

THE
MYSTERIOUS

HUMAN
GENOME

WORLD
OF THE

By the same author

Viroolution

Tuberculosis: The Greatest Story Never Told

Virus X

Darwin's Blind Spot

Metamorphosis: Unmasking the Mystery of How Life Transforms

M Y S T E R I O U S
T H E

H U M A N
G E N O M E

W O R L D
O F T H E

F R A N K
R Y A N



WILLIAM
COLLINS

William Collins
An imprint of HarperCollinsPublishers
1 London Bridge Street
London SE1 9GF

WilliamCollinsBooks.com

First published in the United Kingdom by William Collins in 2015

20 19 18 17 16 15
10 9 8 7 6 5 4 3 2 1

Text © FPR-Books Ltd 2015
Diagrams by Mark Salwowski

The author asserts the moral right to be identified as the author of this work. All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

A catalogue record for this book is available from the British Library.

ISBN 978-0-00-754906-1

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out or otherwise circulated without the publisher's prior consent in any form of binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

Typeset in Plantin 11/16 pt by
Palimpsest Book Production Limited, Falkirk, Stirlingshire
Printed and bound in Great Britain by
Clays Ltd, St Ives plc.



MIX
Paper from
responsible sources
FSC™ C007454

FSC™ is a non-profit international organisation established to promote the responsible management of the world's forests. Products carrying the FSC label are independently certified to assure consumers that they come from forests that are managed to meet the social, economic and ecological needs of present and future generations, and other controlled sources.

Find out more about HarperCollins and the environment at
www.harpercollins.co.uk/green

To Oswald T. Avery

Possibly I am a scientist because I was curious when I was young. I can remember being ten, eleven, twelve years old and asking, 'Now why is that? Why do I see such a peculiar phenomenon? I would like to understand that.'

LINUS PAULING

contents

Introduction	1
1. Who Could Have Guessed It?	5
2. DNA Is Confirmed as the Code	24
3. The Story in the Picture	36
4. A Couple of Misfits	50
5. The Secret of Life	59
6. The Sister Molecule	92
7. The Logical Next Step	112
8. First Draft of the Human Genome	124
9. How Heredity Changes	137
10. The Advantage of Living Together	146
11. The Viruses That Are Part of Us	156
12. Genomic Level Evolution	172
13. The Master Controllers	185
14. Our History Preserved in our DNA	197
15. Our More Distant Ancestors	210
16. The Great Wilderness of Prehistory	225
17. Our Human Relatives	243
18. The Fate of the Neanderthals	257
19. What Makes You Unique	281
20. The Fifth Element	292
Bibliography	305

Chapter Notes	309
Index	321
Acknowledgements	341

Introduction

No special act of creation, no spark of life was needed to turn dead matter into living things. The same atoms compose them both, arranged only in a different architecture.

JACOB BRONOWSKI, *THE IDENTITY OF MAN*

Bronowski begins his more famous book, *The Ascent of Man*, with the words, ‘Man is a singular creature. He has a set of gifts which make him unique among the animals: so that, unlike them, he is not a figure in the landscape – he is a shaper of the landscape.’ But why should we humans have become shapers of the landscape rather than mere figures inhabiting it? We differ from, say, a sea horse or a cheetah because our genetic inheritance, the sum of the DNA that codes for us, is different in humans when compared to the horse or the cheetah. We call this the genome, or, to be more specific in our case, the human genome.

Our genome defines us at the most profound level. That same genome is present in every one of the approximately 100,000 billion cells that make us who we are as individual members of the human species. But it runs deeper than that. In more personal terms, in myriad tiny variations that we each possess and are individual to us only, it is the very essence of us, all that, in genetic and hereditary terms, we have to contribute to our offspring, and through them to the sum total evolutionary inheritance of our

The Mysterious World of the Human Genome

species. To understand it is to know, in the most intimate sense, what it means to be human. No two people in the world today have exactly the same genome. Even identical twins, who will have been conceived with exactly the same genome, will have developed tiny differences between their genomes by the time of their births: differences that may have arisen in parts of their genomes that don't actually code for what we normally mean by genes.

How strange to realise that there is actually more to our individual genome than genes alone. But let us put aside such details for the moment to focus on the more general theme. How could a relatively simple chemical code give rise to the complexity of a human being? How could our human genome have evolved? How does it actually work? Immediately we are confronted by mysteries.

To answer these questions we need to explore the genome's basic structure, its operating systems and its mechanisms of expression and control. Some readers might react with incredulity. Surely any such exploration promises a journey into extraordinary complexity, one that is far too obscure and scientific for a non-scientist reader? In fact this book is aimed at exactly such a reader. As we shall see, the basic facts are easy enough to grasp, and the way to grasp them is to break the exploration into a series of simple, and eminently logical, stages. This journey will lead us through a sequence of remarkable revelations about our human history – even into the very distant past of our ancestors' lives and their prehistoric exploration of our beautiful life-giving planet.

The exploration will raise other, equally important, questions, too. How, for example, does this extraordinary entity that we call the human genome enable our human reproduction – the fertilisation of our maternal egg with the paternal sperm? How does it control the quasi-miracle of the developing embryo within the mother's womb? Returning to generalities for the moment, though, we can be sure that an important ingredient of the genome, and

its essential nature, is memory – the memory, for example, of the totality of every individual human’s genetic inheritance. But how exactly does it perform this remarkable feat of memory? We know already that this wonder chemical we call DNA works like a code, but how could any code recall the complex instructions that go into the making of cells and tissues and organs, and then once made, bring them into function in the single coordinated whole that comprises the human being? Even then we have hardly begun to confront the mysteries of the human genome. How does this same extraordinary structure acquire the programming that gifts the growing child with the wonder of speech, that bestows the related capacity for learning, writing and education, and which makes possible the maturing of the newborn to the future adult, who then repeats the cycle all over again when he or she becomes a parent in turn?

The wonder is that all of this might be encompassed in a minuscule cluster of chemicals including, but not exclusive to, the master molecule we call deoxyribonucleic acid – or DNA. This chemical code somehow records the genetic instructions for making us. Built into that code must be the potential for individual liberty of thought and inventiveness, enabling every human artistic, mathematical and scientific creativity. It gives rise to what each of us thinks innately as our private inviolate ‘self’. Somehow that same construction of ‘self’ made possible the genius of Mozart, Picasso, Newton and Einstein. It is little wonder that we look at the repository of such potential with awe. No more is it surprising that we should want to understand this mystery that lies at the very core of our being.

Only recently have we come to understand the human genome in sufficient depth and subtlety to be able to put together its marvellous story – to discover, for example, that there is rather more to it than DNA alone. This is the story I shall attempt to convey in this book.

The Mysterious World of the Human Genome

A few years ago I gave a lecture on a related theme at King's College London. The chairman asked me if I planned to write a book about it. When I said yes, he asked me to please write it in words that a lay reader, like himself, could readily understand.

'Just how simple do you want me to make it?'

'I want you to assume that I – your reader – know nothing at all to begin with.'

This, then, I promise to do. There will be no complicated scientific language, no mathematical or chemical formulae or unexplained jargon, and I shall introduce no more than a handful of simple illustrations. Instead I shall begin from first principles and assume that the readers of this book know little about biology or genetics. Even non-biologists might recall the many surprises when the first rough draft of the human genome was announced to the world, in 2001. The discoveries since then have confirmed that a good deal of the human genome – in its evolution, structure and workings – is far from what we had earlier imagined. Those surprises do not diminish the importance of the wealth of knowledge that had gone before, but rather, like all great scientific discoveries, they enhance it. Thanks to this new understanding, humanity has entered what I believe to be a golden age of genetic and genomic enlightenment, which is already being extrapolated to many important fields, from medicine to our human prehistory. I think society at large deserves to understand this and what it promises for the future.