Chapter 1
Introduction: Collapse Is Not a Bug, It Is a Feature

"Esset aliquod inbecillitatis nostrae solacium rerumque nostrarum si tam tarde perirent cuncta quam fiunt: nunc incrementa lente exeunt, festinatur in damnum." Lucius Anneaus Seneca (4 BCE-65 CE), Epistolarum Moralium ad Lucilius, n. 91, 6

"It would be some consolation for the feebleness of our selves and our works if all things should perish as slowly as they come into being; but as it is, increases are of sluggish growth, but the way to ruin is rapid." Lucius Anneaus Seneca (4 BCE-65 CE), Letters to Lucilius, n. 91, 6 (translated by Richard Gummere)

This is a book dedicated to the phenomenon we call collapse and that we normally associate with catastrophes, disasters, failures, and all sorts of adverse effects. But this is not a catastrophistic book as there are many, nowadays, and it doesn't tell you of the unavoidable doom and gloom to come. Rather, it deals with the "science of collapse," explaining why and how collapses occur. If you know what collapses are, then they don't have to come as surprises, they are preventable. You can cope with them, reduce the damage they cause, and even exploit them for your advantage. In the universe, collapse is not a bug, it is a feature (Fig. 1.1).

So, this book explains what causes collapses, how they unfold, and what are their consequences. That may be useful in various ways: sometimes you want to avoid collapses; then you will develop "resilience" to avoid the kind of sudden changes that cause a lot of damage to people and things. But, sometimes, you may well *want* something old and obsolete to collapse, leaving space for something better. If the old never disappeared, there would never be anything new in the world!

Collapses turn out to be varied and ubiquitous phenomena, their causes are multiple, the way they unfold is different, they may be preventable or not, dangerous or not, disastrous or not. They seem to be a manifestation of the tendency of the universe to increase its entropy and to increase it as fast as possible, a principle known as "maximum entropy production" (MEP) [1, 2]. So, all collapses share some common characteristics. They are always collective phenomena, meaning that they can

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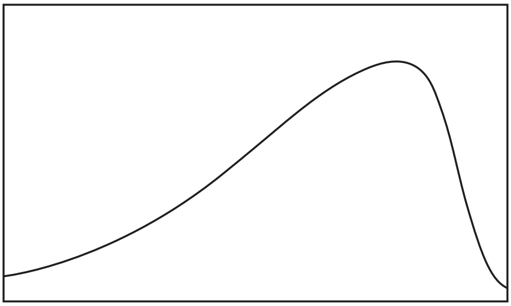

Fig. 1.1 The "Seneca Effect" as modeled using the method known as "system dynamics". This curve is very general and describes many kinds of physical phenomena that grow slowly and decline rapidly. The term "Seneca Effect" is inspired by the ancient Roman philosopher, Lucius Annaeus Seneca

only occur in those systems that we call "complex," networked systems formed of "nodes" connected to each other by means of "links". A collapse, then, is the rapid rearrangement of a large number of links, including their breakdown and disappearance. So, the things that collapse (everyday objects, towers, planes, ecosystems, companies, empires, or what have you) are always networks. Sometimes the nodes are atoms and the links are chemical bonds; that's the case with solid materials. Sometimes the nodes are physical links between elements of artificial structures, that is one of the subjects of study for engineers. And sometimes the nodes are human beings or social groups and the links are to be found on the Web or in person-to-person communication, or maybe in terms of monetary exchanges. This is the field of study of social sciences, economics, and history.

All these systems have many things in common, the main one is that they behave in a "non-linear" way. In other words, they don't react proportionally to the intensity of an external perturbation (called "forcing" in the jargon of the field). In a complex system, there is no simple relationship between cause and effect. Rather, a complex system may multiply the effect of the perturbation many times, as when you scratch a match against a rough surface. Or, the effect may be to dampen it in such a way to be scarcely affected by it, as when you drop a lighted match into a glass of water. This phenomenon of non-linearity of the reaction is often called "feedback", an all-important characteristic of complex systems. We speak of "enhancing," "amplifying," or "positive" feedback when the system amplifies an external perturbation. We speak of "damping," "stabilizing," or "negative" feedback when the system dampens the perturbation and mostly ignores it. Complex systems, it has been said, always kick back [3], sometimes they kick back with a vengeance and, at times, they just do what they damn well please.

One way to look at the tendency of complex systems to collapse is in terms of "tipping points." This concept indicates that collapse is not a smooth transition; it is a drastic change that takes the system from one state to another, going briefly through an unstable state. This concept was discussed, among others, by Malcolm Gladwell in his 2009 book, "The Tipping Point" [4]. In the science of complex systems, the concept of tipping points goes together with that of "attractor." (sometimes "strange attractor," a term made famous by the first movie of the "Jurassic

Park" series). An attractor is a set of parameters that the system has a certain propensity to reach. The tipping point is the opposite of the attractor in systemic terms: the attractor attracts the system; the tipping point repels it. A system in the condition called *homeostasis* tends to "dance" around an attractor, staying close to it but never reaching it. But, if the system moves far enough from the attractor, for instance because of an external perturbation, it may reach the tipping point and fall on the other side, toward a different attractor. In physics, this drastic change is called "phase transition" and it the basic mechanism of the phenomenon we call "collapse."

The capability of a system to maintain itself near an attractor and away from the tipping point, even in the presence of a strong perturbation, is what we call resilience, a term that may be applied in a wide variety of fields, from materials science to social systems. In studying resilience, one quickly discovers that the idea of sticking as close as possible to the attractor may not be so good. A rigid system may be the one that collapses all of a sudden and disastrously, as a piece of glassware that shatters. On this point, we may be reminded of a piece of wisdom that comes from another ancient philosopher, Lao Tsu in his *Tao Te Ching*, "*hard and rigid are associated with death. Soft and tender affirm greater life*." Indeed, the Seneca effect is most commonly the result of trying to resist change instead of embracing it. The more you resist change, the more change fights back and, eventually, it overcomes your resistance. Often, it does this suddenly. In the end, it is the result of the second principle of thermodynamics: entropy that does its job.

It is not by chance that philosophers often tell you that you should not be attached to the material things that are part of this difficult and impermanent world that continuously changes. It is good advice and, in the history of philosophy, the school called "Stoicism" was among the first to adopt this view and to try to put it into practice. Seneca was a member of this school and his thought is permeated with this view. The idea that "fortune is slow, but ruin is rapid," is part of the concept. So, when dealing with collapse, we may remember the advice that Epictetus, another master of the Stoic school, *Make the best use of what is in your power, and take the rest as it happens*.

There follows that you can avoid the Seneca cliff, or at least soften its impact, if you embrace change rather than fight it. It means that you should never try to force the system to do something that the system doesn't want to do. It should be obvious that you cannot fight entropy, but people often try. Jay Forrester, the person who created the field called "system dynamics," noted this tendency long ago when he said, "*everyone is trying very hard to push <the system> in the wrong direction.*" [5] (Forrester could have been a Stoic philosopher if he had lived in Roman times). So, politics seems to have abandoned all attempts to adapt to changes, rather moving into a brutal way of describing everything in terms of short slogans that promise an impossible return to the old times of prosperity (e.g. "making America great again"). In human relations, a lot of effort is spent in keeping together relationships that would be better let to fade away. In technology, tremendous efforts are made to develop ways to keep using old devices—such as private cars—that we probably would better abandon. We also stubbornly cling to our job, even though we may hate it, and even realize that we would do better moving to something different.

Entire civilizations have faded and disappeared because they refused to adapt to change and that's a destiny that may well await us as well, unless we learn to embrace change and abandon our obstinate addiction to fossil fuels that are ruining the planet on which we live. If we destroy what makes us live, then we are truly moving fast along the way that leads to ruin. Are we still in time to avoid disaster? Perhaps not completely, but we may at least soften the impact that that awaits us if we learn what to expect and how to adapt to the rapid changes ahead. And remember that you may be able to solve a problem but you can't solve a change. You can only adapt to changes.

The chapters of the book are all relatively independent from each other, and you can read them in sequence, or starting with the ones you find most interesting for you.

So, this book takes you in a journey through the multi-faceted science of complex systems. It starts with what I might call "the mother of all collapses," revisiting the fall of the Roman Empire, even though not the first ancient civilization that collapsed. Then, it goes into the details of the collapse of simple (but still complex) systems, describing the breakdown of everyday objects, from ships to planes, a field that can be understood in terms of the universal tendency of dissipating thermodynamic potentials at the maximum possible speed. Then, the book moves to the collapse of large structures, from pyramids to the twin towers of the World Trade Center in New York, on Sep 11, 2001. These events offer us a chance to examine the behavior of networks, a fundamental element of system science. It is a section that goes into some of the details about how thermodynamics applies to real world systems, but don't worry if you find that it is a bit heavy. You skip it and move to the following chapter dealing with other cases of systemic collapses: the financial system, famines, mineral depletion, resource overexploitation and, finally, the greatest possible collapse within the limits of our planet, the "death of Gaia," the extinction of the Earth's biosphere. The second part of the book examines how collapses can be managed. Can we avoid them? What is the role of "resilience" in managing complex systems? Isn't it better to let collapses occur, to rebuild something newer and better afterward? The conclusion deals, again, with the thought of Seneca and of his stoic contemporaries, whose wisdom may perhaps help us in our troubled times. Finally, the appendix gives you some details of one of the most common methods to study complex systems, the field called "system dynamics."

Nothing in this book is supposed to be the last word on anything, but rather a starting point in the journey to the knowledge of the science of complex systems. This subject is so large that no single book, and no single person, could reasonably hope to cover the whole field in detail. So, I made no attempt to put together an in-depth treatise on system science (for this, you would do well in reading the book *Principles of System Science*, written by George Mobus and Michael Kalton [6]). Yet, I tried to emphasize how system science is a fascinating way to look at the world around us. This is how the field started with the first studies of ecosystems, such as with Alexander Von Humboldt and his *Kosmos*, published in 1845 [7], and, more than all, with Darwin great synthesis of *On the Origin of Species* (1859). Neither Humboldt nor Darwin used equations and, studying complex systems, you quickly discover that there is no such a thing as an equation that can be solved in the same way as you can do for the motion of a body in a gravitational field. That doesn't mean that complex systems can't be understood. There is no such a thing as an “equation of the cat,” but cats exist and you can still predict—with a fair degree of certainty—that a cat will behave like a cat, running after birds in the garden and loving kitty treats. So, you can study and understand complex systems even with no other tools than common sense, knowledge, and perseverance.

I would like to conclude this introduction by apologizing for the many things. I was forced to leave out for lack of space and of personal knowledge, and also for the unavoidable inexactitudes and mistakes when one tries to tackle a wide, interdisciplinary field. But I hope that what you’ll find inside this book will be sufficient to convey at least some of the interest and of the fascination I experienced while studying these subjects.