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The Species that Changed Itself

How Prosperity Reshaped Humanity

Edwin Gale



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The Species that Changed Itself

Edwin Gale studied English Literature at Cambridge before switching to a career in medicine. He worked in Cambridge, Nottingham, Copenhagen, and as a professor at St Bartholomew's Hospital, London. Research into the rise of diabetes stimulated his interest in our changing phenotype. He moved with his team to the University of Bristol in 1997, and retired in 2011.

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Like most people, I thought I knew how to write a book and – like most people – I was wrong. Unstinted thanks therefore to Laura Stickney, Holly Hunter and Rowan Cope for their coaching, to Cecilia Mackay for the pictures and to David Watson and the production team for showing me what professionalism is.

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At a more personal level, this has been a two-cat book, and Tom Socks and Sophie have slumbered peacefully in a desk drawer throughout its gestation. Emily, Rebecca and John viewed the whole enterprise with healthy scepticism and useful insights and have made it all feel worthwhile. It has been said 'show me a man with an obsession, and I will show you a happy man'. When I mentioned this to my wife, she responded with 'and I'll show you an unhappy woman!' Thank you for reassuring me that this has not been your experience, Judith, and this book is yours.

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Author's Note

The coronavirus epidemic struck while this book was in proof, and it changed the ground rules of life in the twenty-first century. My book describes (among other things) the way in which we have distanced ourselves from traditional causes of infectious disease, but I did not foresee the extent to which this might also increase our vulnerability to a shape-shifting virus. Our attempts to contain this have – to date – managed to limit its spread, but they threaten to precipitate an economic recession that could cost more lives than the virus itself.

Enforced isolation has caused untold misery to many, but I was fortunate enough to be stranded by a river in one of the most beautiful parts of Wales. Contrails and pollution vanished from the sky, and an uncanny silence filled with birdsong settled upon us. Life shifted down a gear, and it was an unimagined opportunity to revisit the world we have lost.

The enforced global shutdown was a once-in-a-lifetime opportunity for reflection. To borrow John Cage's phrase, it gave us all an interval of time that was free from intention. More important, it finally shattered our collective illusion of control. It was a reminder that our lives are shaped by the world we made, and that this will be our legacy – poisoned or otherwise – to the next edition of humanity.

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Prologue

The prophet Isaiah saw the New Jerusalem in a vision. 'Never again', he said, 'will there be in it an infant who lives but a few days, or an old man who does not live out his years: he who dies at a hundred will be thought a mere youth: he who fails to reach a hundred will be accursed.'[1] Isaiah could not have imagined that we might reach this happy state by our own unaided efforts, yet we are getting close. Death has for the most part been banished into old age and we are, in material terms, the most fortunate generation ever to have lived.

If you release rabbits on an island without predators, feed them well and free them from major infections, their numbers will increase exponentially. They will have escaped the constraints of natural selection, just as we have done. Our own escape began some 200 years ago, when people from Western Europe tapped into fossil energy and hit upon a recipe for generating wealth and knowledge in ever-increasing amounts. Earth scientists refer to this as the Anthropocene – the man-made era.

In theory, Rabbit Island should result in population overgrowth followed by population collapse. This has not happened to us – as yet – because we have been able to limit population growth and to expand our food supply. In doing so, we changed the world – but we also changed ourselves. A typical European is nearly 20 cm taller than two centuries ago, and young adult Americans have gained 12 kg over the past 100 years. Our skeletal proportions have altered, as have our skulls and faces. We reach sexual maturity three to four years earlier, live forty years longer and die of once-rare diseases. Our experience of life has altered, and we think differently. All this

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took place within a few generations. I call it the phenotypic transition, and this book is about what happened and why.

THE KINGDOM OF COCKAIGNE

A medieval legend tells of an imaginary land in which food is present in inexhaustible quantities. Italians knew it as the *Paese di Chucagna* – the land of cake – and the French celebrated it in a thirteenth-century ballad called the *Recueil des Fabliaux et Contes de Cocaigne*. In Cocaigne (known to the English as the Kingdom of Cockaigne) there are six Sundays to every month and four Easters each year. Lent comes round every twenty years, and fasting is optional. Germans knew it as *Schlaraffenland*, the Glutton's Paradise,[2] and the Dutch as *Luilekkerland*, roughly translated as 'sweet and happy land'. Pieter Breughel the Elder's depiction shows a soldier, a clerk and a peasant – representatives of the three orders of society – sleeping with distended bellies in a world where 'roasted pigs wander about with knives in



Figure 1: *Luilekkerland*. Engraving after Pieter Breughel the Elder (1567).

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their backs to make carving easy, where grilled geese fly directly into one's mouth, where cooked fish jump out of the water and land at one's feet. The weather is always mild, the wine flows freely, sex is readily available, and all people enjoy eternal youth.'[3]

We live in a world that our ancestors could only dream about, and we reached it in three stages. The first was largely complete when people with genes like ours left Africa. The second stage, driven by our own activities, committed us to ever-accelerating technical development. The third came when we reached escape velocity from the tug of natural selection and began to hurtle towards an unknown future, self-domesticated animals in a world tailored to our convenience.

Our genes express themselves differently in different environments. Each form of gene expression is known as the *phenotype*, a term proposed by the Danish botanist Wilhelm Johannsen in 1911. He showed that genetically identical beans grow differently in varied conditions of soil and light – no surprise there – but that their descendants revert to the same size and shape when planted side by side. Geneticists of the time believed that characteristics acquired by parents would be inherited by their children, but Johannsen had confirmed Mendel's belief that the units of inheritance travel in sealed packages, unaffected by the parental environment. These mysterious units still lacked a name, and Johannsen opted to call them *genes*. Collectively they formed the 'gene type' or *genotype*, and he called the expression of that genotype in a given environment the 'phenomenon type' or *phenotype*.[4]

Like beans, like people. Koreans were traditionally short; in the nineteenth century men averaged 161 cm and women 149 cm. The war of 1950–53 had the effect of dividing them between a free enterprise economy and a repressive totalitarian regime. Those born before 1950 grew to much the same size on either side of the 38th Parallel, but a United Nations survey in 2002 showed that pre-school children in North Korea were 13 cm shorter and 7 kg lighter than in the South. The height of adult North Koreans was unchanged, whereas South Korean women had set an international growth record of 20.2 cm and enjoyed the fourth-longest life expectancy in the world.[5] A line on the map had translated into a difference in biology.

People talk about genes with remarkable confidence, given that the

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experts still argue about what exactly a gene is or how many we have. The concept that your environment is reflected in your phenotype is less familiar, which might explain why we have been slow to appreciate that our phenotype is changing. So, what exactly is a phenotype? Johannsen said it was anything about an organism that you can see or measure. There is not much to see or measure in a bean, but people are endlessly variable.

A dating site is a good place to begin. You will be looking for someone of a certain age and have certain preferences as to background and appearance. You will probably want to know if they smoke and consider themselves to have a sense of humour. Weeks later, you meet up with the phenotype of interest in a restaurant. Your first glance takes in outward appearance – middle height, reddish hair, trim shape, a pleasant face, a hint of laughter lines around the eyes. Before long, you are deep in conversation, for you grew up in similar circumstances, you laugh at the same things, your temperaments match, and so too do your interests. Above all, your date seems kind, considerate, a possible future friend and companion.

What then is a phenotype? The short answer is that it represents everything about the person you just met. It is the expression of their genes, filtered through their environment and moulded by their journey through life. Some aspects of a phenotype – eye colour for example – are wired into you. These are *simple traits*, and you can't change them. You will not dwell on the colour of your date's eyes, however, unless you happen to be falling in love. You will be more interested in such things as charm, personality and intelligence. These are *complex traits* – complex because they arise from the interaction of many genes, and because the outcome of that interaction will vary from one person to the next. Simple traits are *categorical*; you either have blue eyes or you do not. Complex traits are of the 'more-or-less' variety and imply a comparison between people: they are *dimensional*.

The dialogue between genes and environment begins when a fertilized egg – a zygote – implants in the lining of a mother's womb, and it ends with our final breath. The journey in between has its own unique history. Things happened in one way and not in another; some paths were taken, others were not, and the combination of genes and happenstance finally converged upon the person holding

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this book. Time is the true medium of our existence, and a phenotype is the narrative of a journey through time.

THE WAR OF THE EGG

When Lemuel Gulliver visited the world of Lilliput, he found its tiny inhabitants at war with their neighbours concerning an important point of doctrine. The Lilliputians insisted that an egg should be eaten from the small end, and their enemies claimed that you should eat it from the big end. The debate as to whether nature or nurture, genes or environment, are 'more important' is of comparable significance.

The answer, as so often happens, will depend upon the way you ask the question. If you raise laboratory rats in the same cage, for example, any difference between them will largely be due to their genes. The same will apply to people who share the same environment. But what happens when people with the same genes inhabit different environments? Korea is a striking example, another being a classic study from the 1930s which showed that second- and third-generation Japanese immigrants to Hawaii were physically very different from people in the villages they left behind.[6]

Genes largely determine differences *within* a population, whereas the environment determines differences *between* populations. You might picture this in terms of boats at anchor in a tidal basin. The relative height of their masts will vary according to design ('genes'), but all boats will rise together when the tide comes in. Those who argue for the importance of genes are comparing boats, and those who argue for the environment are comparing tides.

Reports of identical twins separated at birth are routinely quoted to emphasize the paramount importance of genes, and remarkable coincidences have been reported. Confirmation bias apart, we should remember that these twins shared the same uterus and grew up in the same society. But suppose that they had been separated following conception and implanted in different surrogate mothers? One twin might grow up in North Korea, for example, and the other in the South. Or – since the imagination knows no limits – one might develop in Cro-Magnon times and the other in modern New York.

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What then? Our twins will have the same face, but they will differ in other important respects, and this difference is what we will be interested in. Charles Darwin said that 'it is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change'. Our genes can be the agents of change. The flexibility this confers is known as *phenotypic plasticity*, and natural selection operates on the phenotype rather than the gene.

A SHORT HISTORY OF THE PHENOTYPE

Our journey through time has been driven by the quest for food: a quest that took us all the way from vegetarian primates to the adult baby food that lines the shelves of our supermarkets. Food is reflected in our growth and development, and each major transition in food production has generated its own characteristic phenotype.

Homo sapiens lived in small mobile groups for 95 per cent of its existence as a species, and twentieth-century hunter-gatherers who followed the same way of life were often as lean and fit as marathon runners. I call this archetypal pattern the *Palaeolithic* phenotype. Things changed 10,000 or so years ago – a blink of an eye in evolutionary terms – as the cultivation and consumption of grain came to shape our bodies and our societies. The bony remains of people who lived by subsistence agriculture testify to lives of toil, disease and recurrent famine, and they varied remarkably little between the foundation of Jericho and modern times. I call this the *agrarian* phenotype. Subsistence farmers left us no record, for history was made and written by those who lived on their labour. These, the elite members of past societies, were better housed, better fed and taller – people looked up to them. Theirs was the *privileged* phenotype and, to some extent, it anticipated our own.

Plagues and famines swept through agrarian populations, generating a fluctuating equilibrium between birth and death which economists refer to as the 'Malthusian trap'.[7] The escape from this trap began in Europe. In England, for example, the years leading up to AD 1300 were years of prosperity, and its population increased

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rapidly, only to be halved by plague and famine in the disastrous fourteenth century. The respite from population pressure created space for innovations in food production, thus creating a 'Malthusian holiday'. England's population took four centuries to recover to the level of AD 1300, but the country produced 50 per cent more milk and wheat and twice as much beef in 1700 – and with fewer acres under cultivation.[8]

Increasing prosperity brought more food, better living conditions and better health to nineteenth-century Europe. Its population rocketed, but it avoided a Rabbit Island scenario by importing food and exporting its surplus population. Even so, famine threatened when the frontiers of global cultivation were reached towards the end of the century, and was only averted by the subsequent revolution in agriculture. The whole world could now enjoy a Malthusian holiday.

All this lay in the future at the start of the twentieth century. Prosperity was largely restricted to the western nations, and numbers had expanded so rapidly that one in three of the global population could claim European ancestry by 1930. This was set to change, however, for the European birth rate had gone into sharp decline, and contemporary demographers saw the 'population problem' as one of falling numbers. A declining birth rate heralded what became known as the demographic transition.

The global economy entered a new phase after 1950. Europe and Asia had been devastated by war, but the demands of wartime production had generated massive investment, a central command economy and mobilization of scientific and technical know-how in the United States, thus jerking it out of stagnation. Food was cheap, energy was cheap, and automation brought a new dimension to productivity, increasingly tailored to desire rather than to need. The new model spread rapidly, and the triumph of capitalism marked the emergence of the *consumer* phenotype. A worldwide population boom followed in the second half of the twentieth century, but food production kept pace. Famines still occurred, but for preventable reasons such as political breakdown. Food abundance, freedom from infectious disease and a sedentary lifestyle spread around the world, and the consumer phenotype went global.

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THE PHENOTYPIC TRANSITION

People of European descent towered over most other populations at the start of the twentieth century, for the combination of rising affluence and a declining birth rate was reflected in the accelerated growth of their children. Increasing height and longevity became a feature of many western populations from around 1870, as did many other changes in our phenotype.

Life begins with a mother, and the interaction of genes with environment begins with conception. High fecundity was an essential feature of our species when only one child in two or three survived to reproduce, but became a handicap when survival into adult life was the norm. Management of reproductive life was a precondition of the phenotypic transition, and the possibilities of womanhood were transformed in the process.

A mother's quality of life is reflected in her child, and birth weight has risen progressively over several generations. This is partly because mothers are healthier and better fed, partly because taller women have bigger babies, and partly because bigger babies turn into taller adults. The long bones of our arms and legs have increased in length, changing our physical proportions. Our skulls are taller and narrower and our jaws are lighter, crowding teeth together and making more work for dentists. Bigger bodies combined with an increased capacity to pile on muscle changed the face of power-to-weight sports. Athletic records have tumbled even as those who prefer a sedentary lifestyle have acquired smaller muscles and more fat.

We are not alone in our journey through life, and multitudinous unseen life-forms live in and on our bodies. The Palaeolithic phenotype favoured long-lived parasites and infections that were transmitted vertically from one generation to the next. The transition to agrarian life crowded people into permanent communities, thus allowing a range of new infections to take root in the human population. Some gave rise to the epidemic diseases that feature in our history books. Our co-existence with invisible life-forms changed once again in recent times. Age-old partners have been lost, the terms of engagement are different, and there have been far-reaching consequences for our

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health and well-being. All this is reflected in the development of our immune phenotype.

A phenotype is a journey through time, and the average lifespan has virtually doubled in the course of a century, not just because of better living conditions and medical care – although these are important – but also because we are ageing more slowly. The combination of increasing longevity and overconsumption has placed increasing stress upon the internal economy of our bodies, as shown for example in the 'metabolic syndrome', a characteristic phenotype in which accumulating obesity predisposes to progressive failure of regulatory systems controlling blood pressure, sugars and fat. We view the so-called 'degenerative' disorders of later life as diseases, but they might equally be seen as natural responses of an ageing phenotype.

The phenotypic transition has produced many detectable changes in our physical lives, but what about the changes we cannot see? Are we the same, or are we different? Some passages from Homer speak to our understanding in a way that makes time stand still, but the past really was another country. Premature death and bereavement have become rare events, and the death of a child is experienced as a dreadful tragedy rather than as a routine occurrence. 'Had five, buried two' was a standard response to the usual medical question in the first half of the last century. Parents grieved for their children then as now, but recurrent bereavement might explain the curiously flat emotional affect of parents in the early modern period.[9] Their ability to shrug off the death of a child – or to inflict violence upon the living – appears at times to border on the pathological. In *Pilgrim's Progress*, an allegory of the Christian journey through life, John Bunyan's protagonist abandons his wife and children to their fate in order to seek his own salvation, a decision that we would scarcely consider praiseworthy.

How can we be so different, and yet the same? Our phenotype, broadly defined, encompasses the way our brains and bodies work, our emotional repertoire, the way we interact and our social identity. If these things change, so too must we. I was born into a world of landline telephones with operators, wireless sets with valves and typewriters with ribbons, yet I walk around with a hand-held device that allows me to talk to people anywhere on the planet and to access almost any piece of information. And yet – it is an age-old

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paradox – my younger self is somehow embedded within an older man with different physical capabilities, desires, expectations, knowledge and experience. He is contained in me, but I am not contained in him. As with the individual, so it is with the collective. Our predecessors are embedded in our experience. We have some insight into their lives, but what would they make of us?

Literary critics write of something called sensibility, an elusive concept that describes the way in which novelists or writers of diaries experience the world around them. The way in which this is expressed, and therefore presumably felt, has changed over the past three centuries. The psychologist Steven Pinker argues in *The Better Angels of Our Nature* that (despite many horrific instances to the contrary) people have developed a much greater capacity for empathy. One simple fact stands out: we are far more literate. UNESCO estimated that around 10 per cent of the world's population could read 200 years ago, as against 90 per cent in 2017.[10] This probably had greater impact upon the way in which people think and feel about themselves than any other feature of the phenotypic transition.

It is challenging enough to understand our own thought processes, let alone those of others, especially people who come from a radically different culture. How, then, is it possible to measure our minds against those of previous generations? Intelligence tests offer one objective measure, since they purport to measure raw intellectual ability, unaffected by training effects or cultural background, and independent of time, place or circumstance. The IQ test is adjusted to the mean of the population tested, which is arbitrarily set at 100. The psychologist James Flynn noticed in 1984 that IQ testing centres were obliged to adjust the mean upwards on a regular basis.[11] His analysis suggested that test scores were increasing at a rate of three to five points per decade. Are we becoming more intelligent – unlikely – or do we just use our minds differently?

PHENOTYPES AND SOCIETY

We created Rabbit Island, but other creatures share it with us. No wild species has ever changed as we have done, but our domestic

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animals have changed even faster. They too grow bigger and mature earlier; they too breed in and out of season; and they too live longer and get fat. Like us, they have lighter bones and skulls with more crowded teeth. They too accept hierarchy and live in crowded conditions without undue resort to violence. The parallels are obvious. Are we a self-domesticated species? The answers, as Tom Sawyer might have said, are 'tough but interesting'.

Domesticated or not, we are social animals. In pre-industrial times the age structure of the population was pyramid-shaped, and children greatly outnumbered old people. Rapid growth, earlier sexual maturity, compulsory education and a minimum age limit for employment created the phenomenon of adolescence, and a distinctive youth culture emerged when young people entered the workforce with increased spending power and fewer responsibilities. More recently, a declining industrial base has produced a free-floating population of underemployed young people in western countries, and an explosive surplus elsewhere in the world. Meanwhile, older people accumulate at the other end of the age spectrum. Their prolonged survival hinders the transfer of wealth, property and responsibility from one generation to the next, high-tech medical interventions have made the business of dying more expensive, and wealth is siphoned off by care for the elderly instead of moving between generations. Even the most prosperous nations are beginning to stagger under this burden.

Other consequences of a longer lifespan are less obvious. Marriages last as long today as they did 200 years ago, but terminate in divorce rather than death. Kurt Vonnegut describes the union of two perfectly matched but immortal humans in one of his novels and concludes that no marriage could survive eternity. Another consequence of increased security is the pursuit of safety, now an obsession among the safest people who ever lived. No surprise in this, for people with a lifespan of 200 years might well take extra care when crossing the road.

A changing phenotype has altered the face of society, and a changing society has taken on much greater responsibility for the phenotype of its citizens. My ancestor John Gale featured in the census of 1801, only six generations ago, but he knew nothing of central government, and government knew only his name. States became more organized

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as the century went on and made increasing use of information (appropriately known as 'statistics') concerning their citizens. Intrepid Victorians discovered a heart of darkness in the slums of their cities, hard-headed employers sought workers with educational skills, generals needed healthy soldiers, and the British dreamed of a new imperial race. Nation-states took more interest in the lives of those they governed, even as the economic clout of the industrial masses resulted in political trade-offs which acknowledged their importance. National insurance schemes came into being, states assumed greater responsibility for the lives of those insured, and political parties quarrelled about the extent of that responsibility.

APOLOGIA

I reached this book by a roundabout route. As a research physician, I was puzzled by the fact that both major varieties of diabetes were increasing so rapidly. Why should a disease change? The answer, when it came, seemed obvious enough: *diabetes isn't changing, we are*. The more I looked, the more obvious it became that we are a species in transition, yet this rather obvious fact scarcely rates a mention in many accounts of human biology. Since genes don't change within a generation or two, it seemed equally obvious that this transformation must have something to do with the way genes function. Genes make us what we are, but they do not execute an unchanging blueprint. Instead, they operate a growth programme which is responsive to cues from the environment. Flexibility is built into our genome.

The history of biology tells us that each generation underestimates its ignorance. We are no different. An understanding of our plasticity is beginning to emerge, notably from the study of epigenetics, but there is still a long way to go. My task, therefore, is merely to offer a brief history of the phenotype, and to describe what others will need to explain.

I begin by showing how the pursuit of food has shaped both our long-term evolution and our changing phenotype. In time, we managed to free ourselves, if only in part, from the major agents of natural selection. Overpopulation and famine should have followed, as in the

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fable of Rabbit Island, but food production increased faster than population in more fortunate parts of the world and promoted the emergence of the consumer phenotype. I then go on to describe the phenotypic transition in more detail, starting with our bodies and our experience of old age and disease, and moving on to our changing minds. We will then look at the way in which our changing phenotype has affected society, and at how society shapes our phenotype. I conclude with the inevitable question: is it possible to change so much – and yet remain the same?

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PART I

The Great Escape

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1

The Promethean Moment

Imagine yourself on the African veldt, watching the rise of a huge red sun. It is 100,000 years ago, and vast herds are roaming in the distance. You are naked: no clothes, no tools, no power objects. Your skin is defenceless against biting insects, and your hands and feet are too soft to be useful. If you could find something to eat – a tuber, perhaps – you would be unable to chew or digest it. That noble organ, your brain, is not much help. Who might imagine that people like you would inherit the earth?

We are, to all appearances, the most helpless of species. Plato's version of the Prometheus legend relates that the gods set out to create mortal creatures, got bored and left the job unfinished. Roughly shaped figures lay inert in the clay, awaiting the summons to life. Prometheus and his brother Epimetheus (two titans whose names mean forethought and afterthought) were asked to finish the job, and Epimetheus volunteered for the task. Conscious that creatures need to survive in the wild, he equipped them with an eye to the balance of nature. A hunting animal should not starve, for instance, but neither should it exterminate its prey. Predators should be rare, and the hunted should be fertile. He allocated coverings of fur, hide or feather, and handed out hooves and claws. So absorbed in this task was he that every single gift and attribute had been handed out by the time he reached the human race. Prometheus returned to find that that other animals were 'well off for everything, but man [was] naked, unshod, unbedded, and unarmed: and already the appointed day had come, when man too was to emerge from within the earth into the daylight'.[1] Naked and helpless, we were about to be massacred. Prometheus felt such pity for us that he stole fire from heaven, concealed

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within a giant stalk of fennel, and taught people the arts of civilization. His one omission was the art of politics, which gave Plato the starting point for his dialogue between Socrates and Protagoras. The punishment for his transgression was to be chained to a mountain in the Caucasus while an eagle tore endlessly at his liver.

It is easy enough to see that Plato got the story back to front. We are helpless without fire precisely because we evolved to depend upon it. The German-American anthropologist Franz Boas pointed out in 1911 that we are a cooking species. 'The art of cookery', he said, 'is universal. By its means the character of the food and with it the demands made upon the digestive organs are materially changed.'[2] Cooking means fire, and *Homo erectus* may have made use of fire 1.8 million years ago,[3] quite enough time for evolution to reorganize our digestive apparatus and other features of our anatomy. Let us see what happened.

THE FOOD LADDER

The pursuit of food shaped our evolution and continues to shape our phenotype. On 1 January 1700, the Royal Society of London published an exchange of letters between an elderly physician called John Wallis and the anatomist Edward Tyson, famous for dissecting *Homo sylvestris*, better known to us as the chimpanzee.[4] Wallis's question was this: were we intended to eat meat? He began in theological mode by pointing out that Adam and Eve must have been vegetarian, for God told Adam 'I have given you every herb bearing seed, and every . . . fruit of a tree-yielding seed, to you it shall be for meat [i.e. food].' This remit was extended when Noah was told (presumably after the animals had quit the Ark) that 'every moving thing that liveth, shall be meat for you'. Consumption of meat, said Wallis, is a degenerate characteristic which post-dates the Fall of Man. We are lapsed vegetarians. He admits one difficulty with this argument, which is that plant-eating animals have a very big large intestine, whereas humans resemble carnivores in having a small one. The difference between our primate relatives and us is striking in this respect (see figure 2).

Plants invest the energy from sunlight in fruit, fuel and structural

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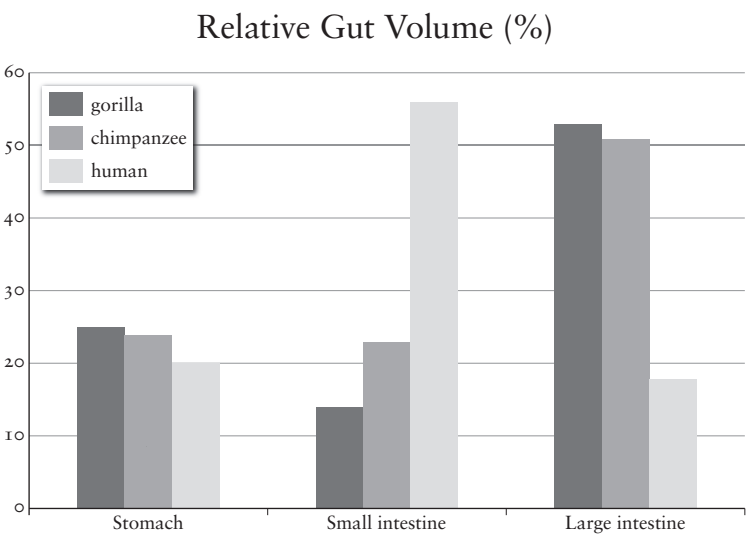


Figure 2: The proportions of the large and small intestines are reversed in humans and our closest primate relatives.[5]

material. Fruit is energy-dense and designed to be eaten: so much so that people with a plentiful supply – from the lotus-eaters encountered by Odysseus to the Kalahari Bushman who could see no point in cultivation when mongongo nuts were so plentiful[6] – are not motivated to change their ways. Energy is stored as starch and oils, and we cultivate plants that produce them in abundant quantities. Plants invest the rest of their energy in structural carbohydrates such as cellulose, a dense polymer woven from glucose molecules held together by chemical bonds that we and other animals are unable to digest because we don't have the necessary enzymes. We are locked out of the most abundant source of food energy on the planet, and plant-eaters must therefore team up with symbiotic bacteria (which do have the enzymes) in order to access it. Animals that chew the cud keep these bacteria in a special accessory stomach, and other herbivores house them in a capacious large intestine. Since this arrangement is highly inefficient, vegetarian primates spend an estimated 48 per cent of their waking lives eating, as against 4.7 per cent of ours.[7]

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Carnivores are much less reliant on intestinal bacteria than herbivores and, as Wallis pointed out, our intestines resemble those of a carnivore. Why are we then able to digest large quantities of vegetable matter? Because cooking breaks down the chemical bonds in food, reducing our reliance on bacteria. We still need our gut bacteria – about 10 per cent of our food energy reaches us this way – but a raw food diet is so inefficient that its users are obliged to consume large amounts of vegetation. Since cooking also softens what we eat, previous anatomical arrangements for crushing plant food became redundant; our upper jaws receded and our lower jaws became smaller but more prominent. Flatter faces allowed our facial muscles to convey a complex emotional repertoire, and speech and song entered the world. Social skills became the key to reproductive success, driving evolution of what has been called the social brain.

Anatomically modern humans equipped with these features originated in northern Africa, with a last common ancestor around 200,000 years ago. From the neck down there is little to distinguish us from *Homo erectus*, although modern humans are taller and lighter, and the two sexes are closer in size. The difference is above the neck, for we have bigger brains (1,350 vs 700–900 ml), and our cerebral cortex has mushroomed upwards to give our skulls their characteristic rounded appearance. The brain is our most highly evolved organ, but the energy cost of maintaining an electrical charge across nerve membranes is high – some 20–25 per cent of all the energy required by a resting body. Cooking made supersized brains possible.[8]

THE PALAEOLITHIC PHENOTYPE

Homo sapiens left Africa some 80,000 years ago, possibly earlier. We may visit the unspoilt world our ancestors encountered in our dreams, but we should not forget to wrap up warmly, for global temperatures were 6–8°C below present levels. Mountains of ice covered the Northern Hemisphere, blocking access to North America and opening the sea route to Australia. *Homo erectus* and *Homo neanderthalis* were already widely dispersed in Asia and Europe and co-existed with us for a long time before vanishing from the face of the earth. Why did

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we prevail? It would be nice to imagine that our ancestors showed early signs of superior ability, but these are lacking in the archaeological record. Evidence of so-called behavioural modernity – technical innovation, artistic expression, care for the infirm and respect for the dead – first appeared some 40–50,000 years ago. This was when our ancestors invented bows and arrows, learned how to fish, carved bone and stone, clothed and adorned themselves and left glorious cave paintings. In the words of the anthropologist Richard Klein, 'the behavioral transformation that occurred 50 thousand years ago represents the most dramatic behavioral shift that archeologists will ever detect, and it demands explanation'.[9]

The Brain Change has puzzled evolutionary thinkers. Darwin's rival Alfred Russel Wallace argued that evolution should have stopped when it had crafted a brain that was smart enough to outperform other animals. 'Natural selection', he said, 'could only have endowed savage man with a brain a few degrees superior to that of an ape, whereas he actually possesses one very little inferior to that of a philosopher.' He concluded from this that the ability to compose music and build cathedrals must have arisen by some sort of spiritual infusion.[10] Arthur C. Clarke's novel *2001*, in which extra-terrestrial beings provide the necessary stimulus to an ape's brain, was a secular version of the same idea.

How did we come into possession of a brain so far in excess of our immediate requirements? One explanation is *exaptation*, a term used by evolutionary thinkers for a trait which evolved for one purpose and proved useful for another. Feathers evolved for warmth but made flight possible. Our tongues discovered a new function when we learned to speak. The exaptation hypothesis suggests that the quantum leap associated with the Brain Change came about because we had already acquired sufficient computing power to make it possible. The likely explanation for this was social interaction and competition within our own species. But there is general agreement that, for whatever reason, a radical change in our behaviour made itself apparent some 50,000 years ago and set us on the road to the present.

The Palaeolithic or 'Old Stone' Age is conventionally divided into an early phase, which runs from 50,000 to 20,000 years ago, and a later phase, from 20,000 to 10,000 years ago. These were separated

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by the end of the last ice age, otherwise known as the last glacial maximum. The world warmed slowly from around 20,000 years ago, and pollen traces show that dense forests followed the retreating ice. Life moved northwards, and *Homo sapiens*, the last remaining human, moved with it. Hunting requires a high level of physical fitness, but the work of a forager is more sustained than that of a hunter and just as exhausting. Observation of the !Kung San of the Kalahari showed that a mother carried each child for something like 7,800 km during the first four years of its life, and gathered 7–10 kg of plant food in the course of a typical day. Hunter-gatherers ate less fat and more protein than we do, and consumed more vegetable fibre but a lot less salt. People raised in this way are lithe and physically fit; their bodies contain as little fat as modern marathon runners, averaging around 15–20 per cent in men and 20–25 per cent in women. Their exercise capacity (estimated by oxygen consumption) was typically 30 per cent greater than that of age-matched westerners. Some were capable of running an antelope to exhaustion. Unlike us, they did not gain weight as they aged, their blood pressure did not rise, and diabetes and vascular disease were almost unknown.[11]



Figure 3: Gravettian skeleton from Grottes des Enfants 4, Grimaldi, Italy.

Reconstructing people from a few fragments of bone is tricky, and early archaeologists conjured up early ancestors 2 metres in height. More sober estimates followed, but some of our predecessors were relatively tall: In Europe, men averaged 174 cm 20,000 years ago, as against 162 cm for women.

Another 'modern' feature was the length of their legs relative to their overall height (figure 3). This was particularly marked in skeletal remains found in Italy and former Yugoslavia amid bones of mammoth, rhinoceros and reindeer. The Gravettians lived 20–30,000 years ago, and many were more than 183 cm tall. Studies of the Y haplotype (which marks male descent) show that many modern Europeans are descended from them.

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Genes determine relative height, as we saw earlier, but the absolute height of a population depends upon its environment. This being the case, the interest lies in the fact that Europeans were taller in the Ice Age and did not regain their former height until modern times. The reason was almost certainly nutritional, for the Gravettians lived in the golden age of hunting.[12]

Life was less easy for their successors, broad-spectrum foragers who were obliged to supplement their diet with fish and small game. Dental caries testify to their increasing reliance upon a plant-based carbohydrate diet, and they were considerably shorter. Men averaged 165.3 cm as against 154.5 cm for women, a decrease of 8.8 and 7.3 cm respectively.[13] This was the prelude to what was once seen as the Neolithic revolution.

THE REVOLUTION THAT WASN'T

Prehistory began as a happy hunting ground for half-baked ideas. Amateurs and crackpots with preconceived notions ranged freely over territory later to be claimed by specialists in archaeology, anthropology, ethnology and linguistics. Distinguished gentlemen, ignorant of the local language, converted brief visits to some foreign shore into authoritative two-volume publications. The beliefs and customs of the local inhabitants were confidently extrapolated, and snippets garnered in leather armchairs were patched into learned fantasies such as the sacrificial priest-kings of James Frazer. Prehistoric folk wanderings were the order of the day, biological inequality was widely assumed, and long-headed Aryans roamed the prehistoric world, raising the tone wherever they went. The twentieth century saw the emergence of professional archaeologists who, slow as they were to shrug off the legacy of previous thinkers, nonetheless introduced the principle of meticulous scientific excavation coupled with cautious extrapolation from the facts.

Gordon Childe (1892–1957) was the sort of socialist who would be lined up against a wall in the aftermath of any revolution. Small, wiry, carrot-haired, odd-looking, awkward and intellectual, he stood out against any background. At the peak of his fame he would go about in

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