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ISSN 2197-1188 ISSN 2197-1196 (electronic)
ISBN 978-3-662-43525-0 ISBN 978-3-662-43526-7 (eBook)
DOI 10.1007/978-3-662-43526-7
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014945103

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Los Angeles, a few years from now? You're walking down a city street. Dark skies drip with acid rain. Monolithic buildings covered in neon advertising dominate the landscape. Ahead you see a woman running toward you. She's being followed by a man with a gun. He fires at her and she crashes through a plate-glass window and hits the ground. She lies on the concrete, surrounded by broken glass and blood. Police ask the man for his credentials. He's Rick Deckard, a police officer known as a *blade runner*. It's his job to track down *replicants* (genetically engineered creatures composed entirely of organic substance) and "retire" them.

This is the world of Ridley Scott's *Blade Runner*. It's a dreary place, to be sure. People pack the streets tightly, and animals are all but extinct. Rain pours from the sky, and even when the sun is shining, it seems dark. Advertising screams, sometimes literally, from every direction. Flying cars—spinners—ferry police officers from place to place. It's a world of high technology and low empathy. Not a very *human* place to live.

Blade Runner is set in 2019, and while there may not be replicants running around the streets a few years from now, we may not have to wait long. After all, we live in an era in which the application of technology is relentless: the mapping of the human genome, life-support machines that extend metabolic processes beyond brain death, and countless other recent scientific developments have challenged our understanding of what it means to be human. But, while these technologies appear futuristic, the predominant effect of recent technological advances has not been to transform bodies in any significant way.

That is about to change.

Just like the sci-fi environments inhabited by bioengineered replicants, the intersection of technology and life will soon become a reality, and the specter of human genetic engineering, human cloning, and bioprinting will challenge the conception of what it means to be human even more. In *Beyond Human*, technology's infiltration of the organic—so familiar today in the form of genetic research and biotechnology—is presented neither as a transcendent savior nor as a maker of monsters. By presenting the trajectory of human genetic engineering, human cloning, and technologies such as bioprinting, *Beyond Human* underscores the limits of the human body in a world where technology will soon threaten it with obsolescence. *Beyond Human* goes to the heart of human genetic engineering, cloning, and synthetic DNA manipulation to explain how replicant/bioengineered humans will be a reality—perhaps within a generation.

In *Blade Runner*, replicants can do all sorts of work. They're especially well-suited for jobs that are too hazardous for "natural" humans to do. Adverts for moving to off-world colonies promote the opportunity to own a replicant as an incentive. Genetic engineers design replicants and other life-forms using a combination of organic and synthetic materials. *Beyond Human* explores this theme by delving into the possibilities of gene doping in sports and designing ruggedized humans.

Should we be optimistic? *Beyond Human* asks what the existence of genetically engineered humans will mean for society and explores the possible relations between human beings and their replicant counterparts. Will the existence of genetically engineered and/or cloned humans result in a dystopian future similar to the one portrayed in *Blade Runner* or will the replicants of tomorrow be treated no differently than someone with a prosthetic limb?

Why the fixation on science fiction? Primarily because science-fiction writers make science entertaining and, while this is not a science-fiction book and I'm not a science-fiction writer, I decided to make the topic of human genetic engineering more accessible at the popular science level by referencing the subject material to science fiction movies with genetic themes. And, of all these movies, the darkly prophetic masterpiece *Blade Runner* stands out in the crowd because it served as the template for so many later films that dealt with genetic themes: *The Island*, *Gattaca*, *The 6th Day*, *Splice*, *Resident Evil*, etc.

Most people assume the term *genetic engineering* was coined recently by the scientific community—in the past 20 or 25 years perhaps? You'd be surprised. If you search for the term *genetic engineering* in the archives of the journal *Science*, you will find the following article: Stern C. Selection and Eugenics. *Science* 26 August 1949 110: 201–208. In Stern's article, the term *genetic engineering* is used in the breeding sense rather than the molecular biological sense, which isn't surprising given that Watson and Crick didn't publish the structure of DNA until 4 years later. Also, back in those days there was no scientific means to modify human genes, although genetics and eugenics had been hot topics in the 1930s and 1940s, thanks in part to the work of Hermann Muller, who won a Nobel Prize in 1946 following his work on radiation and the heritable mutations that could be caused by X-rays. Since then, the potential applications and implications of intentional genetic manipulation have supplied much plot-material for science-fiction novels and films.

In contemporary sci-fi movies, genetic engineering (*Gattaca*, *Blade Runner*, *Splice*) and cloning (*The Island*, *The 6th Day*, *Judge Dredd*) often compete for attention with other favorite sci-fi topics such as cybernetics (*The Terminator*, *Alien*, *Aliens*) and artificial intelligence (*Dark Star*, *The Matrix*, *2001: A Space Odyssey*). But what attracts film directors such as Ridley Scott to genetic engineering is not so much its scientific content as its relationship to more universal concepts such as heredity, reproduction, or replication, and its close connection to contemporary concerns concerning loss of identity (*The Island*) and authenticity (*Gattaca*) in a society increasingly dominated by technology (*Blade Runner*) and big business (*Splice, The 6th Day*).

Of course, in common with many films featuring science, medicine, and technology prominently, films with genetic themes have often been criticized on grounds of scientific inaccuracy. And, although not all cinematic treatments of genetics are wildly inaccurate, some may argue the cinema is perhaps not the best place to reference accurate information about the principles of human genetic engineering or cloning technologies. After all, if you watch the credits of many of these films, you'll notice that very few carry credits for scientific advisors, attention instead being focused on the modus operandi of genetic engineering or human cloning, rather than on the basic science of genetics. Sometimes the technologies described and portrayed bear little or no resemblance to any known genetic technology—take the suspect methods employed by the sinister Replacement Technologies Corporation to clone humans in the Schwarzenegger flick *The 6th Day* for example. But this doesn't mean nothing valuable can be gained from the study of sci-fi films in which genetic engineering plays an important part. It just means that to do so it is necessary to set aside strict criteria of scientific accuracy and realism. One of the reasons I chose to write this book the way it is written is because sci-fi films have a remarkable capacity for visualizing future scenarios in which science in general, and genetics in particular, plays an important role. If you want to learn about the intricacies of genome manipulation and if you want to understand the complex ethical arguments for and against human genetic engineering there are a myriad books out there. But not many of these publications venture into the unknown and speculatively guess about the ways in which current science and technology may develop. This is the beauty of the sci-fi film, which can reach and influence millions of people from all walks of life who may never watch a documentary on genetics. These films are, in short, a form of mass communication which the scientific world and those who write about it cannot afford to ignore. And, while some films, like *The 6th Day*, are cleverly contrived and slickly marketed mass entertainment products, a few, like *Blade Runner* and *Gattaca*, are works of considerable intellectual value, which is why their themes are revisited in this book.

In writing this book, I have been fortunate to have had reviewers who made such positive comments concerning the content of this publication. I am also grateful to Angela Lahee at Springer and her team for guiding this book through the publication process and gratefully acknowledge all those who gave permission to use many of the images in this book, especially EnvisionTec. Finally, I also express my deep appreciation to Deborah Marik, whose meticulous and unrelenting attention to detail greatly facilitated the publication of this book, and to eStudio Calamar, Figueres/Spain, for creating the cover.

Sandefjord, Norway
August 2014

Erik Seedhouse

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Human Genetic Engineering

This is not like anything we have ever seen…
It isn't like anything that has ever been done.
Philip K. Dick, author of *Do Androids Dream of Electric Sheep?,*
after being shown footage of *Blade Runner*

For many sci-fi enthusiasts, and I am among them, *Blade Runner* is arguably the greatest and most powerfully prophetic sci-fi film of all time. When Ridley Scott's masterpiece first appeared in 1982, the year 2019 was 37 years in the future and nobody was talking about human genetic engineering—except sci-fi enthusiasts perhaps. But today, in 2014, we're just five years away, and practically every popular science magazine has at least one article dedicated to the subject of genetic manipulation in each issue. Rarely has a film been so prescient. For those unfamiliar with Ridley Scott's epic, the *Blade Runner* story, which is loosely based on Philip K. Dick's novel *Do Androids Dream of Electric Sheep?*, is fairly straightforward. Set in 2019 Los Angeles, the film revolves around Deckard (played by Harrison Ford), a Blade Runner (member of a police special operations unit), who must hunt and retire (read: kill) replicants (genetically engineered beings virtually identical to humans). In short: cop hunts and kills super-humans. For me *Blade Runner* was much more than a simple prediction of the future. At the movie's core is the question of what it means to be human, although this question is never explicitly asked in the film. The idea of genetically enhanced humanity is played out between Deckard and the replicants, especially Roy Batty, the alpha replicant. One of the most thought-provoking themes explored in the movie is that these replicants, created for the use of humans, could override their own limitations and develop humanity, as evidenced in the film's final scene when Batty saves Deckard from certain death. Then there is the idea of providing the replicants with memories. After all, memories are what separate humans from each other and make them individuals. But, in the *Blade Runner* world, memories have been given to the replicants so their creators can control them better. Memory also gives a person his or her identity, and Batty is no exception, be-

E. Seedhouse, *Beyond Human,* Science and Fiction,
DOI 10.1007/978-3-662-43526-7_1, © Springer-Verlag Berlin Heidelberg 2014

cause his memories make him the most dynamic character in the movie. The themes of identity, perception, memory, time, and humanity are all in this film, which is one reason why, 30 years later, it continues to earn respect. The film's portrayal of a genetically enhanced future may be disturbing for some now, not because it may happen, but because it is already happening, which makes *Blade Runner* the perfect film to reference in this book (incidentally, the original working title of this book was *Replicant Reality*).

While the reader will find several references to *Blade Runner* in these chapters, it isn't the only film used to highlight the technology that is discussed. The main sci-fi references in this book are to film rather than novel because I believe sci-fi films have greater mass appeal than sci-fi novels. One reason for this is that sci-fi films can easily be made spectacular thanks to increasingly visceral and fast-paced special effects, which not only make the science portrayed in the film more believable, but also more memorable than a description in a book. Why sci-fi? Sometimes referred to as "speculative fiction," sci-fi is probably the most valuable medium for engaging in prediction; it also happens to be an effective and entertaining way to portray plausible futures, such as that in *Blade Runner*. And today, in 2014, given the potential for redesigning humans, *Blade Runner* has never been more relevant.

> My friends are toys. I make them. It's a hobby. I'm a genetic designer.
>
> J. F. Sebastian (William Sanderson), *Blade Runner*, 1982

Watching *Blade Runner*, it is obvious Philip K. Dick spent considerable time imagining what the world might be like in 2019. And judging by the world we live in today, the author wasn't far off the mark on a number of issues: globalization, immigration, cultural identity, and the rise of human genetic engineering, the subject of this chapter. Let's begin by addressing some of the concerns people have with this subject by examining one of J. F. Sebastian's scenes. In *Blade Runner,* J. F. Sebastian lives in a decrepit high-rise, where, being the genetic designer he is, he has surrounded himself with genetically aberrant pseudo-humans whose main purpose is to amuse and keep him company. These genetically modified creatures are like pets, engineered not to be free of defects, but to be entertaining by virtue of their defects. Some are pint-sized, some are uncoordinated, and others have unusual mannerisms. J. F. Sebastian dresses them up in costumes, teaches them welcoming catchphrases for when he returns home, and poses them around his home like stuffed animals. Not the sort of application people think of when you mention genetic engineering, is it? When I first saw that scene, my mind mulled over the myriad ways this technology could be abused, including by lonely people who could one day fashion genetic creations just to keep them company. Perhaps recluses could engineer defects to keep themselves amused as J. F. Sebastian did? You don't think this could happen? Well, there are plenty of maladjusted, agenda-driven people out there. Consider the Royal National Institute for Deaf and Hard of Hearing People and the British Deaf Association, a pair of British deaf-rights organizations that lobbied to give deaf prospective parents the right to genetically engineer deaf children. Yes, you read that correctly. Their efforts were focused on amending the UK Human Tissue and Embryos Bill, which, until recently, prohibited the screening of embryos for the purpose of choosing one with an abnormality. It is not just in the UK where this "intentional crippling of kids" agenda is playing out; according to a 2006 Associated Press report, in a survey of 137 US clinics offering genetic embryo screening, 3 % had provided the service to families intent on *creating disabilities* in their children. Welcome to the slippery slope of genetic engineering!

Organizations such as the British Deaf Association remind us that human genetic engineering directly impinges on reality. That is because as advances in human reproductive technologies allow us to modify our offspring and ourselves, and as these technologies increasingly enable us to create humans of a different sort, we need to pay close attention to human rights violations, prejudices, and inhibitions, such as those portrayed in *Blade Runner*. In the *Blade Runner* universe, replicants are manufactured from genetic and biological components and have been created to serve humans. Making matters worse, replicants have only a 4-year lifespan. Of course, we're talking about a sci-fi film, and you may think the moral issues in *Blade Runner* won't be a problem in the real world. The truth is, human genetic engineering is already here in the form of prenatal health screenings, and it won't be long before more and more of your children's traits will be things you can decide for them. So let's look over the horizon and imagine a time not too far in the future when you can sit down with your geneticist and customize your children. You and your partner provide the DNA, and science can add the positive traits, subtract the negative traits, and fine tune the rest. Ask yourself: how many people in this near future would choose average (natural) kids instead of genetically engineered, hyper-smart, disease-proof kids? I know which I'd choose. The reality is that, in perhaps a generation, genetic engineering may result in a glut of smart, fit, and beautiful people suited to intellectual jobs, and a lack of those suited to more menial jobs. How would society address the balance? One option might be to regulate genetic engineering and let the government decide who may and who may not use this technology. This is the

Fig. 1.1 Plastic surgery. (Courtesy: Wikimedia)

premise in Kurt Vonnegut's short story *Harrison Bergeron*, in which the Office of the Handicapper General manages the Department of Equity in Breeding, which ensures people have to prove their suitability for breeding. Another option would be to import an underclass. Perhaps we'd do both!

Do you think this couldn't happen? Do you think the purpose of human genetic engineering science is to accelerate evolution, prevent chromosomal imperfections, ensure better health and eradicate disease? Do you think we humans are too moral and noble of spirit to intentionally create less-than-perfect children? Think again, because the urge to tamper with nature is pervasive among humans. Consider what we do to ourselves in the name of individuality. We go under the knife for bigger boobs, trimmer bellies, and slimmer noses, we inject ourselves with Botox and collagen, we apply facial wrinkle-fillers by the bucket-load, and we use lasers to burn the skin off our faces. Plastic surgery (Fig. 1.1) is big business in the USA, and that business is booming. In the USA alone, nearly 14 million cosmetic procedures were performed in 2011, with Americans spending $ 10.1 billion on everything from collagen and Botox injections to breast implants and buttock lifts. The point is that it is *human nature* to modify oneself and, when genetic engineering becomes as accessible as plastic surgery, you can be sure people will be lining up. But before discussing the hot genetic issues such as cloning, designer babies, and potential replicants, we'll begin with a genetics primer, as it is helpful to understand the jargon.

1.1 Genetics: A Primer

At the heart of genetics is the basic building block of all living things: the cell. Your body is composed of trillions of these. Cells provide structure, absorb nutrients, convert nutrients into energy, and carry out all sorts of functions. Cells also contain your hereditary material and can make copies of themselves. The command center of the cell is the nucleus, which sends directions to the cell to grow, mature, divide, and die. The nucleus also houses deoxyribonucleic acid (DNA), the cell's hereditary material. Nearly every cell of your body has the same DNA and the information in it is stored as a code comprising four chemical bases: adenine (A), guanine (G), cytosine (C), and thymine (T). Human DNA (Fig. 1.2) consists of about 3 billion bases, and the sequence of these bases provides the information required to build an organism—you! You can think of how these bases work as being similar to how letters of the alphabet form words and sentences: DNA bases pair up with each other, A with T and C with G, to form base pairs. Each base is attached to a sugar molecule and a phosphate molecule, and together a base, sugar, and phosphate are called a nucleotide. Millions of these are arranged in two strands forming a double helix. The structure of the double helix is like a ladder, with the base pairs forming the ladder's rungs and the alternating sugar and phosphate molecules forming the side supports.

A key property of DNA is that it can make copies of itself, since the DNA bases of each strand of the double helix can serve as a pattern for duplicating the sequence of bases. This is important when cells divide because each new cell needs to have an exact copy of the DNA present in the old cell. The DNA inside a cell is arranged into long structures called chromosomes. While most DNA is packaged inside the nucleus, mitochondria (the cells' powerhouses) also have a small amount of DNA, called mitochondrial DNA or mtDNA. Chromosomes are made up of DNA coiled around proteins called histones, which support their structure. In humans, each cell nucleus normally contains 23 pairs of chromosomes, making a total of 46. Of these pairs, 22, called autosomes, look the same in males and females, but the 23rd pair, the sex chromosomes, differ between males and females. Females have two copies of the X chromosome and males have one X and one Y chromosome.

A gene is the functional unit of heredity; it is a region of DNA affecting a particular characteristic. Genes act as instructions to make molecules called proteins. Proteins are complex molecules required for the structure, function, and regulation of the body's tissues and organs, and it is the genes' job to direct their production. They do this in two steps: transcription and translation. Together, transcription and translation are known as gene expression. During transcription, the information stored in a gene's DNA is transferred