Mukherjee, Siddhartha. *The Gene: An Intimate History.* New York: Scribner, 2016. 593 pp. $32.00 cloth (ISBN 978-1-4767-3350-0).

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Heredity has always been, in one form or another, at the center of biological research. There is little doubt that the first scientific experimentation took place about fifteen thousand years ago, when humans started breeding plants and animals in order to domesticate them. Today the science of genetics seems to advance at such a pace that even the experts have trouble keeping up with all the developments. Now we are witnessing the expansion of our understanding of this realm of science to levels unimaginable just a few decades ago.

Among the questions related to heredity that researchers have been trying to understand from the beginning of time are: (1) how does fertilization take place? (2) what is exactly transmitted during copulation that leads to conception? (3) is spontaneous generation possible? (4) is sexual reproduction the only way to produce new individuals? (5) what are the respective contributions to the characteristics of a child made by the father and the mother? (6) does the mother make a "genetic" contribution in addition to nursing the developing embryo? (7) are the gametes (sex cells) formed throughout the body or in specific organs? (8) how is the sex of the offspring determined? and (9) how heritable characters are influenced by external factors such as the environment or even use and disuse?

Although today we have clear answers to these questions, those answers came through centuries of trials and the employment of the latest technologies available by both amateurs and professional scientists from all over the world. Therefore, it is not surprising that heredity has always been a major puzzle to both scientists and those who try to make science understandable to the general public.

The scientific bases of modern genetics as a predictive science were not established until the 1860s with the work of the Austrian Augustinian monk Gregor Mendel; yet, his seminal ideas about heredity were not understood until 1900 when the Dutch botanist Hugo de Vries, the German botanist Carl Correns, and—to a certain extent—the Austrian agronomist Erich von Tschermak, rediscovered Mendel's work and made it well known within the scientific community. By all accounts Charles Darwin did not know of Mendel's work.

After all, he always acknowledged that his theory of evolution by means of natural selection lacked the understanding of the phenomenon of heredity. By the same token it is widely accepted that Mendel did know Darwin's ideas. Mendel marked the copy of *The Origin of Species* that he kept at the library of his monastery with an exclamation point next to the passage "There are many laws regulating variation, some few of which can be dimly seen."

In fact, the whole story of why Darwin never knew about Mendel's work is quite fascinating and has been the subject of a great deal of research.[1] The general consensus of these and other researchers is that had Darwin read Mendel's article, he would have found a detailed analysis of the frequencies observed for different inherited traits from generation to generation of the edible pea. Yet, these results were presented in a mathematical form and that might have been unpleasant for Darwin who once said that mathematics in biology is like a scalpel in a carpenter's shop—there is no use for it.

Darwin might have also found Mendel's conclusions unacceptable. Mendel argued that the transference of characteristics amongst cultivated plants occurred by discrete integral steps and could "transform" it into a different species, which ran contrary to Darwin's belief in blending inheritance.

Later, it was not until the work on the structure and function of the nucleic acids, first by the Swiss physician Friedrich Miescher in 1874 and then by the American James Watson and the British scientists Francis Crick, Maurice Wilkins and Rosalind Franklin as well as scientists working on population genetics, that the full concept of the gene was really developed. Despite the importance of these discoveries, many science popularizers, including the famous Isaac Asimov, had trouble transmitting the scientific basis of heredity to the general public in a way that was easy to understand in its complexity.

Now comes Mukherjee's book on the history of the gene. With nearly six hundred pages of text I read the book with great anticipation. The whole history of genetics is a fascinating one for a number of reasons. First, contributors to this branch of science came from all over the world and at different stages of the history of science. Second, the development of ideas on heredity were not always linear. Third, the history of genetics is full of personal stories including scientists

1. See, for example, B. E. Bishop, "Mendel's Opposition to Evolution and to Darwin," *Journal of Heredity* 87 (1996): 205-13; D. Galton, "Did Darwin Read Mendel?" *Q. J. Med.* 102 (2009): 587–589; and R. S. Singh, R. S. "Limits of Imagination: The 150th Anniversary of Mendel's Laws, and Why Mendel Failed to See the Importance of His Discovery for Darwin's Theory of Evolution," *Genome* 58 (2015): 415-421.

showing the worst of themselves, from back stabbing to appropriation of others' work. Fourth, the science of heredity has been misused for political or ideological reasons to justify even mass murder. Therefore, the history of genetics and its central element, the gene, always provides us with many fascinating stories that would captivate both the specialist and the general public.

There have been many other books and hundreds of scholarly articles dealing with different aspects of the history of heredity; there are just too many to mention here. Thus the book by Mukherjee, an assistant professor of medicine at Columbia University Medical Center and a 2011 Pulitzer Prize winner for his book *The Emperor of All Maladies: A Biography of Cancer*, created all sort of expectations. However, those expectations failed to materialize for a number of reasons.

One of the problems of this book is that by focusing exclusively on the term gene it misses a lot of the context one needs in order to understand its history. In fact, the term gene was coined by the Danish botanist Wilhelm Johannsen in 1909, that is, nine years after the rediscovery of Mendel's work and about four decades after the work itself. And that does not mean that all the research prior to the twentieth century is irrelevant.

There are even many interesting and revealing developments in the history of heredity prior to Mendel. From the domestication of plants and animals as far as fifteen thousand years ago (not mentioned in the book), to many famous ancient Greek thinkers including—but not exclusively—Pythagoras, Plato, Anaxagoras, or Hippocrates who rightly or wrongly proposed influential ideas about heredity. While they were mostly wrong they were still believed by many all the way to Mendel's time. Yet, Mukherjee fails to mention their ideas.

Furthermore, the portrait of Aristotle's contributions to the notions of heredity in Mukherjee's book are not only incomplete and misleading but also he ignores many more contributions made by others between the ancient Greeks and Mendel's times such as those by Theophrastus of Eresus, Herophilus of Chalcedon, Galen, Avicenna, and Leonardo da Vinci who debunked many false ideas about heredity.

Members of the movement that created the period in the seventeenth century known as Modern Science such as William Harvey, Nehemiah Grew or Anton van Leeuwenhoek are also ignored. Eighteen century ideas such as epigenesis or parthenogenesis are never mentioned, nor are the contributions of plant breeders of the seventeenth and eighteenth centuries. And the same can be said about Charles Naudin, a clear precursor of Mendel's ideas.

But lack of acknowledgement to major historical developments and pioneers are not the only mistakes made in the historical analysis of heredity in this book. Lack of describing the influence of certain ideas is also rampant. Probably one of the most egregious examples is that the author completely obviates the impact that the book *The Selfish Gene* by Richard Dawkins had on our thinking on how genes ultimately work. Forty years ago Dawkins proposed that genes strive for immortality and that organisms, from bacteria to humans, are just the carriers of such struggle for survival. Not only that but that all things related to life as a phenomenon, such as behavior, serve the ultimate goal of passing information from one generation to the next. And here Dawkins did use an appropriately good metaphor: genes are selfish. Thus, at the end of the day it is not a particular organism that is trying to survive but the genes within the organism, and that is an "intimate" notion of genes. Although some of Dawkin's ideas are mentioned sporadically, his seminal book and its influence on our understanding of evolution are nowhere to be found in this book.

In addition to the lack of acknowledgement to these and other ideas and precursors, some of the historical characterizations of the individuals mentioned in the text are quite misleading. On page 28 Mukherjee describes Charles Darwin as a "young clergyman." The problem is that this statement gives the impression that Darwin was some kind of a churchman, cleric, minister, or preacher but that was not the case at all.

After dropping out from Edinburgh University school of medicine, which he attended following a long family tradition of producing medical doctors, he dropped out because he could not withstand, among other things, witnessing surgical procedures performed on other human beings without anesthesia. Then, his father pretty much forced him to go to the University of Cambridge in 1828, when he was eighteen years old, in order to pursue theological studies so he could become a clergyman, but although he graduated two years later from Christ's College with a Bachelor in Arts degree, a precondition to be ordained, he never took the vows. Actually he spent most of his time at Cambridge collecting animals, plants, and geological specimens. When Darwin returned to his family home, he had little interest in pursuing a religious career and jumped at the opportunity to go on board the *Beagle* as an unpaid naturalist. In fact, his father opposed the idea of his son embarking on that voyage telling him "You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family."

Another fundamental problem with this book is the scope given by the title: the history of the gene. Unlike a scientific idea such as evolution, heredity, or ecology, the gene is a concept based on a physical entity. As such, we are dealing with a natural object. That is why there are so few books with the title of "history of the atom." It is easier to talk about the atom as an idea later shaped by science than as an object out of context. If you were to encompass genes as part of a history then you should address it as a "history of heredity" because heredity is an idea, a concept, not an object.

Thus, Mukherjee's book goes off the rails in its historical approach and has plenty of other superficialities and inaccuracies that do not make it on par with other books that have been published on the subject.

The book's narrative style does not help either. Mukherjee uses metaphors and similes all the time and if you are not a trained biologist you will get lost in trying to understand the real meaning of his attempts of describing facts. For example, on page 150 the author writes "A single strand of DNA consists of a backbone of sugars and phosphates, and four bases –A, T, G, and C—attached to the backbone, like teeth jutting out from a zipper strand." A single illustration of the world's most famous molecules would have worked better than this simile. And examples of these unintelligible—and sometimes even misleading—comparisons are everywhere in the book.

In conclusion, the history of heredity, genetics and the very concept of the gene is a gold mine to be exploited and clearly explained to the general public. Mukherjee's book does not fulfill those goals.