THE CLIMATE CONNECTION

The Climate Connection highlights the influence of saltatory evolution and rapid climate change on human evolution, migration and behavioural change. Growing concern over the potential impacts of climate change on our future is clearly evident. In order to better understand our present circumstances and deal effectively with future climate change, society needs to become more informed about the historical connection between climate and humans. The authors' combined research in the fields of climate change, evolutionary biology, Earth sciences and human migration and behaviour complement each other, and have facilitated an innovative and integrated approach to the human evolution–climate connection.

The Climate Connection provides an in-depth text linking 135 000 years of climate change with human evolution and implications for our future, for those working and interested in the field and those embarking on upper-level courses on this topic.

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Climate Change and Modern Human Evolution

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CAMBRIDGE
UNIVERSITY PRESS

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

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www.cambridge.org
Information on this title: www.cambridge.org/9780521147231

First published 2010

A catalogue record for this publication is available from the British Library

ISBN 978-0-521-19770-0 Hardback
ISBN 978-0-521-14723-1 Paperback

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The colour plates can be found between pages 174 and 175.

Foreword

Whenever people stop to think about it, there can scarcely be a more obvious and common-sense idea or awareness than that humans, and all their activities, have a relation to climate. The clothes we wear, the houses we live in, the food we eat and where it is produced, our perceptions of the rest of the world and all its living creatures, of the changes in weather and of the seasons – all are influenced by, or are expressions of, the climate of our immediate surroundings and of the whole planet. Each of us, wherever she or he may live, 'knows', instinctively, and through experience, that the climate is a vital and sometimes dominant component of our environment. Also, through our family and collective memories, as well as by simple observation of the natural world around us, through the many stories that are parts of our cultures in most of our societies, and acceptance that there was in the past something called the 'Ice Age', most of us are aware that the climate in the past was somehow different from what we are experiencing today. But just what is the relationship between humans, as intelligent living beings on the dynamically changing planet on which we depend, and the climate which itself appears to be changing? How is the relationship expressed, and how do humans respond? A greater understanding of this relationship may be important, indeed may be vital, in helping people in all parts of the world and their institutions, to understand the problems and to take more effective actions in the years ahead.

This book delves deeply and comprehensively into the background and underlying factors of evolving climatic conditions on the surface of planet Earth and the evolution of what has now become the modern human. It tells the fascinating story of how, again and again, changes in climatic conditions presented groups or populations of the evolving pre-human and human species, wherever they were at the time, with difficulties, limitations and challenges, so that the survivors – our ancestors – used their ingenuity, or ability to migrate, to cope with the challenges; and in so doing they moved a step closer to what today we rather gratuitously call 'behaviourally modern humans'. Clearly, the fact that today we – *Homo sapiens* – are the dominant large

animal on the planet, that we are the only living species of our genus, and that we have planet-wide distribution and have recently been or can be found not only on all parts of all continents but have ventured over and under the seas, into the air, and into outer space, has a lot to do with the fact that changes in climate have obliged our ancestors, or given them the opportunity, to develop the capacity for behavioural change, the flexibility, and the tools to cope with changes in our external environment. In a very real sense, modern humankind in all its present successes is a product of severe climate changes in the past.

However, those same evolved abilities that have brought us to our present pre-eminent position in the global biosphere now have resulted in the situation that our activities are seriously affecting the processes and chemical characteristics that produce the dynamic climate equilibrium and the biological productivity of the Earth itself. To understand what is happening, and to understand whether, and in what way, humans can take action to prevent this situation from being self-destructive, we need to examine carefully our inherited and evolved ability as a species to act within our environment. This book not only tells us where we have come from and what we are today, but calls for sobering reflection on what we can do in light of where we appear to be going. Just at this time in our current history, when our economy, our politics, and the popular concern in many parts of the world is focused on the prospect of impending severe climate change, this book, with its thorough, logical analyses and broad perspective on the connections between climate and humans, is very valuable.

The authors, an eminent evolutionary biologist and an experienced palaeogeographer-ecologist, have teamed up to examine the climate–human evolution connections in a comprehensive and thorough way. To do so, they have taken us back to the story of our planet, the evolutionary and chemical changes in our atmosphere and oceans as the setting in which organic life developed and which, in due course, resulted in living cells and organisms that had the capacity to respond and adapt to changes – changes in the climate as it then was – and to pass characteristics for survival to the next generation. We are reminded that the main units into which the geological timescale is divided, identified a century ago by the disappearance or emergence of distinctive fauna, are testimony to periodic severe climatic disturbances, or to other catastrophes such as bolide impacts or volcanism, which not only have constrained, but have also stimulated the evolution of life.

The story of the growing knowledge of the geologically earliest hominins, and of the discoveries, the interpretations, the premature and disputed conclusions that led to scientific recognition of the genus *Homo* and its several species; of the influence of the dominant personalities who led the thinking in this subject, is well told, in the light of current discoveries and new techniques of analysis. After a century and a half of controversy, the studies of human fossils and of the evidences of human behaviour

and expression – tools, habitations, art, indications of language – together with the evidence of dispersion of early humans to widely scattered locations in Africa, Asia, Australia, Europe, the Americas and Polynesia, especially in the last 135 000 years, make a coherent picture. The issues of whether 'out of Africa' or multiple origins explains the sources of humankind and of the role and distribution of other species *(Homo erectus, Homo ergaster, Neanderthal Man*, and the others including our late little relative *Homo floresiensis)* fall convincingly into place in this larger perspective.

Having reviewed the evidence and our progressive understanding of early humans, the authors address the question of the changes of climate during the last 135 000 years, since the time when our direct ancestors, *Homo sapiens*, left Africa and began forays which would take them throughout the world. To do this, they first bring to our attention the variations of solar energy received by the planet – the Milankovic cycles and modifications – the movements of the continents, variations in three-dimensional ocean circulation, and the progressive changes in atmospheric chemical composition which have affected climate, climate stability and the support of biological life during the past two billion years. They then follow the climate story through planetary evolution, including haphazard but important events such as volcanic outpourings and cycles of glaciation that have affected the conditions and stability of the climate, and thus the development and distribution of vegetation and all animal life, up until the spread of *Homo sapiens* 'out of Africa' to the rest of the world about at the time of the onset of the last global glacial cycle. That cycle resulted not only in glaciers on land and ice in the oceans of northern regions, but also severely affected climate and thus vegetation and food supplies for primitive humans in subtropical regions.

The story of the changes in climate during the last 135 000 years, the evidence for changes in landscape and vegetation, and the progressive evolution, sophistication and distribution of *Homo sapiens* in response to different climates and climatic disturbances, up to the beginning of relative stability about 11 500 years ago – the Holocene epoch – is important. With the compressed timescale made possible by computer modelling, the tale reads somewhat like an adventure story – 'just one damn climate change after another' (though the incidents are separated by thousands of years) – presenting our ancestors with stresses and challenges from which the survivors, rather like Hercules after each of his labours, were better equipped to meet the next challenge. The markers for this remarkable chronicle are the successive 'marine isotope stages' that are well identified in geological and oceanographic data and allow computer simulations of climate that can be correlated with non-biological observations and measurements. The story thus brings human history and various branches of the natural sciences together to set the stage, during the Holocene, for humans to reside in most parts of the world and then, themselves, to have the ability and capacity to make significant changes in the world environment.

The development of agriculture, with the consequent growth of hierarchical societies, domestication of animals, larger-scale fisheries, fixed habitations with people in large numbers, trade between communities, etc., marked a quite new dimension in the human–climate connection. The authors summarize significant climate or climate-related events in different parts of the world and relate them to societal and technological developments in favoured locations or progressive groups, through processes that can be hypothesized as 'catastrophe–communication–collaboration'. That process is still going on. Through it, humankind has developed various civilizations, spread throughout the world in drastically increasing numbers, learned how to exploit living and non-living resources for short-term human ends, and succeeded in managing, for better or for worse, many environmental processes. A new epoch, the Anthropocene, is upon us. But the effects of, and vulnerability to changes of climate are by no means lessened.

While the story of climate and its changes, and its connections to the evolution of humankind over the last two million years or so is fascinating and of great portent as a basis for assessing our ability to cope with the severe climatic changes that are impending, the masterful review and analyses presented in this book also have a significant value as a record of scientific thought and research during the past two hundred years. The book provides a commentary on how understanding of a topic of intense interest to a large number of scholars and investigators, as well as to the general public, grows through careful thought and meticulous work, strong opinions and philosophies in one direction or another, and through new discoveries and new technologies which may overturn or replace established ideas. It presents a unique story of the scientific method itself.

Anyone reading the book cannot help but be impressed with how tempting it is for rational, knowledgeable scholars to draw sweeping interpretations and conclusions from very sparse data or observations. The find of a single human skull, very carefully examined for cranial characteristics which give indications of anatomy, diet, intelligence, etc., is for better or worse, interpreted to represent many generations of a whole human race, until some other find is made. Ideas which seemed sensible deductions or conclusions by the originator sometimes become fixed by the followers, and defended with almost religious inflexibility. Some tools made of stone, which happened not to perish through millennia, are surmised to represent and define a whole way of life of a people, when it is likely that the people who made them mostly used tools of materials that have since disappeared, and the objects found today, while genuine, may not have been representative at all. The authors of this book, through their very comprehensive review (more than 1100 quoted refereed papers) and their careful, generous and yet critical analyses, bring to light the many controversies and different schools of thought, and put them into perspective in the light of recent discoveries and new technologies of dating chronology and

genetics. They lay many misconceptions to rest. Where major uncertainty still exists, the authors do not hesitate to give their personal interpretation, for the reader or future researchers to resolve. Thus this comprehensive book puts into perspective and simplifies what are surely whole libraries of strongly held but often conflicting ideas about the history of our own species and our biological relatives. And the unifying perspective, rarely brought out until now, is the effects of, and responses to, climate changes. This in itself is a very great service to the scientific community and to the advance of knowledge.

The Climate Connection also admonishes us to be more careful about the use of common words, and behind them be careful of the distinctions between concepts often loosely undifferentiated. The 'adaptation' of our ancestors to the climate where our species developed half a million or more years ago is a genetic characteristic that each of us carries within us and which cannot be changed within a few millennia. It is why most of us wear clothes wherever we go, to keep a warm tropical environment next to our skin. Donning clothes is however not adaptation, but a form of 'adaptability'. Adaptability is a characteristic that enables humans to change our behaviour relatively quickly in any number of ways (by developing new tools, etc.) to cope with, or escape from, changes in the environment. It is our adaptability that has enabled us to survive through, and in the long run benefit from, rapid climate changes in the past. And it is our adaptability that we must call upon to meet the challenges ahead.

While presenting a balanced and comprehensive review of who we are as modern humans, the only surviving species of our genus, and how we got to where we are today as an animal shaped by successive encounters with climatic challenges, the book does not pull any punches with respect to the challenges ahead. That the impending rapid change in climate, with reduction of planetary biological productivity on land and oceans, and geologically rapid change in sea level, may be in large measure due to human actions and our own short-sightedness does not make it any less real. The authors do a commendable job in outlining the evidence for the challenges ahead. They note a selection of indicators and plausible speculations about what may lie in store for the living resources and environmental conditions upon which we all depend, and describe how modern complex societies that have apparently become locked into increasing numbers of people, increasing use of energy, and use of biological resources far beyond the ability of the planet to produce them, are increasingly vulnerable to failure because of changes in climate, hydrological systems or sea level. Whether the *adaptability* built into the make-up of *Homo sapiens* will enable us to survive, and ultimately to benefit from the coming climate change, and whether terrestrial and ocean ecosystems can ever recover from the severe damage that human actions in the past century have done, is an open question that this book leaves the reader to ponder. We have no knowledge of the

losses that were suffered by human groups in each or any of the climate change challenges in the past, so aptly described herein; but we do know that some individuals, enough to carry on our story, survived and progressed. Their story at least is encouraging.

Fred Roots
Science Advisor Emeritus, Environment Canada, and Chair of the Canadian National Committee for the UNESCO Man and Biosphere (MAB) Programme

Preface

Another beautiful sunny summer day has dawned on Canada's west coast. Gulls glide across the cloud-speckled blue sky. Eagles dive, plucking their dinner from the cool ocean. Children play on the beach, clams squirting their bare legs. It is an idyllic paradise. Striations on the bedrock are evidence of the two-kilometre-thick ice sheet that blanketed this land fifteen thousand years ago. Soon after, aboriginal people lived and played on these beaches leaving behind deep clam-laden middens and stone tools.

Yet, storm clouds brew on the horizon. When we look back on Earth's climate over the last 135 000 years it is clear that climate change is not new but is part of the natural change ubiquitous in Earth's history. Long, long before land- and sea-ice covered the northern hemisphere palm trees grew in the Arctic. Yet even within these cycles, that oscillate between warm and cold, there have been occasions when climate changed rapidly. These events often coincided with the extinction of once-dominant species and rapid, saltatory evolution of others. Thus, it is important to understand the role climate change has and continues to play in the evolution of our species, particularly as we face future climate change.

Adaptation and adaptability are hopelessly confused in the public mind, as well as in the writings of anthropologists and archaeologists. The adaptations with which neo-Darwinists work are random, genetically fixed mutations that require the approval of natural selection to become general species characteristics. Adaptability is what the individual organism can do to respond physiologically and behaviourally to change. In the case of humans, the proper application of intelligence is part of our adaptability. The distinction is particularly important in the context of this book, since the process of adaptation and natural selection in the strict sense is much too slow to respond to sudden environmental alteration. In contrast, the adaptable organism can do something about it instantly. Unfortunately for humans, tradition, ritual, and 'sticking to tried and true ways' can obstruct effective action, despite our potential ability to respond effectively to change.

While the twentieth century stands out in history for two world wars, many local wars, genocides and political revolutions, there were little-considered developments that present us in the twenty-first century with even more menace. Many of us tend not to notice them, or to discount their effects. We do so at our own peril. We refer to the environmental consequences of global warming, deforestation, soil erosion, the degradation of ocean fisheries, expanding populations and inflated economies. We humans have periodically mapped roads to our own downfall, without taking significant action to forestall such fates. In the case of the present danger, it will affect the entire population of Earth.

Our aim in this book is to link climate change with modern human evolution. Our global climate simulations provide 135 000 years of climate change data that are combined with geological proxy data and archaeological evidence to illuminate connections between climate change and key events in human history. We identify the relevance of saltatory evolution to rapid climate change. We introduce the 3 C's syndrome – catastrophe, communication and cooperation – as an impetus for human social evolution. We seek a new way of understanding our past evolutionary relationship with climate, one that makes the connection between human history and climate history; one that will generate a present that does not borrow on our children's future.

Acknowledgements

This book grew from our desire to relate climate change with human evolution, to explain how rapid environmental changes have affected us in the past, and to find ways to cope with a changing future. For years, the authors met weekly to discuss evolution, the environment and humans. Our discussions have frequently benefited from the contributions of Richard A. Ring, Professor Emeritus, Department of Biology, University of Victoria, Rodney Roche, Professor Emeritus, Department of Biosciences, University of Calgary, the late Bill Livant, Professor Emeritus, Department of Psychology, University of Regina, Dawna Brand, PhD candidate, Department of Biology, University of Victoria, and numerous other faculty and students from the University of Victoria Biology Department who joined in our discussions. Gareth Nelson, School of Botany, University of Melbourne has provided much appreciated encouragement at all levels for Robert's evolutionary ideas. Also valued are Elizabeth Vrba's contributions at the Konrad Lorenz Institute Workshop on Environment, Development and Evolution and their influence on our evolutionary ideas. Renée Hetherington's research into climate change and human evolution at the University of Victoria Climate Modelling Lab benefited from Andrew J. Weaver's enthusiasm, vision and support. The authors strayed into unchartered territory and were particularly supported by the UVic Climate Modelling Lab staff – Michael Eby, Wanda Lewis, and Ed Wiebe, postdoctoral fellows – Jeff Lewis and Kirsten Zickfeld, and other staff and students. The last glacial land-ice was interpreted by Shawn Marshall of the University of Calgary. Roger MacLeod has provided graphics and GIS input and advice throughout this project. Kathleen W. Matthews has provided research assistance.

The duration of the writing of this book makes it extremely difficult to thank all those who have contributed. Too numerous to mention are the many colleagues and students with whom we have worked, spoken and to whom we have lectured. They have provided insights and evidence. They have asked questions that provoked us to search for clear, insightful responses. Their assistance has been much appreciated.

E. Fred Roots, Science Advisor Emeritus with Environment Canada, dug up and presented us with climate policy research papers and notes extending back over 25 years, providing a perspective on the current climate debate. We thank him for the foreword to this book and valuable suggestions for improvement of the text. We also thank our editors Audrey McClellan, West Coast Editorial Associates, Joseph Bottrill and Polly Wolf, Out of House Publishing Solutions, and particularly Matt Lloyd, Laura Clark and the rest of the editing team at Cambridge University Press for their thoughtful and expert advice. We very much appreciate the assistance of Beverly Duthie with the index and Robert Thompson, Richard Ring and Rodney Roche for correcting the final proofs. We thank reviewers of various chapters including Nathan Gillett, Research Scientist, Canadian Centre for Climate Modelling, University of Victoria, Richard A. Ring, E. Fred Roots, Andrew J. Weaver, and three anonymous reviewers. For personal communications, we thank Gizelle Rhyon-Berry, Research Associate, The Foundation for Shamanic Studies, Úrsula Oswald Spring, Professor, Regional Centre of Multidisciplinary Research at the National University of Mexico (CRIM-UNAM), Anwar A. Abdullah, Senior Advisor to the Prime Minister on Sustainable Development, Kurdistan Regional Government, Ursula Franklin, University Professor Emeritus, University of Toronto, and E. Fred Roots.

Our friends and loved ones have been particularly supportive during the extended researching and writing of this book. Renée's dear friend Marion Farrant offered encouragement, advice and support from the outset and was instrumental in its inception. Margaret Fulton has provided friendship, advice and encouragement. Robert's daughter, Clio Reid, has provided valuable personal support and editorial assistance. Renée's sons, John and Ryley, gave willingly their love and support and inspired us to see the world through the next generation's eyes and to recognize the responsibility we all share for our future. Robert I. Thompson, Renée's husband, has provided ongoing love, support and encouragement; without him, this book would never have been written.

The Canadian Foundation for Climate and Atmospheric Sciences and the Natural Science and Engineering Research Council of Canada indirectly funded part of the research via their operating grant programmes. Renée was also supported by a Social Sciences and Humanities Research Council of Canada postdoctoral fellowship.

This book is a contribution to UNESCO and the International Geological Correlation Programme Project No. 526 'Risks, Resources, and Record of the Past on the Continental Shelf.' Any errors, omissions or inconsistencies are solely the authors' responsibility and in no way reflect on the contributions made by all the people we have mentioned and the many we have not named here, but appreciate nonetheless.