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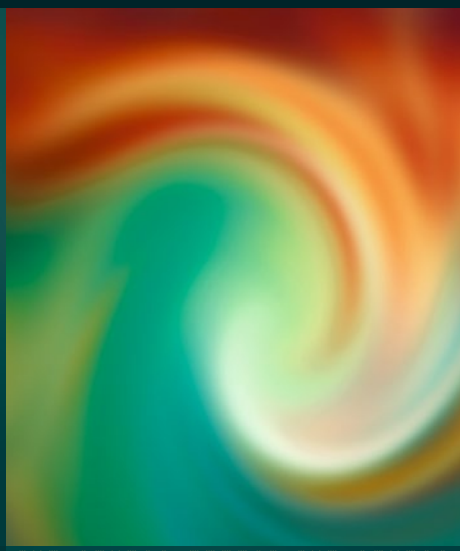

Ugo Bardi

THE SENECA EFFECT

Why Growth is Slow but Collapse is Rapid

A Report to the Club of Rome

THE CLUB OF ROME

Springer

THE FRONTIERS COLLECTION

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The books in this collection are devoted to challenging and open problems at the forefront of modern science, including related philosophical debates. In contrast to typical research monographs, however, they strive to present their topics in a manner accessible also to scientifically literate non-specialists wishing to gain insight into the deeper implications and fascinating questions involved. Taken as a whole, the series reflects the need for a fundamental and interdisciplinary approach to modern science. Furthermore, it is intended to encourage active scientists in all areas to ponder over important and perhaps controversial issues beyond their own speciality. Extending from quantum physics and relativity to entropy, consciousness and complex systems—the Frontiers Collection will inspire readers to push back the frontiers of their own knowledge.

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Why Growth is Slow but Collapse is Rapid

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This book is dedicated to my daughter, Donata, who hopes that the models will turn out to be wrong.

A Report to the Club of Rome

Formed in 1968, the Club of Rome comprises around 100 notable scientists, economists, businessmen, high-level civil servants, and former heads of state from around the world. Its mission is to promote understanding of the long-term challenges facing humanity and to propose holistic solutions through scientific analysis, communication, and advocacy. Part of the Club's work involves the accreditation of a limited number of peer-reviewed reports, the most famous of which is *The Limits to Growth*, which was published in 1972. To be considered as a Report to the Club of Rome, a publication must be innovative, present new approaches, and provide intellectual progress, as compared to other publications on the same topic. It must be based on sound scientific analysis and have a theme that fits the priorities of the Club. *The Seneca Effect* by Ugo Bardi is the latest such report.

Advance Praise for *The Seneca Effect*

"Why do human societies collapse? With today's environmental, social, and political challenges it is a question that is more than academic. What can we learn from history? How can we avoid the pitfalls? In this fascinating book Ugo Bardi provides many of the answers. Packed full of insights and ideas which will leave the reader satisfied, curious, and stimulated, we are delighted that this book is an official *Report to the Club of Rome.*"

Graeme Maxton, Secretary General of the Club of Rome

"Stock markets take a long time to rise, then crash quickly. Poker players go 'on tilt,' after being conservative for hours. Economies and ecosystems enter phase shifts where declines occur much faster than growth. Polymath writer and scientist Ugo Bardi expertly describes this widespread 'Seneca' phenomenon and its relevance to our socioeconomic system in coming decades."

Nate Hagens, Professor of "Reality 101" at the University of Minnesota, Co-founder Bottleneck Foundation

"*The Seneca Effect* is probably the most important contribution to our understanding of societal collapse since Joseph Tainter's 1988 masterpiece, *The Collapse of Complex Societies*. Since we live in a society that is just in the process of rounding the curve from growth to decline, this is information that should be of keen interest to every intelligent person."

Richard Heinberg, Senior Fellow, Post Carbon Institute, Author, *The End of Growth*

"In this book, Bardi explains the intricate mechanisms of collapse with the captivating eloquence of a seasoned storyteller, the pluralism of a polymath, and the incisive precision of a scientist. Despite its ubiquity, collapse is not an inevitable law of nature. Bardi offers a call to policy makers, scientists, and citizens of the world to reinstate the dormant resilience mechanisms in our societies."

Sgouris Sgouridis, Masdar Institute of Science and Technology, University in Abu Dhabi, United Arab Emirates

Foreword

In the volume you are about to read, Professor Ugo Bardi takes us cheerfully into a dark cave of the science and engineering behind collapse. Like a miner turning on his headlamp and descending into the pit, Bardi has conquered whatever misgivings might come with peering at a highly risky task, and he makes the best of a grim situation. Bardi reminds us early and often that collapse is not a failure, it is a feature.

We are on a discovery of catastrophe, but the journey is neither gloomy nor hopeless—quite the opposite. As I pondered my own reaction to the "Seneca effect," it came to me that the teachings of Zen and of European existentialism might be helpful. The existential moment of enlightenment, satori to the Zen Buddhists, arrives when we awaken to our own true nature. This awakening comes when we confront our own mortality and accept our impermanence as beings on earth. Each of us exists with some circumstances of birth, for example, our socioeconomic status and our childhood—what existential thinkers refer to as our "thrownness" in the world. Satori means that we accept these conditions but, crucially, that we realize that the meaning of life on earth comes through the choices we are able to make. We have the ability to choose how we deal with our circumstances, and we have the responsibility that comes with the consequences of these choices. We come to see that as sentient beings, we can choose to be miserable or to be happy, within this knowledge of our impermanence.

Armed with the strength and peace of Satori, we can understand how each of us forms part of a complex ecosystem. Native Americans and most other indigenous peoples understood the circular nature of life in a natural system that is in a state of homeostasis. We make choices every day about our use of natural resources, about how we treat others—how we act in the world during our time on it. Ugo Bardi, with a chemist's pragmatism, informs us that our way of life, perhaps even humanity itself, is rushing toward the edge of a cliff. How are we to react to this grim news? Some of us consider ourselves sovereign in our lifetimes and take the divine right of kings as our creed. This would hold that it is our birthright to make the most of what we have while we are on this earth. As for future generations, they will have their turn, and they will find ways to enjoy their lives as best they can and manage the

world as they find it. The fruits of our discoveries are for us to enjoy. Our children, so this approach goes, will figure out their own solutions to the problems they face.

Others may believe in intergenerational equity, that we have an obligation to preserve the planet and our society at least in its current level of resources. This humanistic approach holds that we are visitors on this planet, that we have a moral obligation to future generations to leave the world in a condition that enables them to live as happy a life as is possible.

Most of us, I suspect, don't think much about either option and just do what we can to make ends meet and raise our children. Whatever the case may be, Bardi reminds us that we are hurtling through space on a planet that responds, as a complex system, to the laws of nature. Death, collapse, decay, entropy, decline, and scarcity—these are gloomy realms to roam. Like Kierkegaard's unflinching journey through existential despair, Ugo confronts these startling facts of life on earth as a complex system and challenges us to incorporate them more actively into our narrative about being alive. Collapse is a feature of the universe; he repeats often: we have to learn not only how to live with it but also how to exploit it for a better way of traveling on the vehicle we call earth.

As I write this, our world faces a resurgence of nationalism, anti-globalization, xenophobia, and populism not seen in nearly a century. The "Seneca effect" that Bardi describes here may be taking place now with the post-World War II order. While this chapter of history remains to be written, we can take heart from Ugo Bardi quoting the statement that "nothing is impossible if it is inevitable." The invitation Bardi extends is one that we must ponder deeply. Have we reached a tipping point, whereby the fruits of globalism have become, as in the tragedy of the commons, so familiar as to become an object of contempt? The downsides of globalization—migration and economic dislocations as capital and employment seek the highest returns and sluggish, consensus-based decision-making—are now in high relief. Investors, who are paid to make good decisions about allocating capital, should pay attention to Bardi's themes. The societal shocks that Bardi describes—events such as the sack of Rome, the arrival of the Conquistadores in the Americas, the use of the atomic bomb in Hiroshima and Nagasaki, and the terrorist attack of 9/11—are profoundly damaging and can cause lasting reorganizations in complex systems. In light of current political trends, we must ask how a more tribalistic, fragmented world deals with pollution, natural resource depletion, disease, and ethnic tension? What are we as individuals to make of this? How does the existential dialectic between impermanence and choice inform our paths?

Bardi takes the scientist's rational, objective, and nonjudgmental tools and applies them to an emotive subject: the almost assured collapse of our way of life as it has been the norm during the past decades. This seems appropriate: we place our own and our children's lives in the hands of designers of automobiles, airplanes, and roller coasters that we trust will not catastrophically fail. When it comes to meta-systems such as this vehicle we call Earth, why not conceptualize its safety through a similar lens? Thanks to scientists, we have an understanding of the what and why behind global warming. We have much less clarity around the systemic risk that exists and is building in our political and economic ecosystems. Bardi introduces us

to concepts from materials engineering, game theory, chaos theory, and complexity theory that should serve as a wake-up call to the consequences of choices that we, as free people, get to make every day.

John Rogers is an investment professional, former CEO and president of the CFA Institute and global CEO of INVESCO's institutional business unit. Board director of 'Preventable Surprises.' He is based in Charlottesville, Virginia area, personally and professionally interested in promoting sustainability and investing.

Charlottesville, VA, USA John Rogers
December, 2016

Contents

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

2 The Mother of All Collapses: The Fall of Rome 7
2.1 Seneca and His Times 7
2.2 Whence Empires? 10
2.2.1 The Great Fall 14

3 Of Collapses Large and Small 23
3.1 The Breakdown of Everyday Things 23
3.1.1 Why Ships Don't Have Square Windows 23
3.1.2 Why Balloons Pop 30
3.2 Avalanches 34
3.2.1 The Fall of the Great Towers 34
3.2.2 Networks 46
3.3 Financial Avalanches 51
3.3.1 Babylon Revisited 52
3.4 Famines 67
3.4.1 Malthus Was an Optimist 67
3.5 Depletion 83
3.5.1 The Shortest-Lived Empire in History 83
3.5.2 Tiffany's Fallacy 89
3.6 Overshoot 98
3.6.1 What's Good for the Bee, Is Good for the Hive 103
3.6.2 The Fall of the Galactic Empire 112
3.7 Gaia's Death: The Collapse of the Earth's Ecosystem 121
3.7.1 What Killed the Dinosaurs? 121

4 Managing Collapse 139
4.1 Avoiding Collapse 139
4.1.1 Fighting Overexploitation 139
4.1.2 Resilience 144
4.1.3 Returning from Collapse 148
4.1.4 Avoiding Financial Collapses 152
4.2 Exploiting Collapse 157
4.2.1 Hostile Collapses 157
4.2.2 Creative Collapsing 161
4.2.3 Pulling the Levers in the Right Direction 164

5 Conclusion 169

Appendix: Mind-Sized World Models 171

Figure Copyright Notes 183

References 185

Index 205

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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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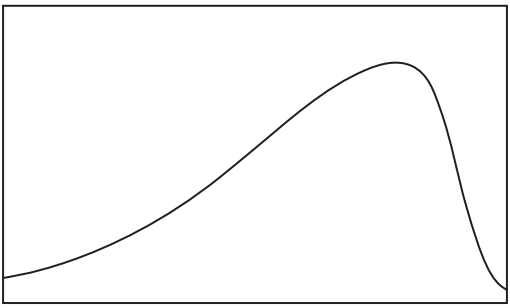

Fig. 1.1 The "Seneca Effect" as modeled using the method known as "system dynamics". This curve is very general and describes many kinds of physical phenomena that grow slowly and decline rapidly. The term "Seneca Effect" is inspired by the ancient Roman philosopher, Lucius Annaeus Seneca

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.

Chapter 2
The Mother of All Collapses: The Fall of Rome

> *Instead of inquiring why the Roman empire was destroyed, we should rather be surprised that it had subsisted so long. The victorious legions, who, in distant wars, acquired the vices of strangers and mercenaries, first oppressed the freedom of the republic, and afterwards violated the majesty of the purple. The emperors, anxious for their personal safety and the public peace, were reduced to the base expedient of corrupting the discipline which rendered them alike formidable to their sovereign and to the enemy; the vigour of the military government was relaxed, and finally dissolved, by the partial institutions of Constantine; and the Roman world was overwhelmed by a deluge of Barbarians.*
>
> *— Edward Gibbon. The Decline and Fall of the Roman Empire, "General Observations on the Fall of the Roman Empire in the West", Chapter 38*

Considering that this book takes its title from a statement by the ancient Roman philosopher Seneca, it seems proper that it should start with a discussion of the fall of the Roman Empire, something that we could define as "the mother of all collapses." Here, I am not pretending to say anything definitive about such a complex issue, but just to see how it can be approached in systemic terms, that is taking into account the internal feedbacks that control the operation of the system.

2.1 Seneca and His Times

Lucius Annaeus Seneca was, by any standard, a successful man (Fig. 2.1). Rich and influential, he even was the tutor, and later the adviser, of Emperor Nero. It was a slow growth of fortune that made Seneca one of the richest men of his time. But all this success rapidly came to nothing. First, Seneca fell out of favor with Nero and

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Fig. 2.1 Lucius Annaeus Seneca, 4 BCE-65 AD. Contemporary bust, presently at the Antikensammlung Berlin (Berlin antiquities collection)

was forced to leave politics and retire to private life. Not much later, Seneca was accused of being part of a conspiracy aiming at killing Nero and installing Seneca himself as emperor. We cannot say if Seneca had ever planned something like that, but the suspicion was enough for Emperor Nero to order him to commit suicide. Seneca complied by slicing his wrists' veins open, as was the custom of that time. It was a rapid end after a long life of successes and we may see this story as one of the best illustrations of something that Seneca had written to his friend Lucilius, that "ruin is rapid." This is what I call the "Seneca Effect" in this book.

Seneca's rapid ruin mirrored the ruin of Rome. At the time of Seneca, the first century of our era, the Roman Empire was still a powerful and majestic structure. But it had started developing the first cracks prefiguring the future collapse. The first ominous hint of the bad times to come may have been the battle of Teutoburg, in 9 CE, when three Roman legions were ambushed and cut to pieces by a coalition of Germanic tribes. It was a terrible shock for the Romans, comparable to the shock that modern Westerners felt with the attack against the World Trade Center in New York on September 11, 2001. For the ancient Romans, being defeated by a band of hairy and bad-smelling barbarians was against all the rules of the universe; it just wasn't possible. But it was what had happened and Emperor Augustus, a consummate politician, exploited the defeat with a masterpiece of propaganda. He spread the rumor that he was so shocked by the defeat that he would wander at night in his palace, mumbling to himself "*Varus, Varus, bring back my legions.*" That sealed the role of Emperors as defenders of the Romans for the rest of the lifetime of the Roman Empire; that was to span almost half a millennium.

The decline of Rome was slow enough that some modern historians say that it shouldn't be described as a collapse but as a cultural transformation. But, still, the decline was real, far more than just a change in the political structure of the Empire