

Human chromosomes and a nucleus in a false-colour image taken by scanning electron microscope.

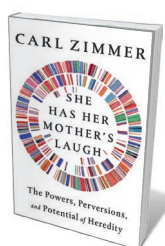
HEREDITY

Beyond the gene

Nick Lane relishes Carl Zimmer's history of heredity in all its messiness, from genes and culture to epigenetics.

Few subjects have afforded more room for doubt, or caused more harm through false certainty, than heredity. In *She Has Her Mother's Laugh*, an illuminating survey of the concept through history, science writer Carl Zimmer shows that scientists have often clung to travesties of the truth — and that we are still in danger of doing so.

The book is a beguiling narrative of more than 600 pages. It blends popular science and history with a personal journey, culminating in a plea for a nuanced view of heredity. Zimmer ably navigates some of the most fraught developments in research, politics, religion and race: from eugenics, slavery and genocide to IQ and genetic engineering in humans. He combines a deep personal empathy with clear scientific understanding. For instance, in presenting controversial figures such as Henry Goddard — who coined the term 'moron' and helped to foster the US eugenics movement in the early twentieth century — he examines their hopes, fears and delusions, before dispassionately gutting their scientific errors and the disastrous consequences.



She Has Her Mother's Laugh: The Powers, Perversions, and Potential of Heredity
CARL ZIMMER
Dutton (2018)

Compellingly, Zimmer delves into his own genome. After having it sequenced at 90% coverage by Illumina in San Diego, California, he got his hands on the raw data, and approached experts such as Dina Zielinski of the New York Genome Center to help him unravel his genes' secrets. Zimmer uses this backstory to illustrate how genomes break up into millions of short stretches of DNA, each with its own history from around the world.

Being told you have ancestors everywhere is one thing; it's quite another to pin that down with visceral intensity. Of the 3,559,137 bases in Zimmer's genome that differ from the human reference (a representative sequence based on a number of donors) he shares 1.4 million single-nucleotide polymorphisms,

or SNPs, with two volunteers from China and Nigeria — plus another 530,000 with the Chinese individual and 440,000 with the Nigerian. On top of his roughly 1% Neanderthal inheritance (standard for a person of European descent), Zimmer even has a few Denisovan genes. We should think of the Denisovans as the eastern Neanderthals, he explains. One of their genes, *EPAS1*, might even have helped Tibetans to adapt to high altitudes, although most Denisovan DNA dwindled, leaving little more than a hint of our species's promiscuous past.

At a deeper level, the book is a serious treatise on why we need to overhaul our views on heredity. Zimmer shows how the idea evolved from medieval times, with the passing down of possessions, to our modern focus on genes. He recounts how nineteenth-century genetics pioneers Gregor Mendel and August Weismann seemed to bring clarity by defining simple laws of inheritance in sexual organisms, and by distinguishing between sex cells in the germ line and cells in the rest of the body (see J. Maienschein *Nature* 522, 31–32; 2015). But heredity soon returned to a swamp of ambiguity. Charles Darwin's cousin Francis Galton, a deeply flawed Victorian statistician and racist (who in 1904 founded what would become the Galton Laboratory at University College London; see go.nature.com/2i6uelm) crops up repeatedly, each time with a new layer of nuance or downright murkiness.

It took the best part of a century for Mendelian genetics to be fully reconciled with complex hereditary traits such as height. Sophisticated statistical methods reveal such traits to be 'omnigenic', influenced by millions of genetic markers. Intelligence is even worse; fairly heritable, certainly, but with a complexity that mocks simple ideas of Mendelian inheritance.

The book goes on to tackle meiotic drive, in which 'selfish' genes evade Mendel's laws by killing the 50% of sex cells that lack the selfish elements, so almost all the offspring inherit the selfish genes. Then we're onto cell lineages, where mutations acquired during development make genetic mosaics of us all; and microchimaeras, in which cells slip, in both directions, across the placental barrier between mother and fetus, sometimes persisting for decades and colonizing whole tissues. (The entire lobe of one woman's liver, Zimmer notes, was composed of Y-chromosome-bearing cells from a male fetus, the paternity of which could be traced to her boyfriend.)

Zimmer explicates transmissible tumours, which infect species including dogs and Tasmanian devils, and can persist in populations for thousands of years, picking up new mitochondria from their hosts. He treats transgenerational epigenetic inheritance with due care, showing how some genetic settings controlled by chemical changes can be passed on with the genes themselves, ►

► modulating their activity over multiple generations. That can be seen in eighteenth-century taxonomist Carl Linnaeus's 'monstrous' peloria, a toadflax (*Linaria vulgaris*) with unusual, trumpet-shaped flowers — “no less remarkable than if a cow were to give birth to a calf with a wolf's head”, as he put it.

Zimmer completes his tour with chapters on the microbiome (some of which is as heritable as anxiety, and partly accounts for the inheritance of traits including weight), and cultural inheritance. Genes are expressed in a human-altered environment, Zimmer notes, and their effects are as plastic as the culture that shapes their selection, right down to social inequalities. Our inherited environment governs our future more rigidly than our genes.

In this encompassing view of heredity, we get a correspondingly nuanced vision of what, for example, germline editing using CRISPR will really mean. By acknowledging the ambiguous way in which genes actually work, and by embracing all these other factors that shape our lives, we make CRISPR less threatening because it is less definitive.

Zimmer deconstructs the idea of the body as a genetic temple, built on Mendel's sacrosanct 'laws', along with genetic determinism. Instead, he calls for a view that includes “culture, epigenetic marks, hitchhiking microbes, or channels we don't even know about yet”. His argument is balanced and fair, comprehensive and bang up to date. Whatever your views on the power of genes versus other forms of heredity, you will be in for a few surprises.

There are some weaknesses. Zimmer makes no real attempt to explain how Mendel's laws arose in our single-celled ancestors, and offers rather cursory descriptions of early evolution. And his sympathy for the underdog can go too far. His portrait of crystallographer Rosalind Franklin, for example, seemed to me too partial. You would never imagine, from Zimmer's depiction of her meticulous science, that Franklin had circulated an obituary of the DNA helix nine months before Francis Crick and James Watson's paper on the double helix appeared in *Nature*. But these are quibbles.

In *She Has Her Mother's Laugh*, Zimmer has built a subtle, multifaceted and deep understanding of heredity, grounded in revelatory insights from genome sequencing. And he shows that we will need it to face our uncertain future. ■

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Untitled 2018, one of Peter Kogler's installations of computer-assisted art.

TECHNOLOGY

Can robots make art?

Laura Spinney encounters a Paris exhibition that probes the concept of algorithmic creativity.

Visiting the exhibition *Artists and Robots* at the Grand Palais in Paris, I happened on the artist ORLAN, best known for her work involving body modification. She was standing close to her 2017 work *ORLAN and the ORLANOID*, in which her video presence interrogates a lookalike robot on matters of life and death. Having borrowed the robot's lensless glasses for a photo shoot, she needed her own back. I was struck by the robot's lack of reaction as she made the swap. It underscored my answer to the question posed by this exhibition: can a robot create a work of visual art?

My feeling is no, for the simple reason that it can't see. I recommend the show, nonetheless. It forced me to examine what I mean by seeing or — more broadly — sensing the world, and hence what I mean by art.

Artists and Robots showcases robots and their output in roughly chronological sections. The first recounts how, starting in the 1950s, visionary artists such as Jean Tinguely and Nicolas Schöffer built robots — to begin with, no more than collections of mobile parts driven by motors — to create kinetic art. The second tracks that impulse forward from the digital revolution, starting in the 1970s.

“Artificial imagination has yet to get off the starting blocks.”

Artists and Robots
Grand Palais, Paris.
Until 9 July 2018.

And the third — optimistically entitled ‘The robot emancipates itself’ — explores their present status and looks to the future.

When robots were all jointed arms and motors, they executed an artist's vision channelled by their own capacities as machines. Modern French artist Patrick Tresset's ironic spin on this relationship features in the first section of the show. In the installation *Human Study #2*, three sets of robot arms and cameras — the ‘hand’ and ‘eye’ — repeatedly draw a set of objects including a stuffed fox and a human skull. They are programmed to copy both the objects and Tresset's drawing technique, while introducing small variations that he characterizes as artistic, expressive and obsessional. It's through such serendipitous additions and mistakes, the artist seems to suggest, that the greats became great.

The digital revolution ushered in software and algorithms as artists' tools or assistants, and the possibilities exploded. We see this in stunning works in the second section, from conceptual artist Joan Fontcuberta's self-described “hallucinatory” landscapes to labyrinthine wallpaper from multimedia whizz Peter Kogler. This covers an entire room, so that we seem enclosed in an optical illusion. For me, the works' technical sophistication seems only to accentuate their soullessness,