Stephen C. Cunnane

Survival of the Fattest

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Foreword

In this book, Stephen Cunnane has turned the search for human origins from loose speculations into science. The accepted view of humans evolving a large brain on the savannahs of Africa was sparked by Raymond Dart's words in 1925 when he said that 'open country with occasional wooded belts and a relative scarcity of water, together with a fierce and bitter mammalian competition, furnished a laboratory such as was essential to this penultimate phase of human evolution'. Since then paleaoanthropologists have stuck to what became the "savannah hypothesis" with almost religious fervour. This hypothesis lacked any evidence base. It never explained why every single land-based mammal proportionately lost brain size in relation to body size as they evolved larger bodies. The loss was universal starting from brain representing greater than 2% of body weight for small mammals and primates, shrinking to less than 0.1% of body weight for larger mammals. The 350 gram brain of a one ton rhinoceros pails into insignificance compared with the 1,800 gram brain of the dolphin or the 8 kilogram brain of the sperm whale. This universal and massive loss of brain size in herbivorous land species, occurred despite what must have been successful competition for food against the large carnivores and other mammals. Otherwise, the herbivores could not have evolved larger and larger bodies.

What Stephen has done is to come up with strong support for an alternative, evidence-based view that humans evolved in a coastal ecosystem. A coastal origin was first articulated by Sir Alistair Hardy in the 1960s. Although it found several supporters, it has been roundly rejected by palaeoanthropologists. Yet, there is not a single piece of evidence or even a testable hypothesis to explain how *H. sapiens* escaped the trap of diminishing relative brain capacity with increasing body size on land. Stephen provides evidence. He injects two essential criteria for human cerebral evolution: the requirements for (i) more energy (ii) and more refined structure. He then presents the evidence as to how these two criteria would have been met. The energy cost for human brain growth, which reaches 70% of all the energy the mother ploughs into her fetus during the brain growth spurt, is guaranteed by fat stores unique to humans amongst the primates. Comparative studies first demonstrated the universality of docosahexaenoic acid (DHA) in neural signalling systems of the fish, amphibia, reptiles, birds, mammals and primates alike. Science then showed that deficiency of brain DHA leads to degenerative processes, reduced cognitive and visual function. Conversely, added DHA, even in well nourished Norwegian women, leads to increases in IQ in children. Genomic research has explained that DHA is responsible for transcribing over 170 genes required in brain development. That is, the structural and bio-motive requirement is met by the same fatty nutrients that formed the first neurones in the sea some 500 million years ago.

A second critical feature of the book is that it turns attention away from the macho image of killing or scavenging for food, or even the most recent idea of endurance running to compete for food, towards the singular and paramount importance of the mother. It is an uncomplicated fact that the nourishment of the mother would have determined the forward or backward evolution of the brain. This brings me to the superiority of Stephen's thesis over the savannah proposals. Nowhere in the latter is there a notion of the significance of "brain-selective nutrients". Food is food and that is it. The universal collapse of relative brain size in land-based species despite the advance in massive body size clearly demonstrates there are different requirements for body growth on the one hand (protein and minerals) or for the brain on the other (lipids and trace elements). That fact is so simple, it is strange that it has been ignored. The idea of hominids evolving a large brain by competition on the savannahs contains no predictive power. Yet prediction and test is the hallmark of science and progress. The persuasive evidence presented by

Stephen has the power to predict both forward and backward evolution. His wide view of many facets of evolving humans adds to a compelling story, which has a message not just for our past, but for our present and future. It was a privilege to read this book before its publication.

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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.

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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

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[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.

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Contents

Part 1

The Human Brain: Unique Yet Vulnerable

Chapter 1

Human Evolution: A Brief Overview

What is Evolution?

Evolution involves gradual change in the form and function of organisms. Since one's phenotype is coded for in DNA, either the genotype itself or the way in which the genotype codes for the phenotype must change in organisms that evolve. In organisms such as bacteria in which the reproductive cycle is short, changes in DNA can bring rapid changes in phenotype; in organisms with a long development time, these changes take longer. Though it is an extremely large molecule and has to replicate many times as the body's billions of cells divide, DNA is a highly reliable code. Still, changes in the nucleotide sequence of DNA do occur. If the change in DNA is too extreme or affects a critical site in the genome, the egg may not get fertilized or the embryo may not be viable. If it is too slight, the change may not show up in the phenotype of the offspring.

Each species is said to have a single set of genes or *genome*. But the genome of one individual is slightly different from everyone elses. No single individual has the ideal model genome for that species. Defective copies of a gene in one parent may be silent because the other parent's copy for that gene is correct. Even matching but defective sections of DNA in both parents may not matter because those sections do not code for genes. The basis of evolution is that there is just enough non-lethal change in just the right part of DNA.

Climate (temperature, day length, humidity, radiation), predators, food supply, water supply and population density are all factors that constitute the environment. Part 1 of this book outlines the influence of food components such as brain selective minerals and docosahexaenoic acid on the development of a normal human 'neurological' phenotype; i.e. the physical, biochemical and physiological constituents of normal brain and behavioural development within an individual. Culture also influences brain development but, again, mostly by affecting gene expression within the individual.

The issue related to human brain evolution is – how do dietary, cultural or hormonal influences in an adult affect the genotype or gene expression in that adult's offspring? Nutrient deficiency affecting brain function in a parent doesn't impair brain function in the child unless the deficiency changes gene structure or unless the child also consumes the same diet. Parents' habits or cultural milieu have an important influence on habits of their children but how does that change the child's genotype? If food or the environment don't change DNA in the second generation, evolution doesn't get started.

Random mutations in DNA are exempt because, by definition, they will happen randomly; their timing, frequency and point of impact on DNA are not predictable. Random mutations are also extremely unlikely to hit specifically the right genes and in the right way that a phenotype evolves rather then dies. However, different environments could influence the occurrence of random mutations.

Environments can also change dramatically but they don't change randomly; here today, gone tomorrow. A rare but dramatic environmental change such as a volcano spewing lava, ash and darkness for months, occurs too suddenly for most organisms affected by the sudden change to adapt. There are of course exceptions but, generally speaking, environments change gradually and it is the role of these gradual changes that are of interest here.

Natural Selection : Need Versus Blind Consequence

Charles Darwin coined the influential term used to describe how evolution occurs – *natural selection.* Natural selection involves four