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Preface

SCIENTISTS AND THEIR LOVE–HATE RELATIONSHIP WITH CANCER

“When I want to read a novel, I write one.” Most writers, including myself, would readily subscribe to this honed maxim of British statesman Benjamin Disraeli. After all, writers are first and foremost readers, and popular science authors are no exception.

For some time now, I have wanted to read (and therefore write) a book that is informative and also entertaining for a wide range of readers about the latest discoveries in biology, but the colossal task of what I wanted to do gave me pause. Where do you even start a project like that? Where should I focus? How could I draw connections between so many different, diverging facts into a single thread? And, finally, how could I convince non-biologist readers to dip their toes into one of the most interesting, complex areas of modern science, despite all of the inevitable difficulties for a layperson? I had no answers myself, and so I kept putting off actually writing the book.

As often happens, the question eventually answered itself. In 2014, I was offered a position at the Curie Institute, one of the world’s leading molecular oncology research centers. Previously, I had never been particularly interested in cancer, and I only had a rudimentary

grasp of the mechanisms of malignant tumors, mostly thanks to a medical biochemistry course I had taken two decades earlier. This made it all the more fascinating to open the door to a whole new field of knowledge. The deeper I delved into the subject, the clearer it became that cancer is not simply a disease, or even a group of diseases. Rather, it is a phenomenon that is as complex as life itself. It is even studied as living matter, at every level — from molecular to population (epidemiological) and even cultural levels. (Contemporary writer Susan Sontag, who died of leukemia, wrote many vivid, merciless pages about cancer in her philosophical work *Illness as Metaphor*.¹) Cancer's impact on our lives goes far beyond the confines of medicine, making it not only a biological phenomenon, but also a cultural, social, and even political one. I became certain that cells' malignant transformation is much more than simply a disease after learning that cancer (like life!) is a phenomenon that has no definition.

Science begins with definitions: “An island is a piece of land surrounded by water,” “Byzantium was a state founded following the division and breakdown of the Roman Empire,” “Pushkin was a great Russian poet.” The subject of biology — the science of living things — is not, in fact, strictly defined. Do not think for a second that scientists and philosophers have not been trying to answer the question “What is life?” all along. They have tried time and again, but each attempt somehow fails to do life justice and ends up feeling incomplete. After all, living things are inherently beyond being reduced to neat, unambiguous concepts. With good reason, they say that while physics and chemistry are the “sciences of rules,” biology is the “science of exceptions.” At the end of the day, in order to avoid wasting time on eternal debate, biologists decided to settle for rather loosely defined “signs of life,” which are less a dogma than guidelines, and a very approximate boundary defining the “land of the living” from the material world.

¹ Susan Sontag, *Illness as Metaphor and AIDS and Its Metaphors*. 1st ed. (New York: Picador, 2001).

Lists of these signs of life may vary from one textbook to the next but, in general, most authors agree that living matter is capable of maintaining a constant composition and internal environment (homeostasis), exchanges matter and energy with its environment (metabolism), and has a complex structure. Living things are capable of growing and reproducing. They react to changes in their environment and are able to adapt to external conditions. Finally (and I am adding this sign of life on my own behalf), once it has appeared, life, as a phenomenon, is able to exist and develop, apparently almost indefinitely, though the “immortality” of living things is generally achieved at the expense of its individual units — cells, organisms, species, and entire groups of living things, such as in the extinction of the dinosaurs.

Most strikingly, the majority of these features can be found at any level of existence of living things — from cellular to planetary (the biosphere). The most basic unit of life, the cell, has a complex internal structure, and the functions of its organelles generally replicate those of the actual organs in a multicellular organism. The ecosystem is capable of sustaining homeostasis. Following a forest fire, the forest is able to “heal its wounds” and recover, just as a damaged organ is able to recover its function in time. Individuals are capable of responding to environmental changes, but so are entire groups of animals and plants. The evolution of flowering plants is as impressive as that of the dinosaurs.

All of these basic features of life — the ability to grow and reproduce, sensitivity to environmental signals, a cellular structure — are found in cancer as well, albeit in a highly distorted, deviant way. Cell division, which is a necessary condition for any multicellular organism, becomes a cause of disease and death. The body’s own ability to heal wounds begins to feed tumor growth. The way the body’s own cells work together results in the immune system’s inability to resist invasion. American physician and author Siddhartha Mukherjee writes about this feature of cancer in his book, *The Emperor of All Maladies*:

A Biography of Cancer:² “Confronting cancer is tantamount to confronting a parallel species, a species more adept at survival than ourselves.”

For many years, scientists and doctors have attempted to find a more concise description of the essence of this disease, but they have consistently failed to do so. Two prominent oncologists, Douglas Hanahan and Robert Weinberg, suggested that colleagues take their lead from general biology and avoid any specific definitions, simply limiting themselves to listing cancer’s “key features.” Initially, there were six such features, then ten, and by the time this book has been finished and published, that number may have changed once again, but the point is the principle, rather than a specific figure. Each of these features is included in this book.

According to Hanahan and Weinberg, malignant tumors share the following features:

- genomic instability (Chapter 2)
- maintenance of cell division (Chapter 3)
- avoidance of growth-limiting mechanisms (Chapter 3)
- cellular immortality (Chapter 4)
- disruption of apoptosis (regulated cell death) processes (Chapter 4)
- energy metabolism disorders (Chapter 5)
- chronic inflammation (Chapter 6)
- invasion and metastasis (Chapter 6)
- increased vascular growth (Chapter 6)
- immune control avoidance (Chapter 7).

Some (and perhaps even most) of the items on this list may initially seem like inarticulate scientific jargon, but we will address each of them in this book.

² Siddhartha Mukherjee, *Emperor of All Maladies: A Biography of Cancer*. 1st ed. (New York: Scribner, 2011).

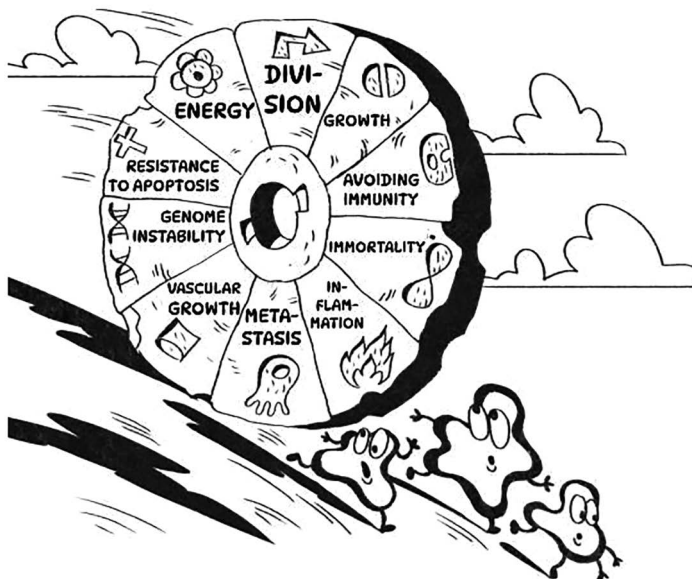


Figure 1. Not only do cancerous tumors differ from healthy tissues, but they are also very diverse among themselves. Within that diversity, however, they all share common key features that allow us to combine them into one disease group.

Why is it that cancer gets so much attention from researchers, whether they are physicians or biologists who study the most basic science, rather than focusing instead on scientific applications? When we observe the distortions inherent to malignant cells, scientists are better able to understand the molecular mechanisms in life's normal, healthy manifestations.

An early novel by brothers Arkady and Boris Strugatsky, *Noon: 22nd Century*, describes a humorous experiment by computer programmers working on a powerful supercomputer capable of creating material models of objects being studied. After teaching the computer to provide a normal description of a sheep, the mischievous scientists

feed it an image of a five-legged animal with no cerebellum, and the poor computer begins to spit out monstrosities, trying to solve an unsolvable problem. When the cause of the anomaly is revealed, the programmers' colleagues first wanted to beat them in retaliation. However, the team then realizes that, thanks to the prank, their research group now has access to the largest collection of data on machine errors and is delighted with the new material for research and analysis.

If we look at cancer cells from the perspective of enthusiastic scientific curiosity, rather than superstition and horror, they are essentially the same five-legged anomalies, the victims of multiple errors — whether genetic, signaling, or metabolic in nature. However, by looking into this “warped mirror,” we have a better understanding of life as it should be. Thanks to experiments on cancer cells, we have made numerous scientific discoveries, which I would like to describe in this book. You will see “Nobel Prize” mentioned at least ten times throughout the book, and not because I enthusiastically follow this prestigious scientific award, but because whether directly or indirectly, a significant portion of the past century's fundamental discoveries in medicine and biology have come from oncology research. As of the writing of this book, the 2018 Nobel Prize in Physiology or Medicine is the most recent example and was awarded for novel cancer immunotherapies based on immune response “checkpoints.” Just as it was awarded, I was, in fact, making my final edits on that very chapter. There are many strange coincidences in life...

In the end, I did not write a popular science book about molecular biology in general, but specifically about cancer. I did not write about disease and death, but about life, and all of its complexities, perfections, and fragility. I am a researcher rather than a physician, and therefore it would be inappropriate for me to speculate about human suffering simply to grab readers' attention. For this reason, tragic “clinical” examples will be few and far between in this book, and in their place I have included detailed (and I hope optimistic enough) descriptions of molecular biology's successes. They say that basic

science is “the satisfaction of personal curiosity at government expense.” But any money taken from the state is taken from society as a whole, and any honest researcher should be ready to explain to people why certain resources should be spent on scientific developments rather than building a new stadium, roads, or social housing projects. Despite what scientists say, the connection between “good science” and a “good standard of living” is not always apparent to the average person. Molecular oncology is a rare and rather impressive example of how fundamental scientific knowledge about the genome’s structure and cellular regulation systems has translated into drugs and diagnostic methods that have saved thousands of lives.

There are few diseases and few conditions of the human body (with the exception of perhaps pregnancy) that have been mythologized by our society as much as cancer. But when I began writing a book devoted to studying the most popular misconceptions in this field, my intention was not to act as a scientific prophet ridiculing and debunking others’ ignorance. Myths, after all, are not born in a vacuum; they are a symptom that society — a wide range of laypeople — considers something to be an important issue, while lacking access to quality scientific information. As a result, people tend to try to answer these questions and fill these gaps with whatever they can. As we will see later on, many common myths about cancer are grounded in real scientific theories that have become distorted and mischaracterized with each retelling. This book aims to try to separate the wheat from the chaff while giving lay readers a simplified but accurate and, most importantly, scientific understanding of the nature of cancer and modern methods for its diagnosis and treatment. Myths belong in mythology, not medicine.

COMMON MYTHS ABOUT CANCER

All of us have heard one or more of the following “authoritative” statements on this list at least once:

1. A cancer diagnosis is a death sentence. No matter how you treat it, there is only one outcome.
2. Progress in cancer treatment? Don’t be ridiculous. People were dying one hundred years ago, and they’re still dying the same way today.
3. Before, there weren’t such high cancer rates because people lived healthy lifestyles, in harmony with nature. And now, we have pollution, radiation, stress, cell phones... That’s what causes cancer. It is a disease of progress, and there’s nothing you can do about it.
4. Cancer is a hereditary disease, and if any of your close relatives have the disease, there’s nothing you can do.
5. Cancer is a contagious disease. Have you heard of oncoviruses?
6. Cancer doesn’t just happen. It’s your own fault you got sick! You avoided cigarettes and alcohol, you exercised regularly, and you got it anyway? I don’t believe it!
7. Cancer treatment is more dangerous than the disease itself. The tumor may still go away on its own, but chemo will definitely kill a person.
8. A cancerous tumor is capable of living forever, so cancer may hold the key to immortality.
9. A malignant tumor needs sugar; cancer is caused by having a sweet tooth!
10. Cancer “acidifies” the body, so on the contrary it must be “alkalized.” Baking soda is a simple and effective cure for cancer.
11. Sharks don’t get cancer, so shark cartilage is a proven means of preventing and treating the disease.
12. Metastases occur because the tumor has been “disturbed” by surgery or chemotherapy. If you leave it alone, it will not metastasize.
13. Cancer is an inflammation.

-
14. Folk remedies and immune boosters that strengthen the immune system can beat cancer. Have you heard of immunotherapy? That's what it is.
 15. Folk medicine is as effective as modern medicine, and may even be better!
 16. A universal cure for cancer was discovered long ago, but greedy pharmaceutical companies and corrupt doctors hide it from their patients in order to continue profiting from people's suffering.

We have counted sixteen such myths, but you may know more... In this book, we will take a close look at each of these common misconceptions and try to figure out what science really knows about each of the issues involved (the connection between heredity and cancer, the influence of lifestyle on the likelihood of suffering from the disease, etc.). We will take a frightening but fascinating journey through cancer as we try to understand the cellular mechanisms that turn healthy tissue into malignant tissue and learn how modern medicine is using the molecular features of cancer cells to develop new and effective means of diagnosing and treating the disease.

For readers who are interested, a full scientific bibliography can be found at the end of the book.

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