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THE HUMAN BRAIN

Chairman's introduction

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Much has been said at the symposium about the pre-eminent role of the brain in the continuing emergence of man. Tobias has spoken of its explosive enlargement during the last 1 Ma, and how much of its enlargement in individual ontogeny is postnatal. We are born before our brains are fully grown and 'wired up'. During our long adolescence we build up internal models of the outside world and of the relations of parts of our bodies to it and to one another. Neurons that are present at birth spread their dendrites and project axons which acquire their myelin sheaths, and establish innumerable contacts with other neurons, over the years. New connections are formed; genetically endowed ones are stamped in or blanked off. People born without arms may grow up to use their toes in skills that are normally manual. Tobias, Darlington and others have stressed the enormous survival value of adaptive behaviour and the 'positive feedback' relation between biological and cultural evolution. The latter, the unique product of the unprecedentedly rapid biological evolution of big brains, advances on a time scale unknown to biological evolution.

Sherrington wrote that most animal life is mindless, but that the behaviour is purposeful in the sense used in J. Z. Young's introductory remarks, of adaptation for survival to reproduce and to protect the brood. At some level in the evolution of higher animals, and at some stage in the ontogeny of the individuals, there emerge signs of what Sherrington called 'recognizable mind'. Darwin, before him, devoted two chapters of the *Descent of man* to anecdotal evidence of this emergence in wild, captive and domesticated animals.

Brain size is in part related to body size, but the enlargement of the human brain has not gone along with any proportionate enlargement of the body. Big brains have given to the primates the general advantages for survival that attach to adaptive behaviour which is less 'stimulus-bound' than that of lower animals: exploratory drives; internal trial-and-error; orientation to what may be happening beyond the range of sight, smell and hearing; and knowledge of the consequences of particular actions, as in copulation, sowing and harvesting. All this creates selection pressures for yet bigger brains. Enlargement, however, has been local as well as general: of particular areas in relation to specific abilities. Refined geometric analysis of endocranial casts from the skulls of living primates is calibrating the accuracy of measurements of areas of cortex by matching the casts against the fresh brains. Measurements of casts from dated fossil skulls will then be able to tell us over what evolutionary periods the specific enlargements occurred. The method cannot measure the volume of cortex buried in the walls of deep sulci. We still, however, have to look beyond gross morphology, to the increasing intricacy of the intrinsic neuronal microarchitecture that characterizes each area and to the

extrinsic connections that link the areas with one another, with their related thalamic nuclei, and with other levels of the central nervous system. This can be done only by comparative research on the series of living primates.

Elliot Smith thought that the correlation of skilled movements with foveal and stereoscopic vision was a leading factor in primate evolution. Arboreal life 'tended to develop the motor cortex itself, trained the tactile and kinaesthetic senses and linked up their cortical areas in bonds of more intimate associations with the visual cortex'. Hands of primitive pentadactyl structure, whose prehensile function was at first limited to arboreal locomotion, came to replace the muzzle in tactile exploration and manipulation, with differentiation of precision patterns and grips from power grips. Neurological research on Old World primates is filling in the details in Elliot Smith's outline by unravelling the organization of the enlarged visual areas (in front of, as well as behind, the lunate sulcus); of the enlarged peri-Rolandic somaes-thetic and motor areas; and of the enlarged association cortex that lies between. Tuttle has stressed that structural adaptations of the hands of modern apes for arboreal locomotion have not compromised the continuing neurological differentiation of precision patterns and grips. Though incapable of full pulp-to-pulp opposition of thumb and index on account of the relative shortness of the thumb, 'every chimpanzee', according to A. H. Schultz, 'can extract a thorn out of its skin, and this more dextrously than most of us'. Enlargement of hand cortex and differentiation of hand function considerably antedated bipedalism. It has advanced still further in skilled man. A century ago, Hughlings Jackson remarked 'the more movements, the more grey matter'.

Language is unique to the genus *Homo*. A taxonomist visitor from another planet might well write *Homo loquax*. Every human infant with healthy brain and hearing, and exposed to human speech, will learn to speak. Fewer are exposed to reading and writing. We are not yet quite certain if the hemisphere that is dominant for language shows selective enlargement in the region of Wernicke's and Broca's areas, and we know little of their intrinsic neural networks for the analysis and production of elaborate patterns of sound. Specialized organization, however, there must be. With a brain about the size of a chimpanzee's, a microcephalic human can speak more than, for example, the Hayes's 'Viki', who joined their family at the age of three days and after $6\frac{1}{2}$ years could only whisper 'mama', 'papa' and 'cup', often with fingers on lips in the way she had been taught. The brain, not the vocal tract, would be the limiting factor: a whisper is acceptable as speech, and people who have suffered laryngectomy can produce oesophageal speech. The much smaller brain of the parrot evidently contains neural apparatus of a kind that man possesses and chimpanzee lacks. In 1879 the Guy's neurologist, Samuel Wilks, published, in the *Journal of mental science*, 'Notes from the history of my parrot, in reference to the nature of language'. He taught the bird by frequent initial repetition. 'After a few hours it is heard attempting to say the phrase, or, I should say, trying to learn it. It evidently has the phrase somewhere in store, for eventually this is uttered perfectly.' It would repeat the first two or three words, then add 'another and another word', working for hour after hour before becoming word-perfect after some days had elapsed. In forgetting, the last words were lost while the first two or three were retained. 'The result of my observations in respect to the parrot's faculty for acquiring language is – that it has a vocal apparatus of a most perfect kind, that it can gather through its ear the most delicate intonations of the human voice, that it can imitate these perfectly by continued labour, and finally hold them in its memory; also, that it associates these words with certain persons who have uttered them.'

Man's big brain has had enormous survival value in the context of limited social groupings with limited spatial and temporal horizons. Until recently, rare individuals only have ever reckoned with events in distant lands, or beyond the time span of a few agricultural cycles, one session of a parliament, or even a human lifetime. Always there has been intra-species predation on other groups. Sherrington hoped that in the further course of evolution, altruism would replace predatoriness as a leading human characteristic. The apparatus of predation has come far since the Stone Age. Altruism within limited communities has led to local and global overpopulation. There may not be time for the big brain to undergo further biological evolution. Only if cultural evolution can surmount our present crisis will our descendants be entitled to claim that *Homo loquax predatorius* has given place to *Homo sapiens sapiens*.