical studies of Morant do not support this notion altogether, and Morant concludes from his studies that he is only one among several primitive races and has no special affinity with any fossil human type. Cultural studies place him about the Aurignacian level (E. O. James), with a complex social organisation, but with little control over his environment, and no evidence of any provision for future needs, a fact the more remarkable considering the wide fluctuations in food supply from season to season in his country.

The estimates of different observers vary from considering him merely a beast, to supposing him capable of almost any achievement given the opportunity. I have tried with Dr Pulleine of Adelaide to arrive at some more definite result. There are few opportunities of testing any considerable number of pure-blooded aboriginal children by the Binet-Simon intelligence tests, but some are available in Mission schools. We have made some tests and intend to enlarge this enquiry later. In addition we have collated evidence from schoolmasters, farm-managers, and others. We have tried to assess the results of games wherein success depended on the perception of some simple relation, their ability to solve easy arithmetical problems relating to their interests, and to draw conclusions from various interrogations of young adults, etc. Provisionally we suggest that the aboriginal intelligence is about that of an 8-year old child. There is of course great individual variation. Actual testing suggests that the range of visual acuity does exceed that of the white man.

We believe, therefore, we have sufficient evidence to justify the statement that the level of mental performance of the aboriginal is about that of our own least efficient performers. We have no evidence which enables us to dissect the particular element, if such there be, that conduces to this level. Perhaps the results obtained by students on anthropoid behaviour have some relevance to this problem. Köhler, Yerkes, and others have presented evidence from the study of the chimpanzee of his ability to solve problems depending on visual stimuli. There seems to be no reason to suppose that we have any advantage which depends on peripheral visual discrimination. From the results they obtained it is suggested that thought processes, albeit rudimentary, but essentially similar to our own, occur in the brain of the anthropoid. The point which bears on the present problem is the utter inability of the anthropoid to use or acquire any sort of language. All efforts to teach him one or two simple words appear to have ended in complete failure. It is difficult to imagine what kind of thought processes can go on in the absence of any kind of language. The power of symbolic formulation that depends on this auditory cortex, i.e. language, is then the next great achievement in human evolution. This present study suggests that the neural basis of this mode of symbolic formulation is of a more restricted character than in the white brain and is the factor that determines the cultural level of the Australian aboriginal. He is therefore deficient, not in the sense attaching to feeble-mindedness, but in the sense that his powers of symbolic formulation are definitely limited by the deficiency in growth of the auditory area of his brain.

It is to be remarked that Bean has presented evidence of a deficiency of growth in the temporal region of the brain of the American negro and Hrdlička has found a similar lack in the growth of the same region of the skull.

Attention has been drawn by Elliot Smith to the expansion of the temporal area of the brain of fossil man disclosed by the study of intra-cranial casts. We see then emerging in fossil man the neural basis of the new mode of symbolic formulation, and because of its newness subject to more than the ordinary amount of variation. It is therefore reasonable to expect that the amount of temporal cortex might be the physical basis of our ordinary distinction of primitive and advanced races.

The present study adds thus a few points to the general story of mental achievement. The early development and the absolute and relative amount of occipital cortex afford evidence of the great importance of vision in the evolution of man and suggest why in primitive man symbolic formulation is mainly derived from visual perceptions. The expansion of the auditory area adds a new mode of symbolic formulation reaching different levels in different races. These events have of course their repercussions throughout the rest of the cerebral cortex and so there is a concomitant increase in parietal and frontal cortex. With the full development of the symbolic formulation dependent on the temporal cortex there occurs the last event, the expansion of the frontal

cortex, which at a guess might be correlated with the manipulation of material objects in the highest sense.

There is one other aspect of the growth of fissures which is of interest. Donaldson took his heaviest brain as a standard, giving to its measurements the value of 100. By extracting the cube root of the weight and squaring this he obtained a value which might be regarded as the expected extent of cortex. This value was then compared with the observed values obtained by the above system of measurement.

The values for the aboriginal brain treated in this way suggest that the weight of the hemisphere should yield an extent of cortex of the value of 81. The observed value is, however, 60 only. The length and depth of sulci compared with what might be expected are also low.

It is to be remarked that the brains studied by Donaldson do not give values by this method which would rank the brain according to performance. One of the scholars' brains gives an observed value of 57 against an expected value of 99. The results obtained by measuring the length and depth of sulci are by no means highly correlated with mental performance. However, the deficiency of the observed value in the aboriginal brain is to be attributed most to deficiency in length. This is the more remarkable in that it occurs in brains markedly dolichocephalic.

## THE HISTOLOGY OF THE CORTEX

Donaldson, from the work done by Sugita and others, has concluded that the number of cells in the cerebral cortex is, within the limits of biological fluctuation, the same for all members of the same species.

The Australian brain is smaller than the white brain and the dimensions of its fissures are such that these produce no greater increase of cerebral cortex proportionately than they do in other brains. If then the cortex of the aboriginal should possess the same number of cells as the white then its cortex should either be thicker or should contain a larger proportion of undifferentiated neuroblasts.

The histological sections of the cerebral cortex which follow have been examined for evidence on these points. It may be stated here that the cortex of the aboriginal brain is thinner than that of the white. Cell counts have been made over a large number of sections from different parts of the cortex and the enumerations have been compared with similar sections from white brains and also with counts made from published photographs such as those of Economo. In all cases care was taken, of course, to compare areas from the same level of the cortex and brought to the same magnification. The results so obtained were such as to convince me that the closeness of the packing, the degree of differentiation, and the size of the cells, were much the same in the two kinds of brain and that there must be, therefore, fewer cells in the cortex of the aboriginal. This result is of course in conformity with the ratio of the grey matter to the white.

## OBSERVATIONS ON THE INDIVIDUAL AREAS

The position from which the cortex was taken for the making of the sections is shown by reference to text-fig. 1.

Area 1, the pre-frontal area, is difficult to measure, for most sections are placed somewhat tangential to the cortex. As a matter of fact the width arrived at by measurement of what appeared the most suitable area came to 2 mm. This happens to be identical with the value arrived at by Bolton for the same area. The individual laminae show the following measurements:

| | mm. |
|---|---|
| Lam. zon. | = 0·42 |
| Lam. supragran. | = 0·83 |
| Lam. gran. int. | = 0·24 |
| Lam. infragran. | = 0·54 |

Thus the measurements accord very well with those obtained by Bolton in a normal woman whose brain weighed 539 gr. for the right hemisphere and 515 gr. for the left hemisphere. They are greater than in another case of his (a female, aged 22, brain weight, right 469 gr., and left 465 gr.). In this case the brain weights are almost identical. Bolton has also published a series of micro-photographs of the pre-frontal cortex at various ages. Inspection of these alongside the accompanying microphotograph, as well as actual counts of cells over areas of the same size in normal white brains, suggest the conclusion that there are more cells per unit area in the aboriginal cortex than in the white. This difference in number appears to be due to the greater frequency of small cells in the aboriginal cortex than in the European brain.

Area 2. Intermediate pre-central area. This portion of the cortex studied in the region of the pars triangularis conforms to the description of this area. There are no data available at the moment with which we can compare this area either in the extent of the cortex or the width of the individual laminae. It corresponds to Brodmann's regio frontalis inferior and lies outside the pre-central area in his account. Campbell includes it in the intermediate pre-central area.

The actual microphotograph (Plate I, fig. 6) failed to include the whole of the lamina zonalis. The external granular layer is very broad and the lamina pyramidalis is distinguished by the presence of large pyramidal cells. In the infra-granular layer medium-sized pyramids are present. The total width of the cortex is 2·5 mm., which agrees with the width given for this area by Economo. On the whole the granular layers are moderately well developed and better so than in Campbell's picture of the intermediate pre-central area. It resembles Campbell's frontal area. There are no giant pyramids present.

The actual dimensions of the individual layers are as follows:

| | mm. |
|---|---|
| Lam. zonalis ... ... ... | 0·16 |
| Lam. gran. ext. and lam. pyram. | 1·09 |
| Lam. gran. int. ... ... ... | 0·32 |
| Lam. infragran. ... ... ... | 1·00 |

If the accompanying microphotograph be compared with fig. 25 (*FDΓ*, area triangularis) of Economo it will be seen that the stratification of the layers is not nearly so sharp and also that there are fewer cells present in the aboriginal cortex. This is especially marked in the case of the lamina pyramidalis. The speech centres in the two races present considerable histological differences.

Area 3. Area precentralis—the motor area. The microphotograph of this area (Plate I, fig. 7) may be compared with fig. 12 of Economo. The magnification of the picture here presented is slightly greater but the enlargements are sufficiently close to make the comparison easy.

The cortex is 3·27 mm. in depth. As is well known, this is the thickest part of the human cerebral cortex and an average of about 4 mm. is to be expected. Economo gives a range from 3·5 to 4·5 mm. Thus it is to be concluded that the aboriginal cortex is thinner in the motor region than is the white brain.

The cellular type shows in the aboriginal a general trend toward the pyramidal form but this transformation is less complete than in the white brain. The external granular layer, for instance, is more conspicuous and broader than in the white brain. The pyramidal change is marked in the third layer of the cortex and in fact, in the sections examined and in the one presented, exceeds that of the lamina ganglionaris, the Betz cell layer. The internal granular layer, though reduced, is a more marked remnant than in the white brain. The portion labelled lamina ganglionaris is pyramidal in form but the Betz cells are much less conspicuous than would be expected. It is hoped to reinvestigate this area in a further examination of the aboriginal cortex.

Cell counts show that the number of cells per unit area is less in this region than in the white brain. Some interest attaches in this region to the ratio of the supra-granular to the infra-granular layers. Bolton has estimated these thicknesses as being in the ratio of 4 to 3 to each other. In the aboriginal cortex the ratio is as 1 to 1.

Thus the present examination of this region of the brain suggests a less marked differentiation of the cortex, a thinner cortex and reduction in the number of cells per unit area.

Area 4. Area postcentralis.

*The width of the individual laminae*

| | mm. |
|---|---|
| Lam. zonalis ... ... ... ... | 0·28 |
| Lam. granularis ext.... ... ... | 0·28 |
| Lam. pyramidalis ... ... ... | 0·61 |
| Lam. granularis interna ... ... | 0·36 |
| Lam. ganglionaris with lam. multif. | 0·50 |

The total width is 2·2 mm., whereas 3 mm. is the average in the white brain. The reduction in the total width of the post-central cortex is due mainly to reduction in the supra-granular and infra-granular layers. The width of the internal granular layer is practically the same as that given by Economo for the white brain. In comparing sections from the same area in the two races

there is again a lack of precision comparatively in the stratification of the aboriginal cortex. It is interesting that the reduction in thickness of a receptive area like the post-central cortex should occur not in the primary receptive layer but rather in those parts of the cortex which link the receptive area to adjacent and more distant parts of the nervous system.

Area 5. From the inferior parietal area—the gyrus supra-marginalis.

Area 6. Superior parietal area. Taken from the superior parietal region. This resembles very much the supra-marginal and angular areas. The supra-granular layers are well marked while the infra-granular laminae are not so well developed as in the angular area, for instance. The cortex is here 2·03 mm. in thickness, while it is nearer to 3 mm. in the white brain. Again the stratification is not so sharp.

Area 7. Also from the inferior parietal area—the gyrus angularis.

The piece of cortex taken from the area labelled 5 in text-fig. 1 measures 2·25 mm., while the piece from the area labelled 7 in the same figure is 2·56 mm. in width. They resemble each other in having a well-marked lamina pyramidalis and internal granular layer. The angular area is the thicker and this is due to the greater thickness of the supra-granular layer. In the white brain these areas are nearly 3 mm. in thickness and are therefore thinner in the aboriginal brain. They also differ in being not so well stratified though agreeing in their general conformation.

Area occipitalis. Reference to the numbers 8, 11 and 12 on text-figs. 1 and 2 will show that these have been obtained from the following areas:

8, Lateral occipital area—Microphotograph, Plate II, fig. 12,
11, Posterior calcarine area—Microphotograph, Plate III, fig. 13,
12, Anterior calcarine area—Microphotograph, Plate III, fig. 14.

In this particular aboriginal brain there was no sulcus lunatus. Nevertheless the visual cortex is present on the lateral surface. Reference to the microphotograph (Plate II, fig. 12) actually shows the two divisions of the internal granular laminae undergoing fusion.

In the sections from area 12 the structure shows a universal small-celled cortex in which can be distinguished the inner and outer granules belonging to the stria of Gennari.

In the sections from area numbered 11 in the posterior calcarine area the structure is not so obviously that associated with the visual area. It is 1·56 mm. thick.

In the sections taken from area 8, the lateral occipital area, the structure is that typical of visual cortex. Comparison with the sections taken from a European brain shows that the thickness is much about the same. In each case the anterior calcarine area measures about 2 mm. Though both consist of the same type of small granular cells there are more per unit area in the aboriginal area than in the white brain, showing that the packing is much closer in the former.

Thus the visual area of the aboriginal brain is not only more extensive

actually than in the white brain but has the same thickness; the same, even if not more so, characteristic histology; and possibly even more cells per unit area. When it is remembered that everywhere else the aboriginal cortex is thinner and poorer in cells than the white it becomes obvious how important visual perception must be in the mental life of the primitive Australian.

Area temporalis. The microphotograph, Plate III, fig. 15, corresponds to area labelled 9 on text-fig. 1, and is taken from the superior temporal convolution. The microphotograph, Plate III, fig. 16, corresponds in the same figure to area 10 and is taken from the middle temporal convolution.

Our own examinations of the same areas in the white brain gives us a depth for the cortex of the superior temporal convolution of 2·9 mm. while Economo gives figures of 3 mm. and over. Therefore we conclude this area is much more undeveloped in the aboriginal brain. Furthermore both inspection and counting confirm the impression that the number of cells per unit area of the cortex is less in the aboriginal brain than in the white.

Further measurements showed that the ratio of the infra-granular layers to the supra-granular in the aboriginal was as 7 to 4, while in the white the thicknesses of these two layers were as 5 to 6. That is to say in the aboriginal brain the outer laminae are thinner than in the infra-granular, whereas the reverse is the case in the white brain.

Finally, cell counts per unit area confirm the impression obtained from inspecting sections of these areas from the brains of the two races that there are fewer cells per unit area in the aboriginal brain.

The sections from the middle temporal area more nearly resemble the same area in the white brain.

Thus, in contrast with the occipital area, the temporal area has not undergone any considerable differentiation and this is in harmony with conclusions arrived at in the earlier part of this paper.

## SUMMARY

(1) The brain of the Australian aboriginal foetus in its general conformation resembles the foetal brain of the white.

(2) The extreme dolichocephaly of the adult is due to later unequal rates of growth.

(3) The dimensions of the cortical fissures in the principal areas of the adult brain indicate that absolutely and relatively the occipital area is the most developed; that the parietal and frontal areas are moderately developed, the frontal, however, falling behind that of the white; while the temporal area lags very far behind that of the white.

(4) Comparison of the dimensions of the fissures in the aboriginal foetus and adult indicate the precocious development of the occipital area and its relatively great extent. The backwardness of the temporal area is also evident.

(5) It may be said then that the occipital area is the most important neural basis for symbolic formulation in the aboriginal cortex.

(6) The order of development in the principal cortical areas in man is first the visual area, later the temporal area; with each of these is correlated expansion in the parietal and frontal areas; the frontal area is the last of all to show its characteristic human development.

(7) The histological examination of the cortex shows that the degree of cell stratification is less well established than in the white brain except in the visual area.

(8) Everywhere the cerebral cortex is thinner than in that of the white except in the visual area.

(9) Though a sulcus lunatus may be absent the striate area extends onto the lateral occipital cortex.

(10) The number of cells in the aboriginal cortex is both absolutely and relatively fewer than in the white cortex.

(11) The facts elicited in the presented study afford at least an approximate neural basis for the cultural level of the Australian aboriginal as well as an explanation of his special aptitudes such as those based on visual symbolisation.

For much help in the work involved in this study I wish to express my indebtedness to Miss M. Flecker, of the Medical Faculty, University of Adelaide.

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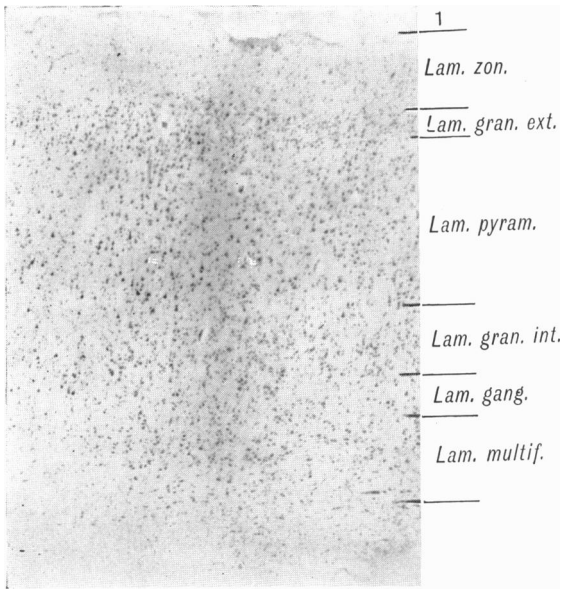
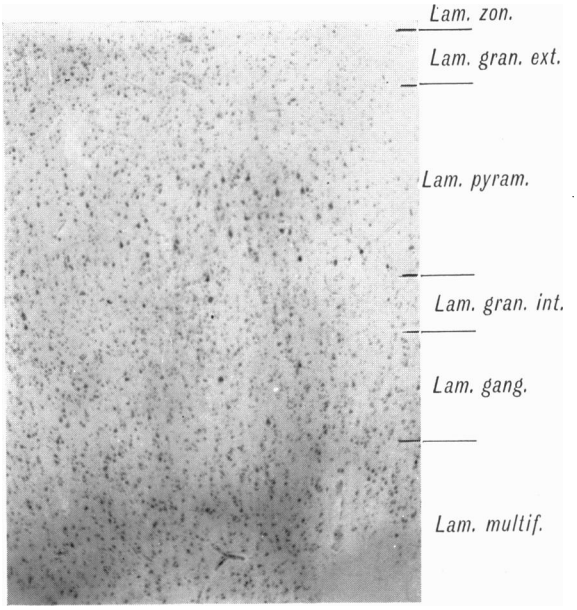



Fig. 5

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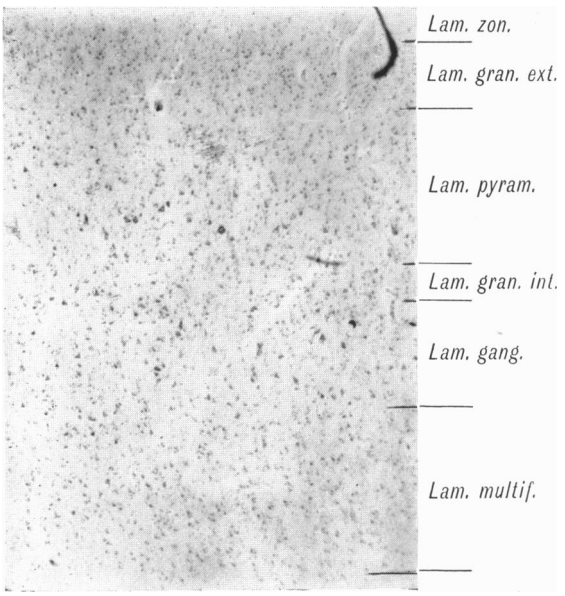


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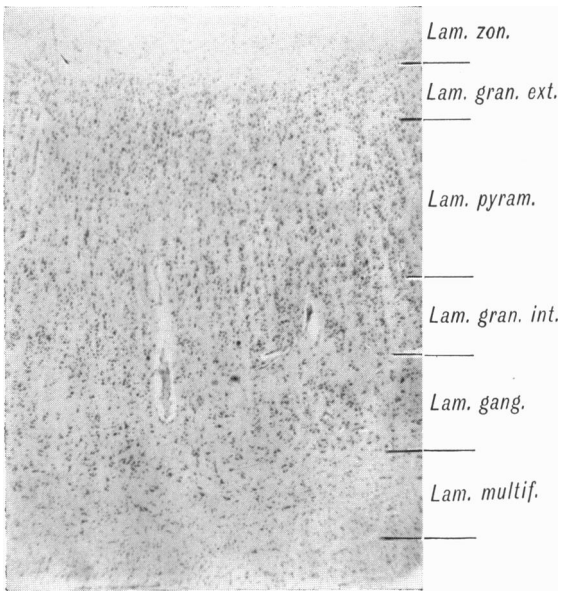


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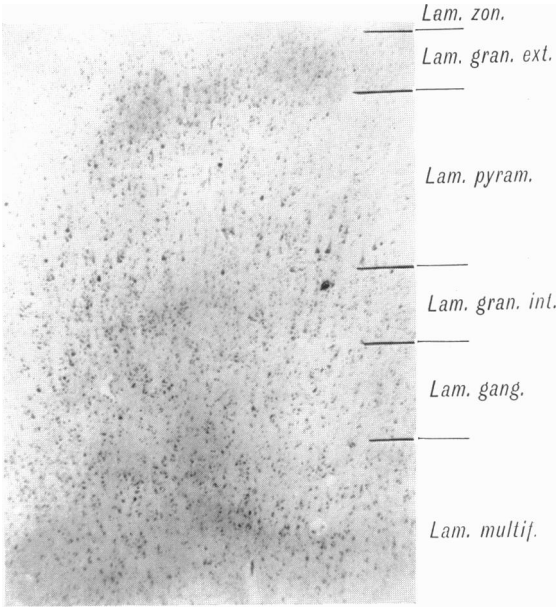


Fig. 9

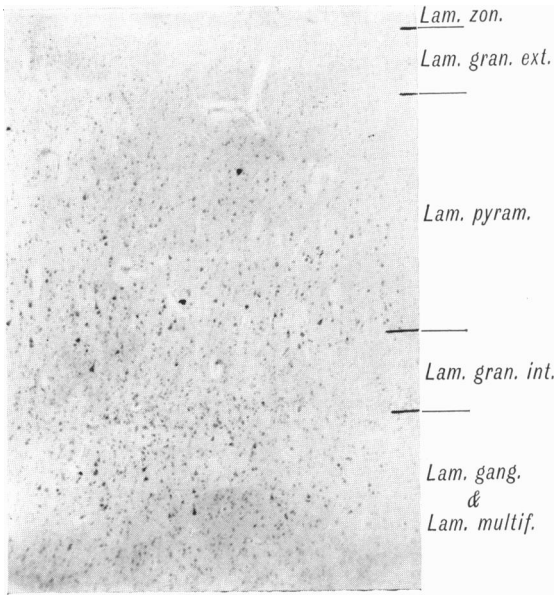


Fig. 10

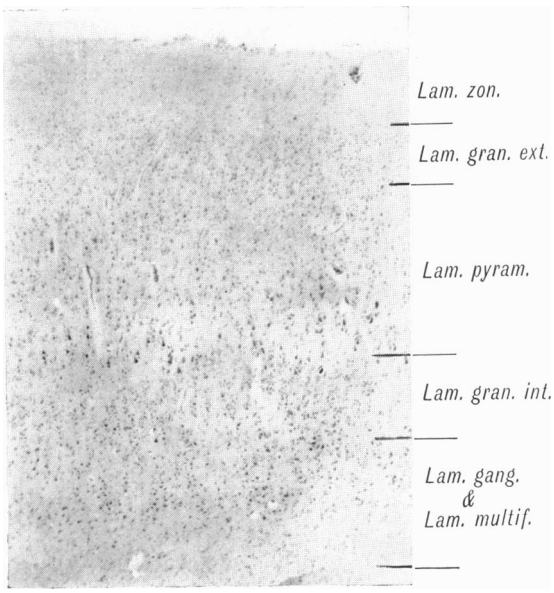


Fig. 11

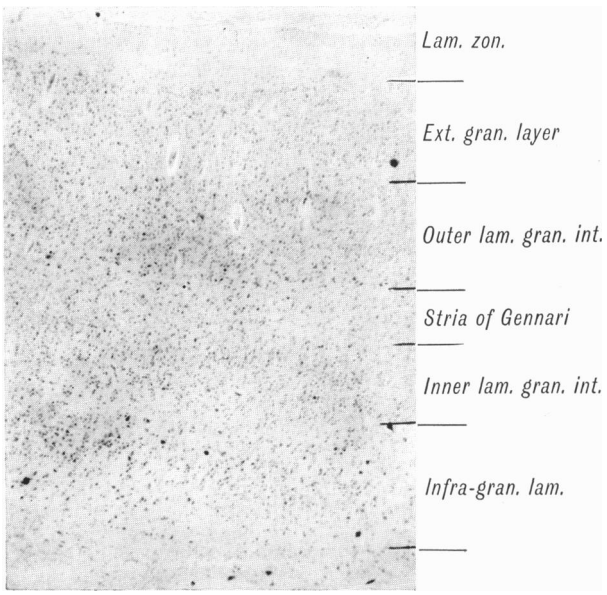


Fig. 12

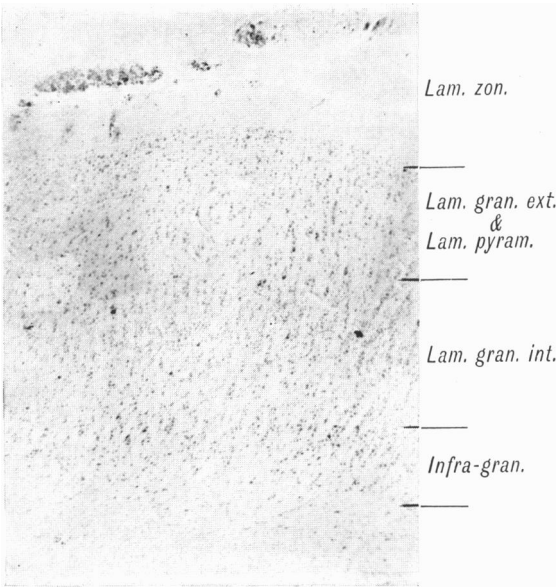


Fig. 13

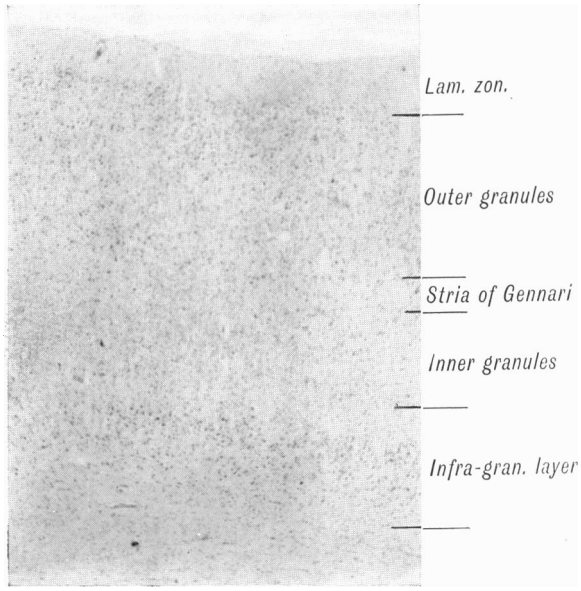


Fig. 14

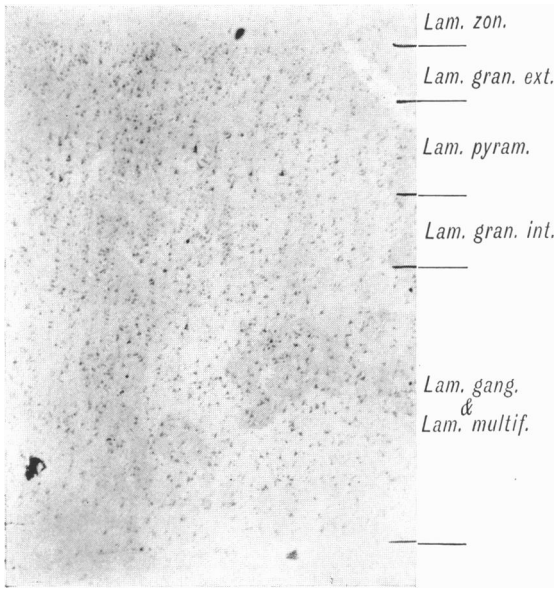


Fig. 15

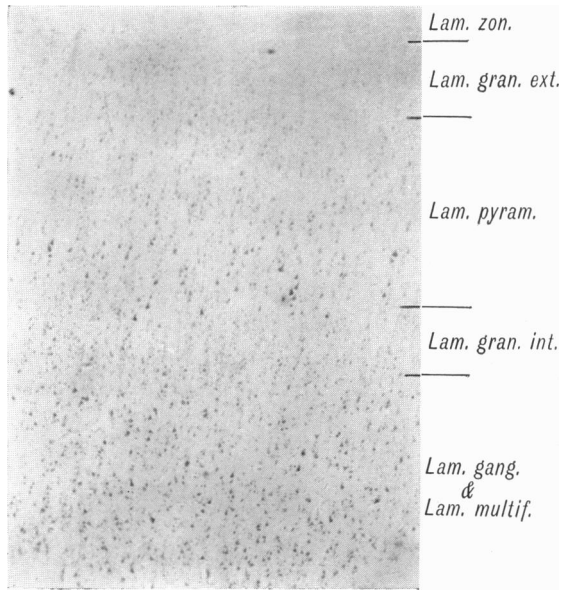


Fig. 16

## EXPLANATION OF PLATES I TO III

Fig. 5. Area pre-frontalis. × 67. Australian aboriginal brain.
Fig. 6. Intermediate pre-central area. Pars triangularis. × 67. Australian aboriginal cortex.
Fig. 7. Pre-central cortex. Motor area. × 47·5. Australian aboriginal cortex.
Fig. 8. Post-central area. × 64. Australian aboriginal.
Fig. 9. Area supramarginalis. × 64. Australian aboriginal brain.
Fig. 10. Area angularis. × 64. Australian aboriginal cortex.
Fig. 11. Superior parietal area. × 64. Cortex. Australian aboriginal brain.
Fig. 12. Lateral occipital area. × 64. Australian aboriginal cortex. On the left the two divisions of the int. gran. layer are fusing together.
Fig. 13. Post calcarine area. × 64. Australian aboriginal cortex.
Fig. 14. Anterior calcarine area. × 64. Australian aboriginal cortex.
Fig. 15. Superior temporal convolution. × 64. Australian aboriginal cortex.
Fig. 16. Middle temporal convolution. × 64. Australian aboriginal cortex.