HUMAN BRAIN EVOLUTION

The Influence of Freshwater and Marine Food Resources

Edited by

STEPHEN C. CUNNANE
Research Center on Aging
Departments of Medicine and Physiology and Biophysics
Université de Sherbrooke

KATHLYN M. STEWART
Canadian Museum of Nature

WILEY-BLACKWELL

A JOHN WILEY & SONS, INC., PUBLICATION

HUMAN BRAIN EVOLUTION

HUMAN BRAIN EVOLUTION

The Influence of Freshwater and Marine Food Resources

Edited by

STEPHEN C. CUNNANE
Research Center on Aging
Departments of Medicine and Physiology and Biophysics
Université de Sherbrooke

KATHLYN M. STEWART
Canadian Museum of Nature

WILEY-BLACKWELL
A JOHN WILEY & SONS, INC., PUBLICATION

Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

Library of Congress Cataloging-in-Publication Data:

Cunnane, Stephen C.
Human brain evolution : the influence of freshwater and marine food resources / Stephen C. Cunnane and Kathlyn M. Stewart.
p. cm.
Includes index.
ISBN 978-0-470-45268-4 (cloth)
1. Brain–Evolution. 2. Human evolution. 3. Cognition. 4. Seafood. 5. Nutritional anthropology.
I. Stewart, Kathlyn Moore. II. Title.
QP376.C857 2010
612.8′2–dc22
2009047979

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

CONTENTS

FOREWORD: EVOLUTION, ENCEPHALIZATION, ENVIRONMENT **vii**
Phillip V. Tobias

INTRODUCTION **xiii**
Kathlyn M. Stewart and Stephen C. Cunnane

CONTRIBUTORS **xix**

CHAPTER 1 *MACROEVOLUTIONARY PATTERNS, EXAPTATION, AND EMERGENCE IN THE EVOLUTION OF THE HUMAN BRAIN AND COGNITION* **1**
Ian Tattersall

Introduction **1**
Natural Selection **1**
Macroevolution **2**
Patterns in Human Evolution **3**
Symbolic Cognition **5**
Exaptation and Emergence **8**
Large Brains and Aquatic Resources **9**
References **10**

CHAPTER 2 *LONG-CHAIN POLYUNSATURATED FATTY ACIDS IN HUMAN BRAIN EVOLUTION* **13**
Michael A. Crawford

Introduction – Lipids and Evolution **13**
The Evolution of Complex Life Forms **14**
The Language of Lipids **15**
DHA **17**
Evolution of *Homo sapiens* **20**
DHA and Neural Pathways? **22**
A Comment on AA **24**
The Third Phase of Earth's Life History – AA and Reproduction in Mammals **25**
Darwin and the Conditions of Existence **26**
Implications **27**
Conclusion **28**
Acknowledgments **28**
Notes **28**
References **28**

CHAPTER 3 *HUMAN BRAIN EVOLUTION: A QUESTION OF SOLVING KEY NUTRITIONAL AND METABOLIC CONSTRAINTS ON MAMMALIAN BRAIN DEVELOPMENT* **33**
Stephen C. Cunnane

Introduction **33**
Brain Evolution in Hominins **35**
Need for A New Paradigm **38**
Brain Development **40**
Energy Requirements of the Brain **41**
Nutrients and Brain Function **44**
Brain-Selective Nutrients **46**
Critical Importance of Baby Fat in Humans **52**
Gene – Nutrient Interactions **57**
Conclusions **59**
Acknowledgments **61**
References **61**

CHAPTER 4 *METABOLIC AND MOLECULAR ASPECTS OF THE CRITICAL ROLE OF DOCOSAHEXAENOIC ACID IN HUMAN BRAIN FUNCTION* **65**
J. Thomas Brenna

Docosahexaenoic Acid (DHA) Molecular Structure **65**
DHA and Neural Function **66**
Metabolic and Biophysical Considerations **68**
Functional Importance of DHA in Retinal and Neural Membranes **70**
Dietary Need for Preformed DHA **71**
DHA Intake During Pregnancy and Lactation: Effects on Higher CNS Functions of the Mother and Infant **73**
Summary **74**
References **74**

CHAPTER 5 *LESSONS FROM SHORE-BASED HUNTER-GATHERER DIETS IN EAST AFRICA* **77**
Frits A.J. Muskiet and Remko S. Kuipers

Introduction **77**
Our Genetic Background **78**

Adaptation to the Conditions of Existence 79
Western Diets and the Human Genome 81
Brain-Selective Nutrients in Health and Disease 83
Dietary Fatty Acids at the Land–Water Interface 84
Tanzanian Breast Milk Fatty Acids Versus Western Recommendations 89
Estimated Fatty Acid Intakes from Shore-Based Paleolithic Diets 93
Conclusions 96
Notes 97
References 97
Appendix 103

CHAPTER 6 *THYROID HORMONE, IODINE AND HUMAN BRAIN EVOLUTION* 105

Sebastiano Venturi and Michel E. Bégin

Introduction 105
Thyroid Hormone Metabolism and Function 105
Fetal Development 108
Antioxidant Activity of Iodine 108
Dietary Sources of Iodine 110
Iodine Deficiency Disorders 111
Human Brain Evolution 113
Thyroid Hormone, Iodine, and Human Brain Evolution 117
Conclusion 118
References 119

CHAPTER 7 *FOOD FOR THOUGHT: THE ROLE OF COASTLINES AND AQUATIC RESOURCES IN HUMAN EVOLUTION* 125

Jon M. Erlandson

Introduction 125
Food for Thought 126
Human Nutrition and Physiology 127
Archaeological Evidence for the Antiquity of Fishing 128
Conclusions 132
Acknowledgments 133
Notes 133
References 133

CHAPTER 8 *THE CASE FOR EXPLOITATION OF WETLANDS ENVIRONMENTS AND FOODS BY PRE-*SAPIENS *HOMININS* 137

Kathlyn M. Stewart

Introduction 137
Hominid Exploitation of Wetlands Environments and Resources 139
Early Hominins: Colonization of New Environments 144
Plio-Pleistocene Climate Instability and Use of Wetlands Resources 147
Intensification of Wetlands Vegetation Exploitation 149
The Shift to High-Quality Foods 151
Preconditions for Encephalization 155
Precessional Forcing, Drying Lakes/Rivers, and Die-Offs of Aquatic Faunas 157
Mammal Meat: A Later Hominin Adaptation? 158
Postscript: *H. heidelbergensis* and *H. sapiens* 160
Summary 161
Acknowledgments 162
References 162

CHAPTER 9 *BRAIN SIZE IN CARNIVORAN MAMMALS THAT FORAGE AT THE LAND–WATER ECOTONE, WITH IMPLICATIONS FOR ROBUST AUSTRALOPITHECINE PALEOBIOLOGY* 173

Alan B. Shabel

Introduction 173
Methods 177
Results 177
Discussion 183
Acknowledgments 186
References 186

CHAPTER 10 *COASTAL DIET, ENCEPHALIZATION, AND INNOVATIVE BEHAVIORS IN THE LATE MIDDLE STONE AGE OF SOUTHERN AFRICA* 189

John Parkington

Introduction 189
Changes 190
Climate Change 196
A New Narrative 198
References 200

CHAPTER 11 *HUMAN BRAIN EVOLUTION: A NEW WETLANDS SCENARIO* 203

Stephen C. Cunnane and Kathlyn M. Stewart

Human Brain Evolution 203
Neurochemical and Nutritional Evidence 203
The Fossil Evidence 204
Plausibility, Prediction, and Parsimony 205
Salient Points 206
Conclusion 207
Reference 207

INDEX 209

FOREWORD: EVOLUTION, ENCEPHALIZATION, ENVIRONMENT

Phillip V. Tobias

Stephen Cunnane of the University of Sherbrooke and Kathy Stewart of the Canadian Museum of Nature, Ottawa, have kindly invited me to write some thoughts by way of a foreword to their new book. This book takes a novel approach to the challenging question of the evolution of the human brain. Not content with the hard (and not-so-hard) facts culled from the fossil record, they and the team of contributors they have recruited look beyond these facts to seek out the impact of the environment, whose overarching force must have played a vital role in the several millions of years since the higher primate brain began to expand, absolutely and relatively, and to reorganize and reconstruct the telltale stigmata of cerebral localization.

About 2.6–2.5 million years ago (mya), there were marked climatic changes in Africa. These were attendant upon uplift of the southern and eastern parts of the continent; this great landmass, which comprises almost a quarter of the earth's habitable land surface, became cooler and drier. At that time and very shortly afterward, eight major changes are apparent in the palaeontological and archaeological record of Africa. They are as follows:

1. The retreat of the great wet forest of middle Africa, and the opening and spread of the savanna.
2. A number of animal extinctions.
3. The appearance of a number of new species and genera in the African fossil record.
4. The earliest stone tools appear in the archaeological archives.
5. The first appearance of a new genus of hominins, *Homo*, represented by the species *H. habilis* or by *H. rudolfensis.*
6. The development in early *Homo* of the first truly human kind of foot.
7. The first signs of appreciable enlargement of the hominin brain, as compared with the smaller brains of African great apes and australopithecines.
8. The earliest detectable appearance of the main speech areas of the cerebrum, namely Broca's and Wernicke's areas, on endocranial casts of *H. habilis*.

Were these all coincidences? It is more parsimonious and more likely that some or all of these phenomena were interlinked. Further, these eight phenomena were causally related to the tectonic and climatic changes in Africa, from a warmer and wetter climate in a more low-lying terrain before 2.6–2.5 mya, to a cooler and drier climate in more elevated terrain at the time of early *Homo*. It is obviously more satisfying and rigorous if logical causal steps linking these phenomena can be established, that is, the much, much earlier oxygenation of the atmosphere which made possible the survival and the flourishing of the aerobic eukaryotes; that was surely more than just a coincidence! As described in some detail, it is my contention that the causal pathway by which the tectonic and climatic changes of 2.6–2.5 mya influenced the development of the hominid brain involved not only selectively advantageous gene mutations, but also the intermediation of water.

Edible plants and animals abound in both marine and freshwater environments. Many specially-adapted types of plants and animals thrive along shorelines of rivers and lakes and along beaches and the shores of estuaries, both freshwater and saltwater, and on tidal and intertidal interfaces between them. These living creatures provide today, and would have provided in earlier times, an abundant source of foodstuffs (see Chapters 8 and 9). Much has been written in recent years about this subject, but we can trace the roots of the discourse back more than two hundred years. In 1798, Thomas Robert Malthus, an English clergyman and economist, published *An Essay on the Principle of Population: As It Affects the Future Improvement of Society.* (Malthus's sub-title hints at an early adumbration of the controversial eugenics movement, almost 100 years before Francis Galton introduced the term "eugenics" in 1883!) Malthus argued that whereas human populations increase by geometrical progression, their means of subsistence increase only by arithmetical progression. Hence, population size is necessarily limited by the means of subsistence. Two centuries later, the crucial role of food in human evolution has been the subject of uncounted important studies, many of which are reflected in the present volume.

While these thoughts on water, food, and mankind were being actively canvassed, the background for the development of the new hypotheses was being furnished by fossil evidence from South and East Africa. Going back to Raymond Dart and Robert Broom, there had been a long-standing hypothesis that early human evolution occurred in a savanna environment. I grew up with this paradigm and it had acquired an aura of sanctity! From the l980s onward, studies of the mammalian and plant species accompanying early australopithecine remains from Makapansgat and Sterkfontein in South Africa, and from Ethiopia, had shown that by and large, these were not savanna species but forms associated with woodlands and even forests. At the Pliocene time depths represented in these deposits, the evidence torn from the ancient rocks told a story that seemed to be incompatible with the Savanna Hypothesis.

To this palaeontological and palaeobotanical evidence, data were added from the study of living forms, including humans. These studies showed that today's mammalian savanna dwellers are not characterized by such features as hairlessness, the great number and the nature of sweat glands and their distribution, the degree of development of subcutaneous fat, excessive urination, the absence of sun-reflecting fur, or poor water drinking capacity and retention. Yet these characteristics are hallmarks of modern mankind. When this anatomical, histological, biochemical, and physiological evidence was added to that of Africa's fossil-bearing deposits, it was clear that the savanna paradigm for early human evolution was passé. At a lecture at University College London in November 1995, I declared that all erstwhile savanna-supporters – including myself – must swallow their former assertions: "Open the window and throw out the Savanna Hypothesis, for it is no longer tenable!," I exclaimed. "The Savanna Hypothesis is dead; we are back to square one!"

With the Savanna Hypothesis put out to grass and perhaps even liquidated, the aquatic influences in human structure, function, and evolution were open to study with liberated and uncluttered minds. Michael Crawford and colleagues (see Chapters 2–4) had already been drawing attention to the special significance of the long-chain, polyunsaturated fatty acid – *docosahexaenoic acid* (DHA). They showed that DHA was necessary for the development of the large brain characteristic of hominids. There is a relative lack of DHA in savanna food. Crawford suggests that this would explain the "degenerative evolution" of the brains of truly savanna species and would be another reason why hominids are unlikely to have evolved their large brains on the savannas. On the other hand, the aquatic food chain has an abundant supply of DHA. Of necessity and convenience, early hominids would have made use of the aquatic food chain thereby making possible the spectacular evolution of the brain and brain size. The claim that the human brain depended on nutrients in the aquatic food chain furnished independent evidence to support the importance of water in human evolution.

DHA is not the only polyunsaturated fatty acid related to brain development and function. Two others are *arachidonic acid* (AA) and *eicosapentaenoic acid* (EPA). DHA and AA both comprise about 8% of the dry weight of the human brain, but EPA is present in much smaller amounts. These three fatty acids play important roles in the brain: both structural and functional roles are subserved by AA, while a structural role is concentrated in DHA and a functional role in EPA. Theoretically, humans could make AA, EPA, and DHA from their precursors (linoleic acid and alpha-linolenic acid), but the capacity for this conversion in humans seems to be inadequate to meet the needs of the developing brain. Also, the incorporation of DHA, AA, and EPA into brain phospholipids may be inadequate in the presence of much saturated fat in the diet. Our brain, therefore, needs a direct dietary supply of DHA, AA, and EPA. It is important to note that much of the AA, EPA, and DHA in the food supply originate from microalgae which grow in water. Hence, aquatic food chains are especially rich in these three important brain fatty acids. As David Horrobin (2001), who also studied polyunsaturated essential fatty acids and brain function, commented, “Perhaps that is why humans love, and pre-humans seem to have loved, water so much. They needed to eat water-based creatures to obtain the AA, EPA and DHA to grow their brains.” Perhaps, also, I should like to add, that is why our mothers and grandmothers used to urge us to eat our fish, “otherwise our brains would not grow.” They must have had some secret knowledge!

The endocranial capacities of *H. habilis* reveal a mean volume of 640 cm^3 (Tobias, 1997), which exceeds the mean value of 451 cm^3 for *Australopithecus africanus* by 189 cm^3. That is, when the values for fossil samples reasonably attributed to these two taxa are compared, the *H. habilis* value for mean absolute endocranial capacity exceeds that for *A. africanus* by 42%. When the absolute capacity values are related to estimates of body size, values may be obtained for *relative brain size*. These, too, show that *H. habilis* was significantly more encephalized than *A. africanus*. When these *encephalization quotients* (EQs) are expressed as percentages of the modern *H. sapiens'* relative brain size, the value for *A. africanus* falls at 46% and that of *H habilis* at 53%. That is, of all fossil hominin series for which EQs are determinable, *H. habilis* is the earliest for which the EQ is over half of that in modern *H. sapiens*; all of the determinable australopithecine species have EQs definitely below 50%.

It is a striking fact that this substantial increase in inferred brain size first becomes evident with the appearance of *H. habilis*. The earliest examples of the latter species occur in the fossil record after the tectonic and climatic changes of 2.6–2.5 mya. The drying and cooling of large parts of Africa would undoubtedly have affected the water resources available to the early hominins. The drying up of many streams might be expected to have set water supplies at a premium. Moreover, the tectonic elevation would have increased runoff and induced reversals of the direction of flow of some rivers. All of these direct and indirect sequelae of tectonic uplift, added to the general climatic desiccation, would have made water a more precious commodity to those living in the affected areas.

It goes without saying that fresh water had always been essential for survival. Under the more strained conditions just described, we may reasonably infer that an even closer proximity between man and water than before would have been of intense survival value. I envisage that such close relationship would have involved not only water for drinking and keeping cool, but also increased dependence upon aquatic food resources. At a time when selective pressures for larger brains must have been strong, the "brain foods" required to sustain brain development were acquired by increased, probably culturally influenced, foraging on aquatic plants and animals. By such a route, it is not difficult to envisage a causal link, or a set of links, between the more exacting challenges for survival and the selectively determined and palaeontologically testified increase in absolute and relative brain size. Water and edible aquatic organisms provided the crucial catalyst when early *Homo* confronted this evolutionary bottleneck. While many species did not survive the crisis of 2.6–2.5 mya, the hominins, some of whom were armed with genetic mutations for larger brains, a penchant for water foods, and stone culture, won through to become the diverse larger-brained species of Pleistocene mankind.

Modern humans need fresh water for drinking. In 1968, L.S.B. Leakey declared that, in order to seek early human remains, it was necessary to find a site that was near water. Prior to that, in his book, *Water, Weather and Prehistory*, Robert Raikes described in 1967 how, in his hydrological surveys in Baluchistan and the eastern Mediterranean, he learned to read the antiquity or recency of fresh water springs from the adjacent presence or absence of suitably ancient stone tools! Water is also essential for keeping cool. Third, as this book makes abundantly clear, water is a source of aquatic plant and animal foodstuffs. These studies have shown *inter alia* the important role that the aquatic food chain plays in providing an abundance of DHA and of AA, and their significance for the development and healthy functioning of the brain.

Waterways have been both deterrents to, and facilitators of, the dispersal of humans throughout Africa, across the Old World, and even into the New World. It has been suggested that the movement of peoples out of Africa tended to follow beaches, shorelines, and river banks, while "island hopping" was a likely means of peopling islands and landmasses beyond stretches of water. Strolling along the beach or swimming or floating or rafting would have been sufficient to carry mankind out of Africa – as Stringer suggested in 2000 and as I had proposed in 1998 in *Water and Human Evolution*. When much water was bound up on land in the Ice Ages, sea levels were lower than they are today. Previously submerged land bridges and insular stepping-stones appeared. At such times, it would have been possible to walk dry-footed from Tripoli and Tunisia to Malta, Sicily, and Sardinia; from South Korea to South Japan and from the Sakhalin Island/Peninsula to Hokkaido, North Japan; from Malaysia to Sumatra, Java, Madura, and Bali; and from Siberia to Alaska.

As noted by Morwood et al. (1998), the crossing by humans – and elephants (*Stegodon*) – into the Indonesian islands of Wallacia, especially Flores, nearly 1 mya raises interesting questions of the antiquity of simple watercraft and of hominids swimming, perhaps together with those splendid swimmers, the elephants. The presence of hominid remains in Iberia, both northern and southeastern Spain, certainly at 1 mya (Aguirre and Carbonell, 2001) and possibly at 1.5 mya (Gibert et al., 1989; Tobias, 1995) raises in an acute form the problem of the route by which these earliest Europeans reached Iberia (Tobias, 2002). The long journey through the Levantine Corridor around the eastern Mediterranean, and the land bridge from North Africa through Malta, Lampedusa, and Sicily to Peninsular Italy, or from North Africa to Sardinia and Corsica, and thence to Peninsular Italy, are several possible routes by which hominids might have migrated out of Africa, then moved westward and finally southward across the Pyrenees to Iberia. By analogy to the crossing from the southeast Asian Sunda Shelf to Flores, there is a reasonable likelihood of a water crossing with "island hopping" from Morocco and Ceuta to Spain. It has been estimated that at times of lower sea levels, with the emergence of a few islands that are at present submerged, and of a small peninsula hanging off the southern shelf of Iberia, the maximum required water crossing would not have exceeded 5 km!

Watercraft or rafts or floating tree trunks might have enabled some adventurous members of early *Homo* to cross. In this context, I propose that swimming has been a hominid activity for over a million years.

The presence of *Stegodon* along with stone tools in Flores across the deep strait of the Wallace Line, and the occurrence of the Algerian elephantid *Mammuthus* in Iberia of the early Pleistocene, raise this question: when one considers the close and intimate relationship that exists between elephants and their mahouts in the Indian subcontinent in recent centuries, it is interesting to speculate as to whether a relationship existed between the movement of early humans and early elephantids across such straits as that between the Sunda Shelf and Flores. If man and mammoths or man and *Stegodon* had a close relationship over a long period of time, it is not impossible that in some way, the *Stegodon* might have facilitated the crossing by humans of the Flores Straits 900,000 years ago. Moreover, could those North African mammoths have been associated in any way with the crossing by humans, from Ceuta and Morocco into Iberia, as long ago as 1.5 mya? At any rate, the possibility should certainly not be dismissed that human beings have been able to swim, or at least paddle with floats such as bladders, for a very long time.

A fifth way in which water is thought to have affected human evolution is an old proposal that mankind evolved some of its distinctive features in an aquatic environment (the Aquatic Ape Hypothesis). Although the idea is commonly ascribed to Sir Alister Hardy (1960), he was preceded by Wood Jones in England in 1929, G.L. Sera in Italy in 1938, Max Westenhöfer of Germany in 1942, and B. Henneberg. Supporters of the Aquatic Ape Hypothesis have listed many features, including bipedalism, voluntary breath holding, hairlessness, the distribution, excessive number, and nature of sweat glands, subcutaneous fat, excessive urination, absence of sun-reflecting fur, poor water drinking capacity, and water retention.

Until recently, the evolution of early hominids in the savanna has been a strongly held, prevailing hypothesis. Yet some of these human characteristics would have made us hopeless savanna dwellers. On the other hand, a number of our features align us with marine mammals, even including face-to-face copulation. Hence the suggestion by Hardy and others was, modestly, that human ancestors must have spent more time in the water in the early days of human evolution. Under these circumstances, it was proposed, humans lost most body hair, developed the layer of subcutaneous fat, and other features. Hardy's work was largely ignored by his contemporaries, but Elaine Morgan (1982, 1990, 1997), Marc Verhaegen (Verhaegen et al., 2002), Michael Crawford, Stephen Cunnane, Leigh Broadhurst, and others have revived interest in the fundamentally sound merits of aquatic diets and habitats, especially for the brain. My own paper, "Water and Human Evolution," (Tobias, 1998) gave a spurt to the resurgence of active interest.

In sum, it is widely accepted that the competing savanna hypothesis is no longer tenable, since I amassed much evidence against it at University College London in 1995. Therefore, I believe that scientists now have a duty to re-examine the evidence for a closer link between hominids and aquatic environments.

(i) The role of waterways in hominid development highlights a real problem that needs to be addressed. We need new investigations such as by fresh, open-minded research students and post-doctoral fellows.

(ii) I am not yet convinced that all of the traits included in the original Aquatic Ape Hypothesis can be reasonably attributed to that hypothesis. Research on those traits should be updated.

(iii) We should not telescope too many phases and characteristics of hominid evolution into a single, over-arching hypothesis.

(iv) Above all, let us keep our thought processes open to changes of paradigms, and especially to the change which would be necessitated with growing evidence of the role of waterways in hominid evolution.

(v) Finally, the role of water, while long appreciated and emphasized by ecologists, has been sadly neglected by human evolutionists.

This volume edited by Stephen Cunnane and Kathy Stewart is a puissant move away from the heavy, earthbound view of hominid evolution and a move toward a greater emphasis upon the role of water and waterways in hominid development, survival, and diversification. I hereby express my personal tribute and admiration to them for conceiving and editing this volume. As always my warm thanks are extended to Mrs. Felicity Krowitz.

Phillip V. Tobias, FRS
University of the Witwatersrand
Johannesburg, South Africa

REFERENCES CITED

Aguirre, E. and Carbonell, E. 2001. Early human expansions into Eurasia: The Atapuerca evidence. *Quaternary International* **75**:11–18.

Gibert, J., Campillo, D., Eisenmann, V., et al. 1999. Spanish Late Pliocene and early Pleistocene hominid, Paleolithic and faunal finds from Orce (Granada) and Cueva Victoria (Murcia). *Human Evolution* **14**: 29–46.

Hardy, A. 1960. Was man more aquatic in the past? *The New Scientist* **7**:642–645.

Horrobin, D.F. 2001. *The Madness of Adam and Eve: How Schizophrenia Shaped Humanity*. London: Bantam Press.

Morgan, E. 1982. *The Aquatic Ape*. London: Souvenir Press.

Morgan, E. 1990. *The Scars of Evolution*. London: Souvenir Press.

Morgan, E. 1997. *The Aquatic Ape Hypothesis*. London: Souvenir Press.

Morwood, M.J., O'Sullivan, P., Aziz, F., et al. 1998. Fission-track ages of stone tools and fossils on the east Indonesian island of Flores. *Nature* **392**:173–176.

Stringer, C. 2000. Coasting out of Africa. *Nature* **405**: 24–27.

Tobias, P. V. 1995. The bearing of fossils and mitochondrial DNA on the evolution of modern humans, with a critique of the "mitochondrial Eve" hypothesis. *South African Archaeological Bulletin* **50**:155–167.

Tobias, P. V. 1997. Evolution of brain size, morphological restructuring and longevity in early hominids. In *Principles of Neural Ageing*, eds. Dani Su, A. Hori, and G.F. Walter, pp. 153–174. Amsterdam: Elsevier.

Tobias, P. V. 1998. Water and human evolution. *Out There* **35**:38–44.

Tobias, P.V. 2002. An Afro-European and Euro-African human pathway through Sardinia, with notes on humanity's world-wide water traversals and proboscidean comparisons. *Human Evolution* **17**:157–173.

Verhaegen, M., Puech, P.-F. and Munro, S. 2002. Aquarboreal ancestors? *Trends in Ecology and Evolution* **17**:212–217.

INTRODUCTION

Kathlyn M. Stewart and Stephen C. Cunnane

Paleoanthropologists and others have traditionally viewed human brain capacity as a matter of fine-tuning over time by natural selection. However, there is no evidence that early hominins, including most australopithecines, "had acquired cognitive capacities significantly different from those of today's apes" (Tattersall, Chapter 1). It is not until about 2.5 Ma that the appearance of larger-brained hominins, with rough stone tools, signaled a cognitive advance. Long periods of "adaptive stasis" followed by cognitive advances and increased brain size also characterize the later evolution of *Homo*. With environmental changes in habitat and food resources being a primary driver in evolution, it follows that at several points in time, such changes contributed significantly to major changes in hominin morphology and behavior. This volume is founded on the premise that continued expansion of the hominin brain required significantly increased abundance and quality of food sources.

Much has been written about the high energy requirements of the human brain, and the need for high-quality food sources to fuel the adult brain. The adult human brain consumes about 23% of the body's energy requirement – much more than in other similarly sized mammals. There is clear evidence today that low intakes of specific dietary nutrients can be limiting for brain development and function. For instance, it is now well established that deficient intake of the omega-3 fatty acid docosahexaenoic acid (DHA) increases the risk of subnormal brain development. In fact, to insure normal growth of the fetal and infant brain, human babies need two dietary long-chained polyunsaturated fatty acids (PUFA): DHA and arachidonic acid (AA).

AA is found in many foods, with significant amounts in egg yolk, meat, seafood, and fish. Dietary sources of preformed DHA, however, are more or less confined to freshwater and marine fish and shellfish, and a few organs, notably the brain. Edible fats in the soft tissues of mammals and other land-based animals are less accessible, contain much lower amounts of long-chain PUFA, and are not consistently available. Given the human brain's specific requirements for these high-quality fatty acids, as well as iodine and iron, the earliest hominins must have evolved in an environment that could provide food resources with abundant availability of these nutrients (referred to as *brain-selective nutrients*). Otherwise, it seems empirically evident that what limits human brain development and function today would surely also have limited its evolution. This volume focuses on the biochemical and nutritional requirements of encephalization of the human brain, and provides several lines of evidence as to how hominins exaptively fulfilled these requirements.

Others have also argued that hominins evolved in an aquatic, wetlands, or shore-based environment (e.g., Hardy, 1960; Morgan, 1982, 1990, 1997; Verhaegen et al., 2002). However, they have focused more on morphological and physiological adaptations to aquatic environments and have said little about the implications of such an environment for the hominin brain. Most of the research studies dealing with the modern human brain and its high energy requirements have been published in journals and books focusing on metabolism or nutrition. Only occasionally has there been any peer-reviewed crossover