Preface

How Did the Human Brain Evolve?

Four elements combine to influence evolution of any biological feature – time, pre-existing rudimentary capability, genetic variation amongst individuals, and some change in the environment. The first two of these elements are not contentious in relation to human brain evolution. Humans today are the living proof that sufficient time - at least five million years - was available to evolve brains that are three fold larger compared to either other living primates or our earliest forebears.

The great apes are the closest genetic relatives to humans and clearly have some rudimentary capability to learn and solve problems. Higher cognitive function was therefore more likely to occur in an ape, which already had a relatively large and advanced brain, than in a cow or even a tiger, both of which have relatively small brains compared to primates. Humans and chimpanzees last had a common ancestor 6 to 8 million years ago and it seems likely that the earliest human forebears had cognitive capabilities broadly similar to that of present day chimpanzees. Hence, two of the necessary elements – sufficient time and preexisting rudimentary cognitive capability in the last common ancestor of humans and apes - are beyond reasonable dispute.

However, there is little agreement on the relative role of the other two elements that participated in human brain evolution: genetic variation and change in the environment. In essence, this is a nature versus nurture debate, the origin of which is at least a century old.

This debate is now hotter than ever as molecular biologists artificially manipulate genes and brain function in ways unimagined even a decade ago.

Despite clear differences in body morphology and brain capacity, there are surprisingly few differences in the genomes of humans and chimpanzees. At a minimum, differences in genes controlling aspects of brain development including neurogenesis, neurotransmitter receptor expression, and myelination are likely to have participated in the emergence of advanced cognitive function in humans. The ways in which these processes operate and are controlled by genes are being intensively explored but have not yet revealed how the cognitive differences between humans and apes evolved.

Humans have the potential for intelligence but, in acquiring that unique specialization, appear to have paid a price in terms of increased vulnerability of the brain, especially during infant development. It takes at least five years before human infants are minimally independent of their parents and even then most cannot survive unaided. In the case of human brain evolution, not only how the additional operating costs of the larger brain were met needs to be accounted for but also how, simultaneously, human evolution tolerated increasing brain vulnerability during infant development.

Neurodevelopmental vulnerability is the clearest indication that an interplay between genes and the environment contributes to the exquisite functional potential of the human brain. That interplay constitutes Darwin's *'conditions of life'* and made possible human brain evolution, just as it makes possible evolution of any other attribute. But how do genes interact with the environment to permit evolution of cognitive skills that have no apparent survival value while simultaneously creating a long, vulnerable period of early development?

Brains in general require a lot of energy so a bigger brain is even more expensive than usual. A large, metabolically expensive, and developmentally vulnerable brain is impressive enough, but *hominids* destined to become humans didn't just evolve larger brains; they also

evolved fat babies[1]. It may seem only moderately difficult to meet the energy and nutrient requirements for a larger brain, but added to the human brain's remarkable early development is the simultaneous accumulation of considerable body fat before birth. The fat accumulating on a healthy human fetus as it approaches birth is not present in other primates but is, in fact, a prerequisite for full development of advanced brain function in human adults.

***

Since the time of Raymond Dart, the environmental catalyst for early hominid divergence from the last common primate stock has been thought to be a hot, dry climate that created the savannahs in East Africa 4 to 5 million years ago. Those conditions were thought to have forced a four-legged, climbing ape to become earth-bound and search for food while becoming *bipedal* (walking on two legs). Now, after well over fifty years of muted grumbling, even from former supporters, the *Savannah Theory* is transforming towards the *Woodland Theory*, in which the climate of East Africa is now viewed to have been less extreme and forests were more abundant. Hominids are still seen as evolving from an arboreal ancestor but they stayed in the woodlands, more-or-less like today's other great apes.

Some of the questions I want to address in this book are: If both the human genome and the environment hominids inhabited were so similar to those of the great apes, especially the chimpanzees, how did some hominids go on to acquire such a unique brain? What was the catalyst not only for evolution of a larger and more advanced brain but neonatal body fat? Insufficient dietary energy or nutrients severely challenge both

[1]*Hominids* are defined as the branch of primates that became bipedal but did not necessarily form part of the final lineage to humans. *Hominins* are the branch of hominids that led to humans – *Homo (H.) sapiens*, or *Homo sapiens sapiens*. Exactly which of several hominid and then hominin species were the forebears of humans is still unclear. In the interests of simplicity, I will use 'hominid' as a general term for bipedal primates, and will specify the species where known or appropriate. I will also use 'pre-human hominid' to denote the pre-human lineage.

brain development and fat deposition in the human fetus today, so did these same deficits curtail evolution of both advanced brain function and fat deposition in the fetuses and infants of non-human primates? This book is about the 'conditions of life' that, starting from an already successful primate blueprint, permitted only pre-human hominids to avoid or squeeze through this double-pronged evolutionary bottleneck.