Short Communication
Volume 9:7, 2021

Journal of
Phylogenetics & Evolutionary Biology

ISSN: 2329-9002

Open Access

Human Brain: Salient Features and the Evolutionary Biology

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Short Communication

The human brain is unique in its structural organization and functional capabilities. In terms of size relative to the body size, the human brain is much bigger than any other mammal. In terms of weight, the human brain weighs anywhere near 1300 grams whereas the average weight of the nearest ancestors, the great apes, weigh only up to a maximum of 500 grams. In the human brain, there are 10 times more glial cells than neurons. Glial cells almost comprise 50% of total human brain cells. Nearly 80% of brain mass is composed of the cerebral cortex containing 100 billion neurons and 10 times more glial cells. However, the cerebral cortex holds only 19% of all brain neurons. The cognitive mechanisms and intelligence functions of the human brain are due to internal patterns of organization at the cellular and molecular levels. The cognitive abilities of the human brain does not depend on the relative brain size but the absolute brain size, the number of cortical neurons, and synapses. The human cerebral cortex subserves cognition and language. In newborns, nearly 80% of the human brain remains in the resting metabolic state and by the age of 5 years, almost 50% of the human brain attains functional status. The human brain has nearly 100 billion neurons with interconnections panning 100000 km and has an estimated storage capacity of 1.25 x 1012 bytes. The human brain is approximately 2% of the whole body mass and consumes 20% of the whole body's energy budget. The brain size of Whales and dolphins is ranked next biggest after human beings, relative to the body size. In humans and primates, the neocortex is big in size. Whales also have neocortex but their structure is different. Whales have independent lineage for 60 million years and developed a social structure similar to primates and humans.[1,2]

The evolution of the human brain and its sophistication have garnered immense interest among scientists and are being characterized genetically as well. Several advanced technologies are now available to estimate brain size. One of the most prominent functional abilities of the human brain is the acquisition of language and this was facilitated by the asymmetric development of the human brain. Not only the size but the shape of the human brain differs from the closest living relative. Magnetic resonance imaging of the brains in monkey, apes and humans followed by application of a nonlinear elastic algorithm for transformation of one brain into another in three dimensions has revealed which areas of the brain that have changed most during primate evolution. During the evolution of the primate, there has been a gradual increase in brain size. The human brain size almost tripled about 1.5 million years ago, nearly 4 million years after the divergence of the human lineage from great apes. The cerebral cortex is especially expanded more than other areas in the human brain. Molecular imaging has enabled analysis of different areas of the brain such as sensory, motor, and association areas and detailed comparison with that of chimpanzees. Most dramatic changes in the human brain occurred in ventro-orbital prefrontal cortex, the ventral stream of the visual cortex, and the hypothalamic neuroendocrine region. Large spindle-shaped neurons are present in the apes and humans and more densely so in humans which take part in decision making in uncertain situations and social interactions.[3-5]

Some people argue that improvement in the quality of diet has enabled enlargement of the brain size and consequently the computing power improved. Therefore, the brain has become metabolically more demanding on the human body. There was a challenge to transmit the information from one part of the brain to another. An increase in the axon size is not a solution as it further enlarges the brain. So the neurons organized locally and differentiated into two halves that are functionally independent in humans. Some people believe that the ability to hunt and forage has driven the evolution of the brain and there was a need to manage social relations through time and space, pooling of resources, better survival, so the brain functioning has advanced. The front part of the brain processes and interprets the information required for social interactions so with better social organization neocortex size also increased. The frontal lobe volume has a direct correlation with problem-solving and cognitive approaches.[6,7]

Changes in the genetic organization and expression pattern cannot be ruled out in the context of human brain evolution. Mutations in the genes causing abnormal spindle-like microcephaly associated and microcephalin were identified which implies that there are greater chances of mutations in these genes leading to a higher rate of cell division and a large brain size as a result. A retrogene namely GLUD2 was derived from GLUD1 that encodes glutamate dehydrogenase. GLUD2 appeared 23 million years ago in hominoids with brain-specific promoters and later acquired amino acid changes allowing its functional supremacy over GLUD1 encoded enzyme. Glutamate dehydrogenase recycles neurotransmitter glutamate resulting in higher neurotransmitter turnover activity in the human brain than in monkeys that lack GLUD2. Nearly 100 genes are differentially expressed in chimpanzee and human brains with different spatial patterns of expression resulting in different functional organization. One of the most prominent mechanisms was the upregulation of certain genes in the human brain associated with metabolism, synaptic organization, and synaptic function. There exists a large gap between the genetic and anatomic differences between the human and ape brain and the actual cognitive and intelligence.

The brain was able to evolve due to ecological, behavioral, and social adaptations, dietary changes, inventions in cooking, introduction of family concept, language, cognition, self-awareness and improved social environment. However, human brain development is not static, there are continuous molecular changes, changes in gene expression, glucose metabolism, synaptic density. DNA methylation is one of the most important regulatory mechanisms in development, learning, memory, and disease in humans. DNA methylation is a form of stable epigenetic modification of genomic DNA and has been regarded as having a significant role in brain development. It was suggested that brain-specific CG methylation was associated with human brain-specific regulation of gene expression. DNA methylation at no CG contexts such as CH methylation where H=A, C, T was found to be relatively abundant in the human brain and was associated with

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Received 05 July 2021; **Accepted** 12 July 2021; **Published** 19 July 2021

postnatal maturation of the human brain and cell-type-specific transcriptional activity. So the development of human brain is a continuous process.

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How to cite this article: Rob Salle. "Human Brain: Salient Features and the Evolutionary Biology." *J Phylogenetics Evol Biol* 9 (2021): 169.