Natural Hazards and Disaster

Class 1: Introduction to the Course and Basic Concepts

- Practicalities
- Course Contents
- The Earth’s Life-Support System and Sustainability
- Hazards, Vulnerabilities, and Disasters
- Concept of Risk
- Thresholds
- Resilience
- Disasters and Sustainability

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Fall 2018: Natural Hazards and Disasters

Natural Hazards and Disasters

Courses:	OEAS 250N (CRN 17463); class 3 credits; and OEAS 250N (CRN 17470), lab 1 Credit
Course title:	Natural Hazards and Disasters
Instructor:	Dr. Hans-Peter Plag
Term:	Fall 2018, August 28 - December 12, 2018
Time:	Tuesdays, 4:20 PM - 7:00 PM (class)
	Tuesdays, 7:10 PM - 8:00 PM (lab)
Location:	SRC 1000
Office Hours:	On request.

Course description

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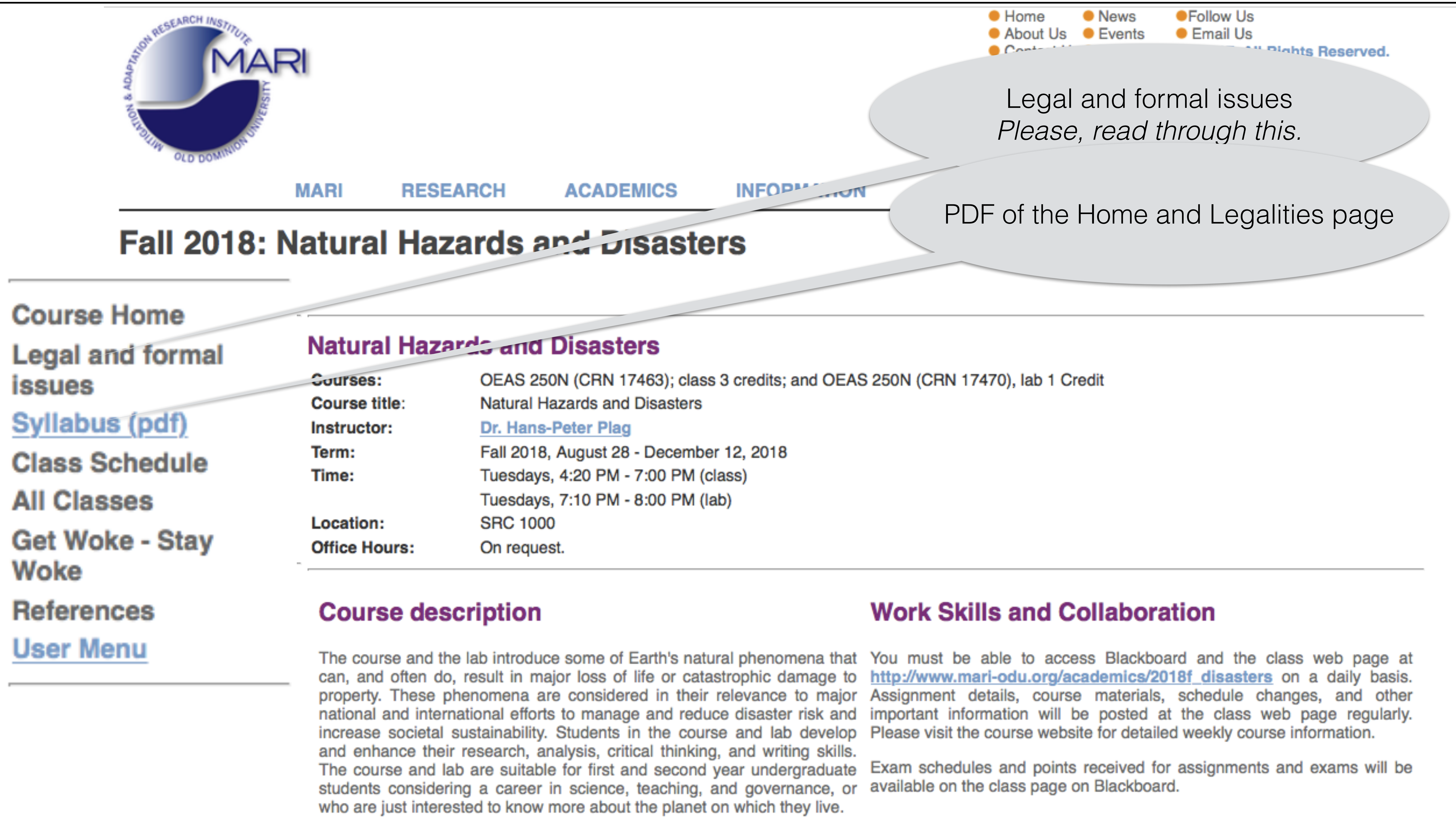

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Class Schedule
Very important, main information source

All class and lab descriptions on one page

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Will be used in every class/lab

All (plus other) literature

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For some of the lab exercises, basic knowledge of Excel or a similar software will be necessary. If you have no such knowledge, you will still be able to carry out the exercises if you collaborate with a student who has the knowledge. For some exercises, it will be easier to use a tool like powerpoint or a graphical software. For the study case papers, you will need to use a text processing software such as Word or a similar program.

From time to time you will be asked to research and bring specific content (e.g., published facts, evidence, sources) to the class or lab. Do not assume that this content will be provided to you if you fail to complete the assignment.

Collaboration is expressly permitted, encouraged, and may even be required for team projects, but must follow these guidelines:

- You must actively participate in the collaborative project;
- You must write your own individual report on any team project work;
- All team members' names must be included in any written project work;
- You must understand the material and be able to answer questions on it.

Reading Material

Access to digital text and reading lists will be supplied to students at no cost. All necessary information for the course, including the reading list and assignments are posted at http://www.mari-odu.org/academics/2018f_disasters. Students must bring a laptop, mobile phone, tablet, or other device for internet access to every class.

You are responsible for reading and complying with all information posted.

Grading

The course combines lectures with lab exercises and project work. There are weekly reading assignments, which correspond to the class contents and the lab exercises. In the lab, 10 sets of questions will be discussed and written answers to the questions are due after the lab. Three case study papers will be required and there will be a midterm and final exam.

The class and lab will be graded with one grade for CNR 17463. The course will be graded on an A to F scale. You will be graded on a standard scale:
100.0-93.0% = A; 92.9-90.0% = A-
89.9-87.0% = B+; 86.9-83.0% = B; 82.9-80.0% = B-
79.9-77.0% = C+; 76.9-73.0% = C; 72.9-70.0% = C-
69.9-67.0% = D+; 66.9-63.0% = D; 62.9-60.0% = D-
0-59.9% = F.

The overall grad for the class and lab will be composed of individual grades using:
Class and lab participation 5%
Written Case Study reports (3 of them) 45%
Question sets (10 of them) 25%
Mid term exam 10%
Final exam 15%.

University regulations prohibit communicating test results via email or by phone. If you wish to talk about your grade, please make an appointment. All scores will be placed on BlackBoard as soon as possible after they are graded.

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Location:	SRC 1000
Office Hours:	On request.

Class Schedule

Note that all deliverables/assignments have to be submitted by email to hpplag@mari-odu.org.

August 2018

Monday	Tuesday	Wednesday	Thursday	Friday
Jul 30	Jul 31	Aug 1	Aug 2	
Aug 6	Aug 7	Aug 8	Aug 9	
Aug 13	Aug 14	Aug 15		
	Aug 21	Aug 22	Aug 23	Aug 24
	Aug 28 Class 1: Introduction to the Class & Basic Concepts Slides for class 1 Lab 1: Risk concept Slides for lab 1 Question Set 1	Aug 29	Aug 30	

Monday	Tuesday	Wednesday	Thursday	Friday
	Sep 4 Class 2: Observing hazards and disaster Slides for class 2 Lab 2: Measuring small changes, getting data, assessing risks and disaster Question Set 2	Sep 5	Sep 6	Sep 7 Question Set 2 due 6:00 PM
Sep 10	Sep 11	Sep 12	Sep 13	Sep 14

Aug 28
Class 1: Introduction to the Class & Basic Concepts
Slides for class 1
Lab 1: Risk concept
Slides for lab 1
Question Set 1

Information about class and lab for that day

Due date and time of assignments

Link to class/lab page gives access to detailed description

Slides are normally available before the class/lab

Practicalities

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Natural Hazards and Disasters

Courses:	OEAS 250N (CRN 17463); class 3 credits; and OEAS 250N (CRN 17470), lab 1 Credit
Course title:	Natural Hazards and Disasters
Instructor:	Dr. Hans-Peter Plag
Term:	Fall 2018, August 28 - December 12, 2018
Time:	Tuesdays, 4:20 PM - 7:00 PM (class)
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Aug 24

Tuesday	Wednesday	Thursday
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Sep 10 | Sep 11 | Sep 12 | Sep 13 | Sep 14

Information about class and lab for that day

Due date and time of assignments

Link to class/lab page gives access to detailed description

Slides are normally available before the class/lab

Question sets and case study descriptions are available well ahead of class/lab

Aug 28
Class 1: Introduction to the Class & Basic Concepts
Slides for class 1
Lab 1: Risk concept
Slides for lab 1
Question Set 1

Practicalities

Fall 2018: Natural Hazards and Disasters

Natural Hazards and Disasters

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Class 1: Introduction to the Course and Basic Concepts

Class 1 Slides

CONTENTS

PRACTICALITIES

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Fall 2018: Natural Hazards and Disasters

Class Slides, should be available prior to the class

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Class 1: Introduction to the Course and Basic Concepts

Class 1 Slides

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Class 1: Introduction to the Course and Basic Concepts

Class 1 Slides

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Brief summary of the class

CONTENTS

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Disasters and Sustainability

Disasters affecting human communities constitute often severe disruptions and can reduce the sustainability of the community or render the community totally unsustainable. Therefore, our efforts to make progress towards sustainable development have to address disaster risk.

There are two main programs at global level that focus on DRG. One of them is the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015). This framework was adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, on March 18, 2015. It aims to achieve a substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries over the next 15 years. It outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks: (i) Understanding disaster risk; (ii) Strengthening disaster risk governance to manage disaster risk; (iii) Investing in disaster reduction for resilience and; (iv) Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

The other program at global level is the United Nations 2030 Agenda for Sustainable Development (United Nations, 2015) with the seventeen Sustainable Development Goals (SDGs). An important impediment to sustainability are disasters disrupting communities. The SDG 11 focusses on "Sustainable Cities and Communities" and aims to "Make cities and human settlements inclusive, safe, resilient and sustainable." Each SDG comes with a number of targets, and several of the SDG 11 Targets directly relate to disaster risk:

- Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
- Target 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
- Target 11.c: Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Class Reading List

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockström, J., Öhman, M. C., Shyamsundar, P., Steffen, W., Glaser, G., Kanie, N., Noble, I., 2013. Sustainable development goals for people and planet. *Nature*, **495**, 305-307.

Pearce, F., 2010. From ocean to ozone: Earth's nine life-support systems. *New Scientist*, Feature, 24 February 2010. html.

Simonsen, S. H., Biggs, R., Schlüter, M., Schoon, M., Bohensky, E., Cundill, G., Dakos, V., Daw, T., Kotschy, K., Leitch, A., Quinlan, A., Peterson, G., Moberg, F., 2015. Applying resilience thinking: Seven principles for building resilience in social-ecological systems. Stockholm Resilience Center, University of Stockholm, Sweden. pdf.

United Nation, 2015. Transforming our World: The 2030 Agenda for Sustainable Development, United Nations, A/RES/70/1. pdf, html.

United Nations, 2015. Sendai Framework for Disaster Risk Reduction 2015 — 2030. United Nations Office for Disaster Risk Reduction (UNISDR), UNISDR/GE/2015 - ICLUX EN5000 1st edition. pdf, local pdf.

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Class Reading List

Reading list for the class; longer than expected to read; make choices.

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Natural Hazards and Disaster

Class 1: Introduction to the Course and Basic Concepts

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Course Contents

Earth's Life-Support System

Humanity is embedded in, and interacts with, the Earth's life-support system (ELSS). The ELSS provides the basis for the welfare of all human and non-human communities, and these communities are adapted to prevailing conditions.

Course Contents

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Natural or anthropogenic?

Although the class is titled "Natural hazards and disasters," it needs to be emphasized that the distinction between natural and anthropogenic hazards is somewhat arbitrary. It would work if humans were in a spaceship and Earth was free of humans. The fact that humanity is an integral part of the ELSS and is modifying the ELSS at a very significant level leads to many hazards that seem to be "natural" but are actually to some extent caused or amplified by humans.

Course Contents

Hazard definition

In the class, we define a hazard as a change of the system state that can lead to a reduction of the system's capability to function. A hazard can be a short event (e.g., an earthquake), a longer process (e.g., extinction), or a slow trend (e.g., sea level rise).

Course Contents

Different origins for hazards

Course Contents

Different origins for hazards

We distinguish:

- extraterrestrial hazards: asteroids, bolides, radiation events, and solar storms
- geo(logical) hazards: those that arise mainly from processes in the solid earth;
- hydro-meteorological hazards: those that are associated with processes in the coupled hydrosphere-atmosphere system;
- biological hazards: pandemics, rodents, insects, algal-blooms, extinction;
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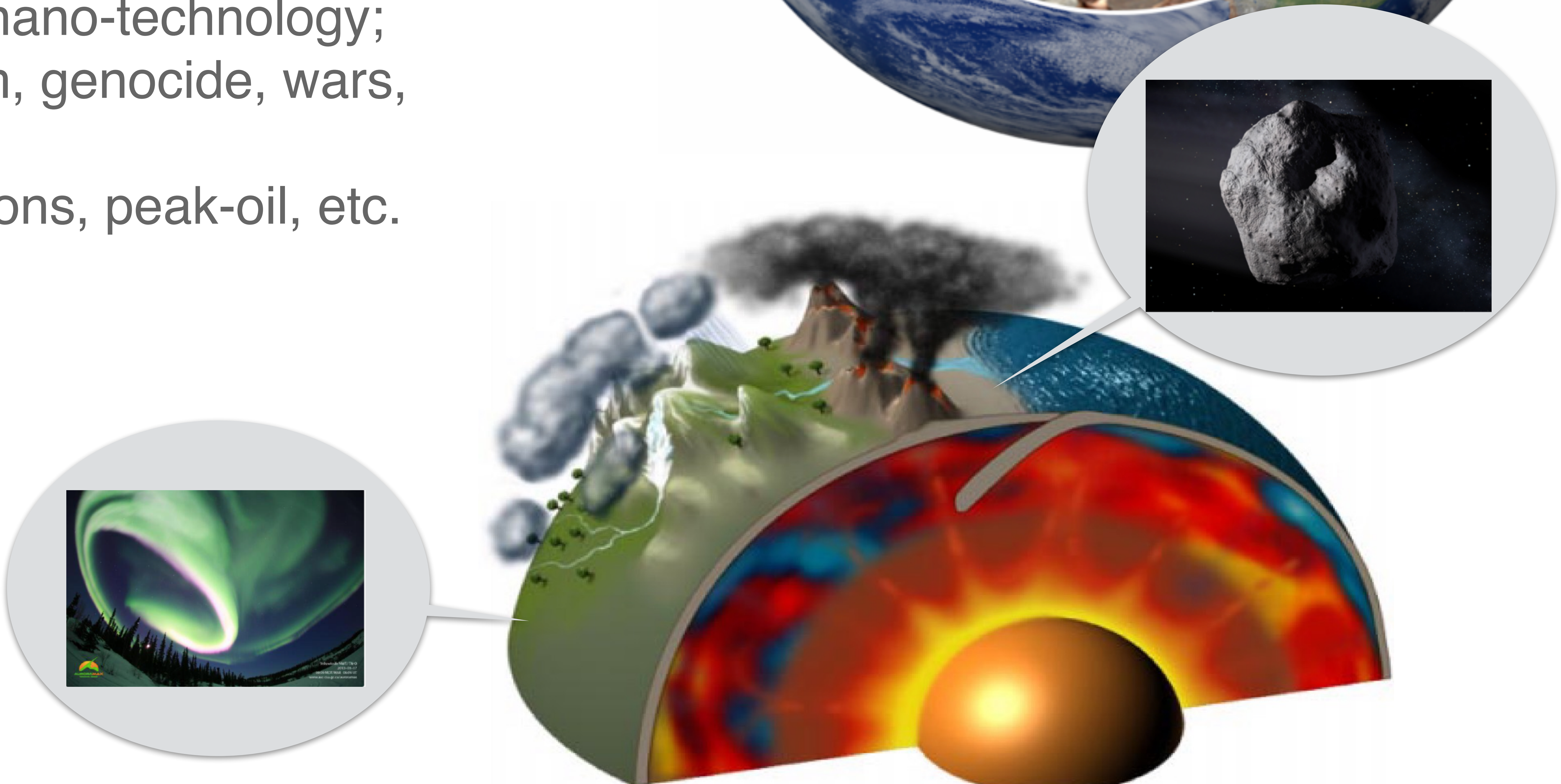

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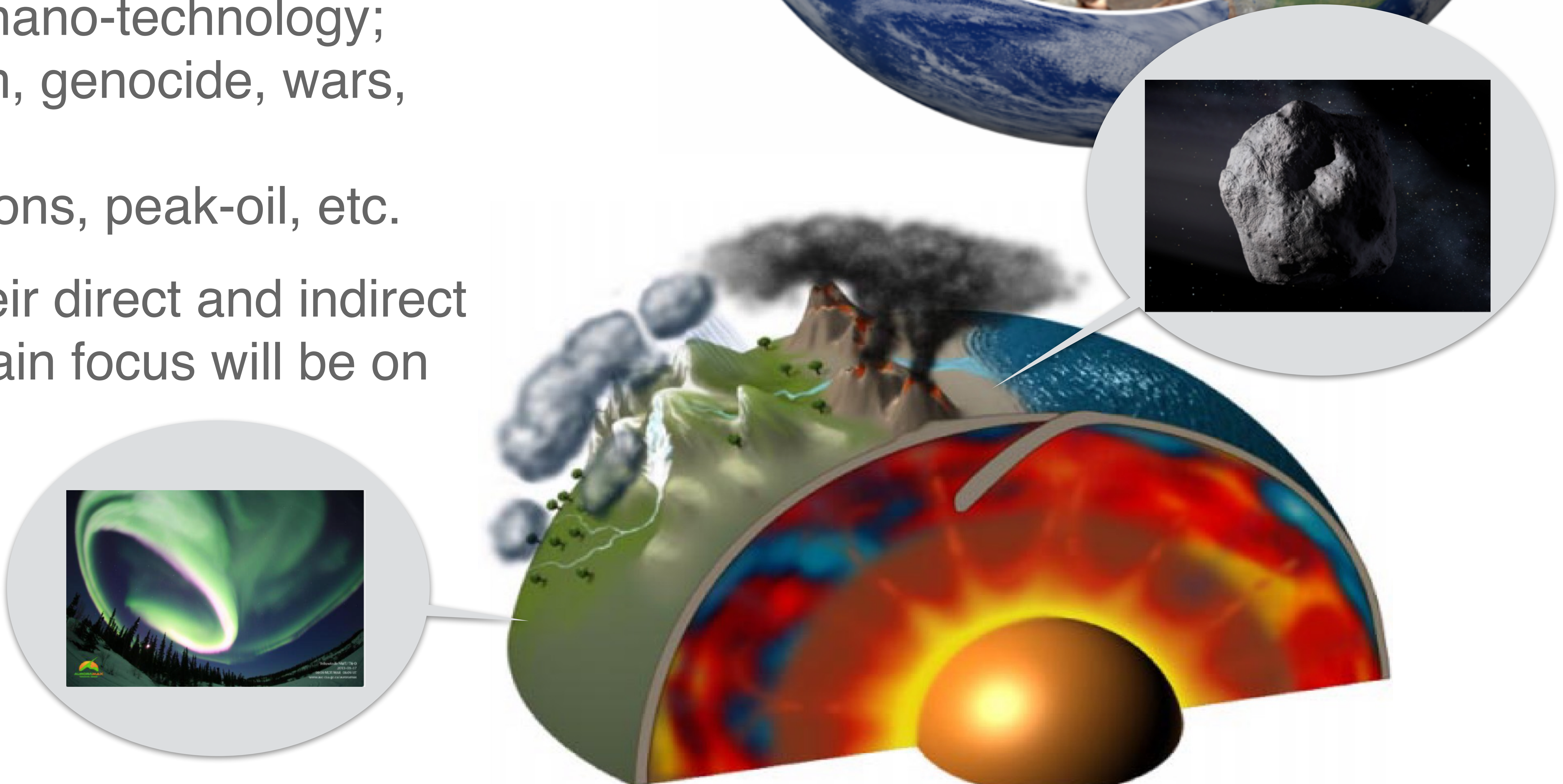
The class will introduce these hazards and discuss their direct and indirect relevance for human and non-human communities. Main focus will be on hazards with pre-dominantly non-human origin.



Concept of Risk

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Humans can modify non-human hazards

The boundary between hazards of non-human and human origin is blurred. Technological hazards can be triggered by non-technological hazards. Human activity can trigger hazards or change the spectrum of hazards in terms of frequency and magnitude. Human activity can also lead to the ELSS crossing thresholds and entering new states with significantly different characteristics and mal-adaptation. The interdependency of human and non-human hazards will be discussed in detail.

Course Contents

Hazards and disasters are linked through processes

Hazards and disasters are linked by processes in the exposed community and its environment that are triggered by a hazardous event. These processes depend on how the community is organized and developed, and the same hazardous event can lead to a wide range of disasters depending on the exposed community's preparedness and adaptation. Understanding the processes that link hazards and disasters is a prerequisite for DRG. The class will analyze these processes based on case studies.

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Human decisions are informed by risk assessments

In the interaction with the ELSS, humans have to make choices about where to settle, how to develop communities and the built environment, how to meet the needs of human communities, and how to prepare for hazardous events. Many of these choices benefit from a risk-based decision-making. For many of the non-human hazards, we cannot change very much the PDF of the hazard, but we can impact vulnerability and exposure of human communities.

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Disaster Risk Governance

The concept of DRG captures this. Risk associated with a specific hazard is defined as the product of hazard probability, vulnerability and value of the assets exposed to the hazard. The class will introduce the concept of DRG and apply to case studies.

Course Contents

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Disaster Risk Assessment

Disaster risk assessments are an important tool to guide community actions to reduce or govern the risk. However, public and governmental support for DRG depends on risk awareness, which is determined by individual, community, country and cultural biases. In modern societies, the media play an important role for the development of, as well as the biases in, risk awareness. The class will review a number of risk assessments and relate them to risk awareness. The role of the media in shaping risk awareness will be analyzed.

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What is sustainability?

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Sustainability is an emerging characteristic of a dynamic system; it is not built into a system by design.

- *the ability to be maintained and function continuously*
- *maintaining relationships within the system and to the system’s environment*
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The Earth's Life-Support System and Sustainability

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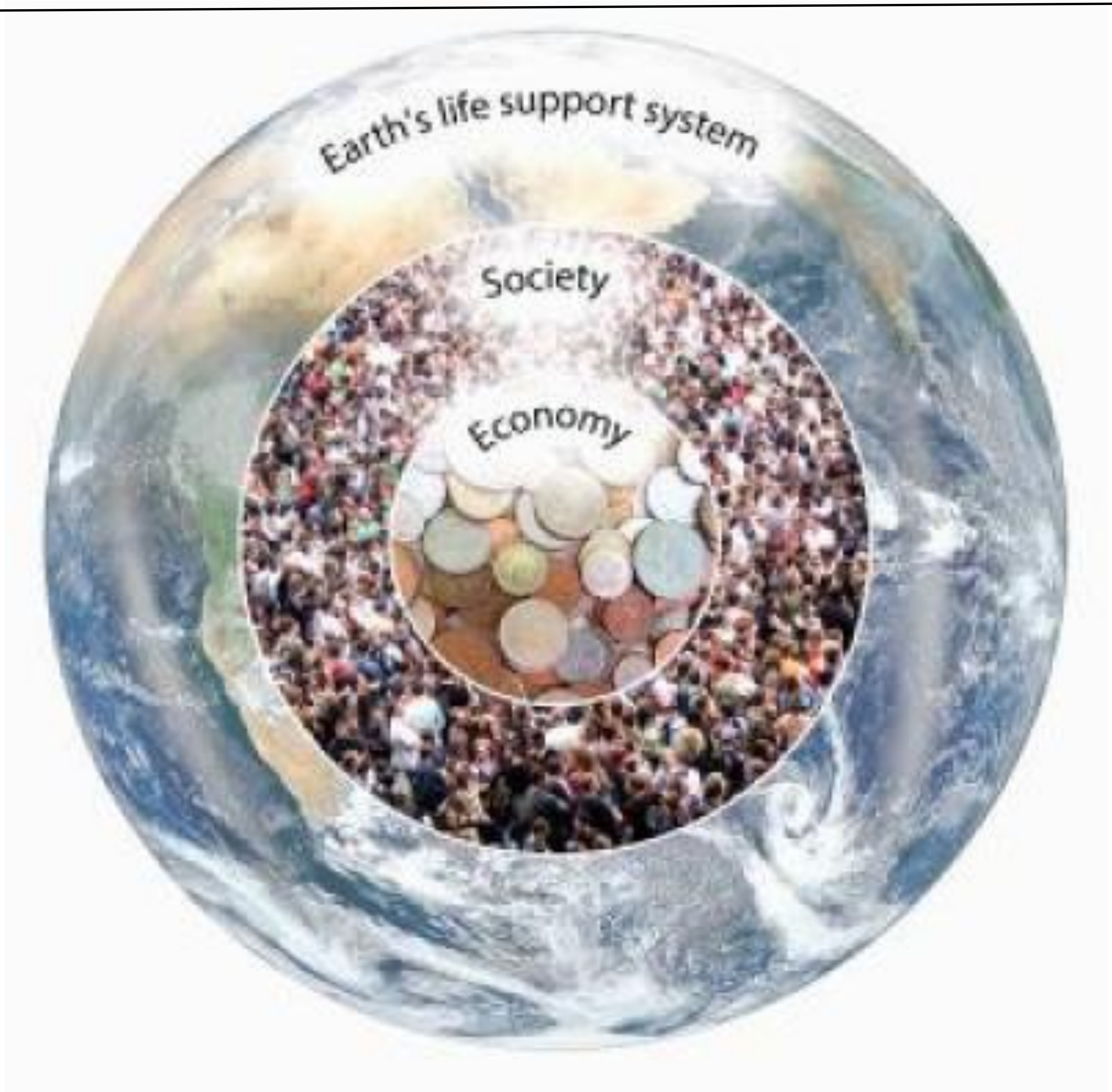
Sustainability is a neutral term, neither positive nor negative.
For human communities embedded in a planetary life-support system, it needs to be connected to a **value system**.

The Earth's Life-Support System and Sustainability

Earth: Our Life-Support System

Motivated by Griggs et al., 2013

Earth: Our Life-Support System



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The Earth's Life-Support System and Sustainability

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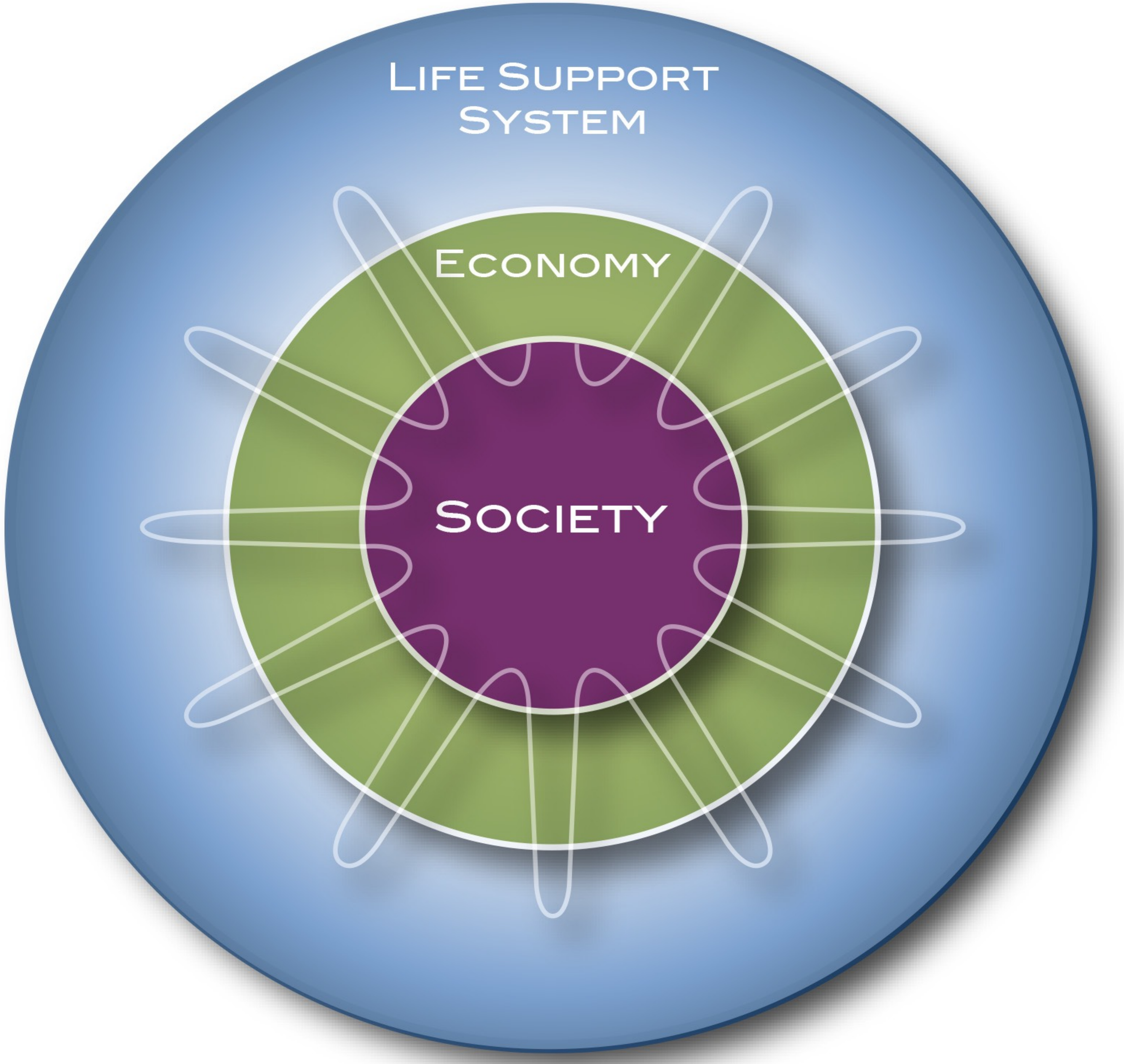

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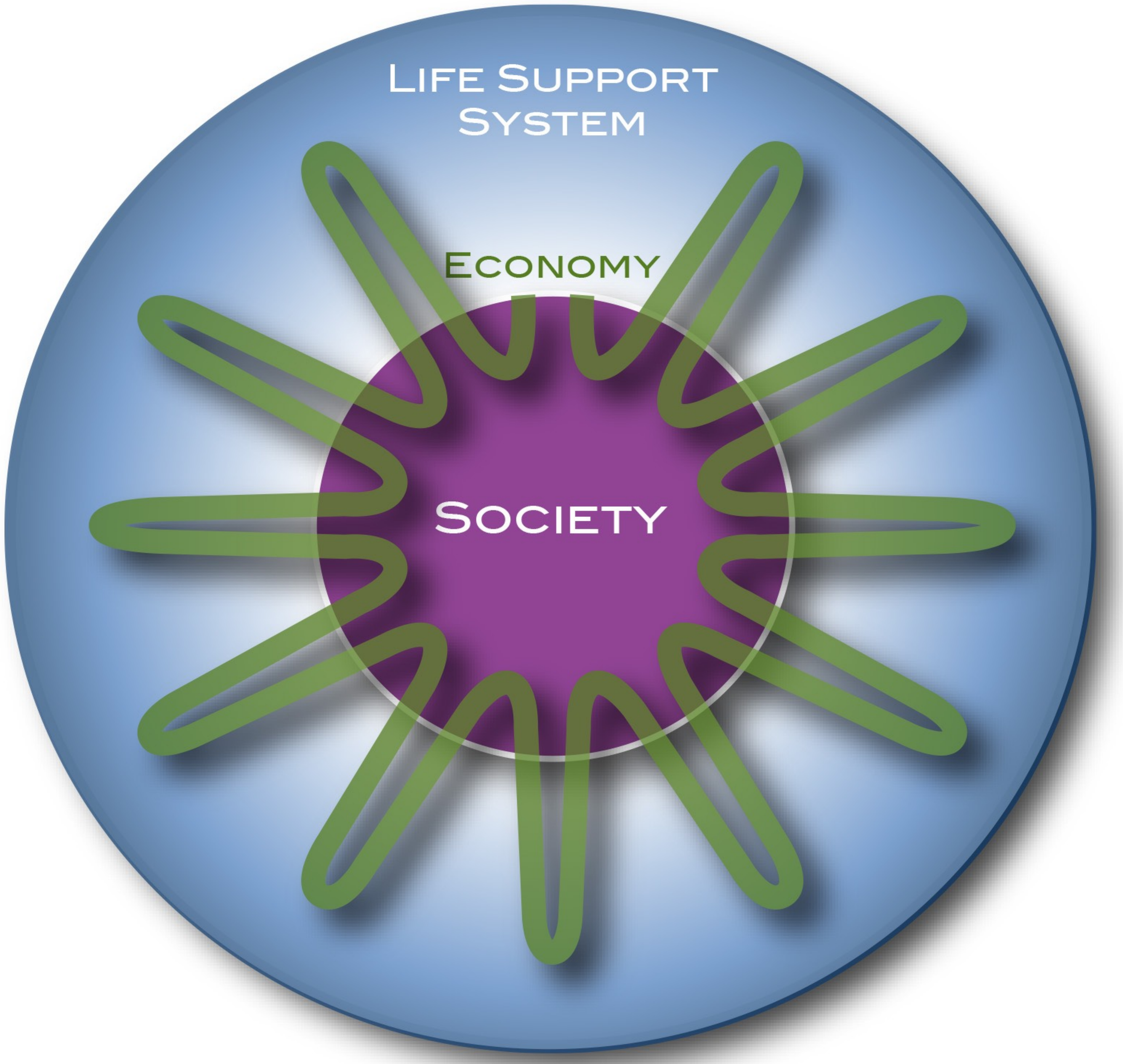

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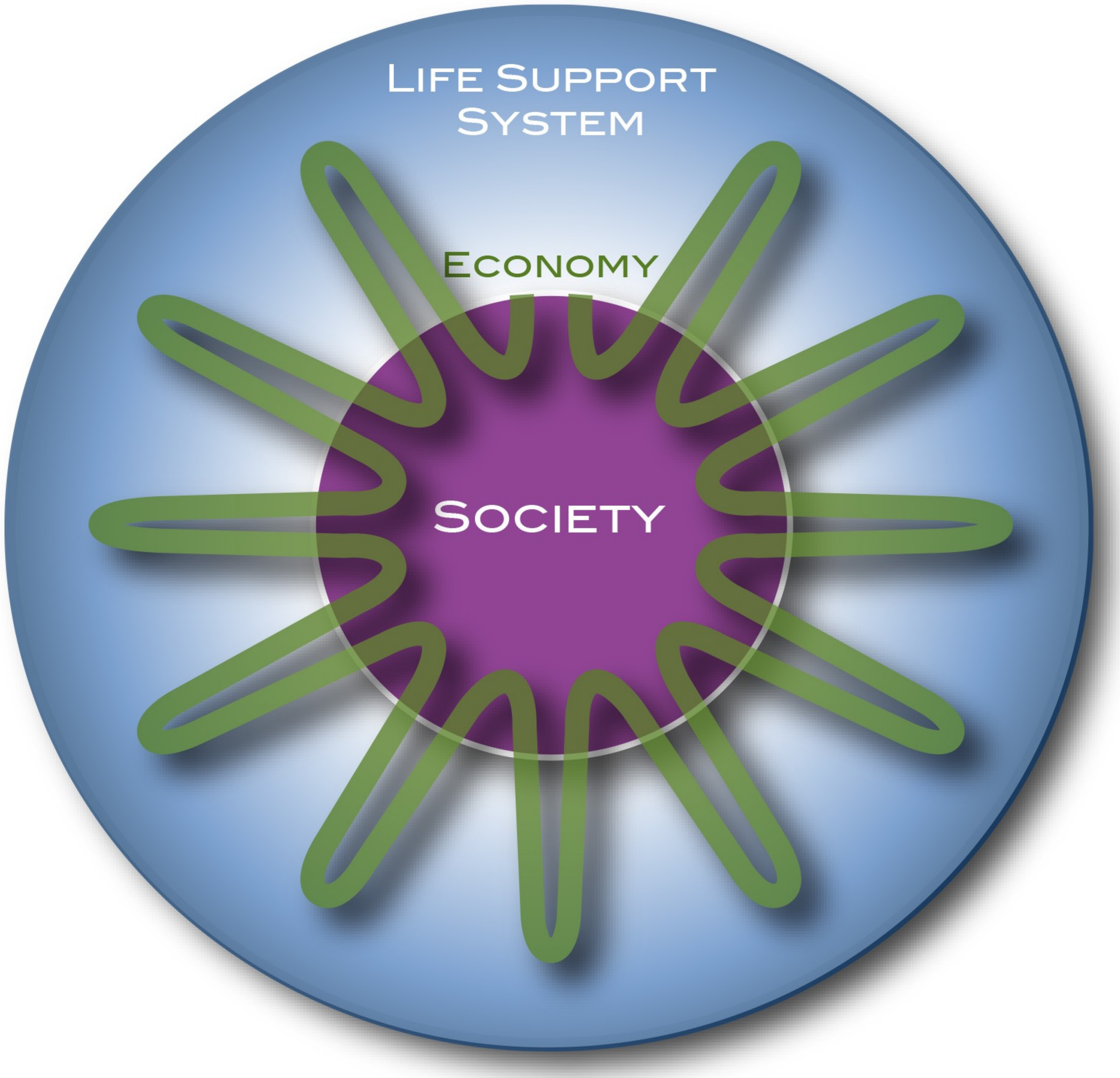
A sustainable development is a development that "meets the needs of the present, while safe-guarding the Earth's life-support system, on which the welfare of current and future generations [of human and non-human animals] depends." *Griggs et al., 2013*



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Hazards, Vulnerabilities and Disasters

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disaster

DICTIONARY | THESAURUS

disaster

noun | di·sas·ter | \di-ˈzas-tər, -ˈsas-\

Popularity: Top 20% of words

Examples: DISASTER in a Sentence

Editor's Note: Did You Know?

Definition of DISASTER

1 *obsolete, occult* : an unfavorable aspect (see aspect 2a) of a planet or star

2 : a sudden calamitous event bringing great damage, loss, or destruction • natural *disasters*; *broadly* : a sudden or great misfortune or failure • The party was a *disaster*.

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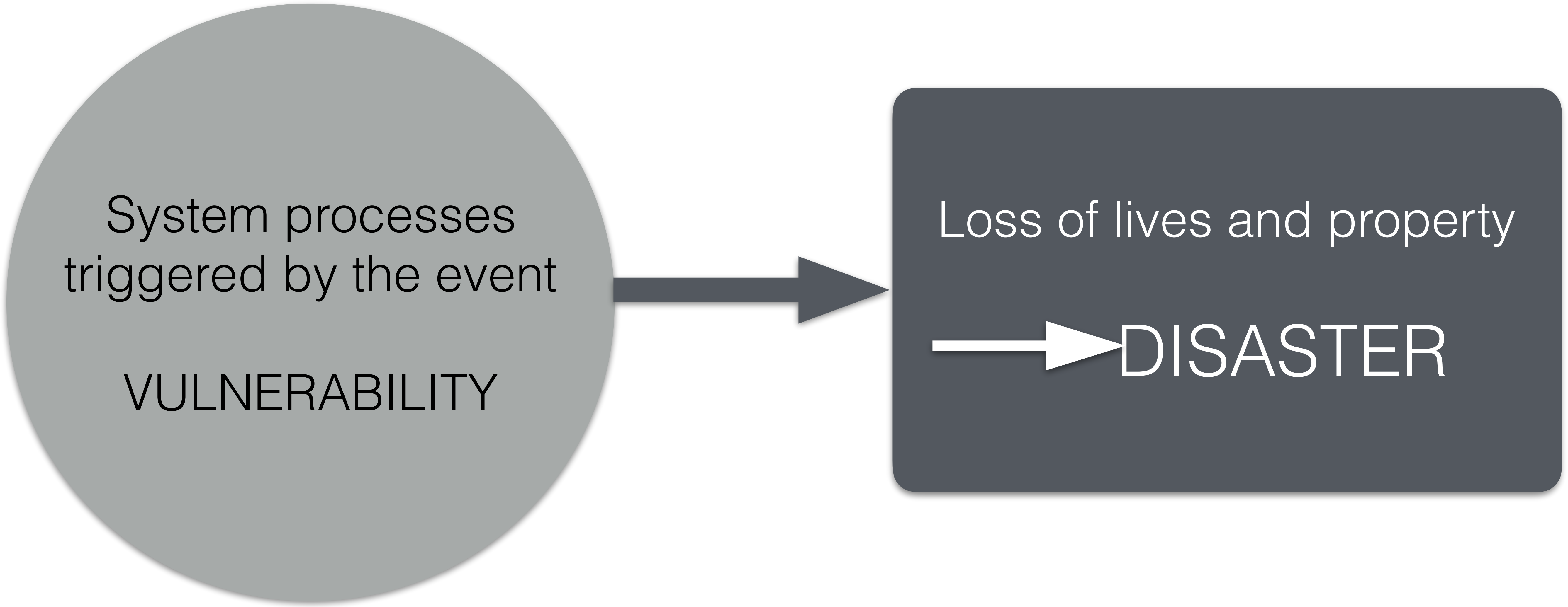

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Hazards, Vulnerabilities and Disasters

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hazard

DICTIONARY | THESAURUS

hazard

noun | haz·ard | \ˈha-zərd\

Popularity: Top 30% of words

Examples: HAZARD in a Sentence

Editor's Note: Did You Know?

Definition of HAZARD

1 : a game of chance like craps played with two dice

2 : a source of danger • *hazards* on the roadway

3 a : the effect of unpredictable and unanalyzable forces in determining events : CHANCE, RISK

• the *hazards* involved in owning your own business

• men and women danced together, women danced together, men danced together, as *hazard* had brought them together — Charles Dickens

b : a chance event : ACCIDENT

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4 *obsolete* : STAKE 3a

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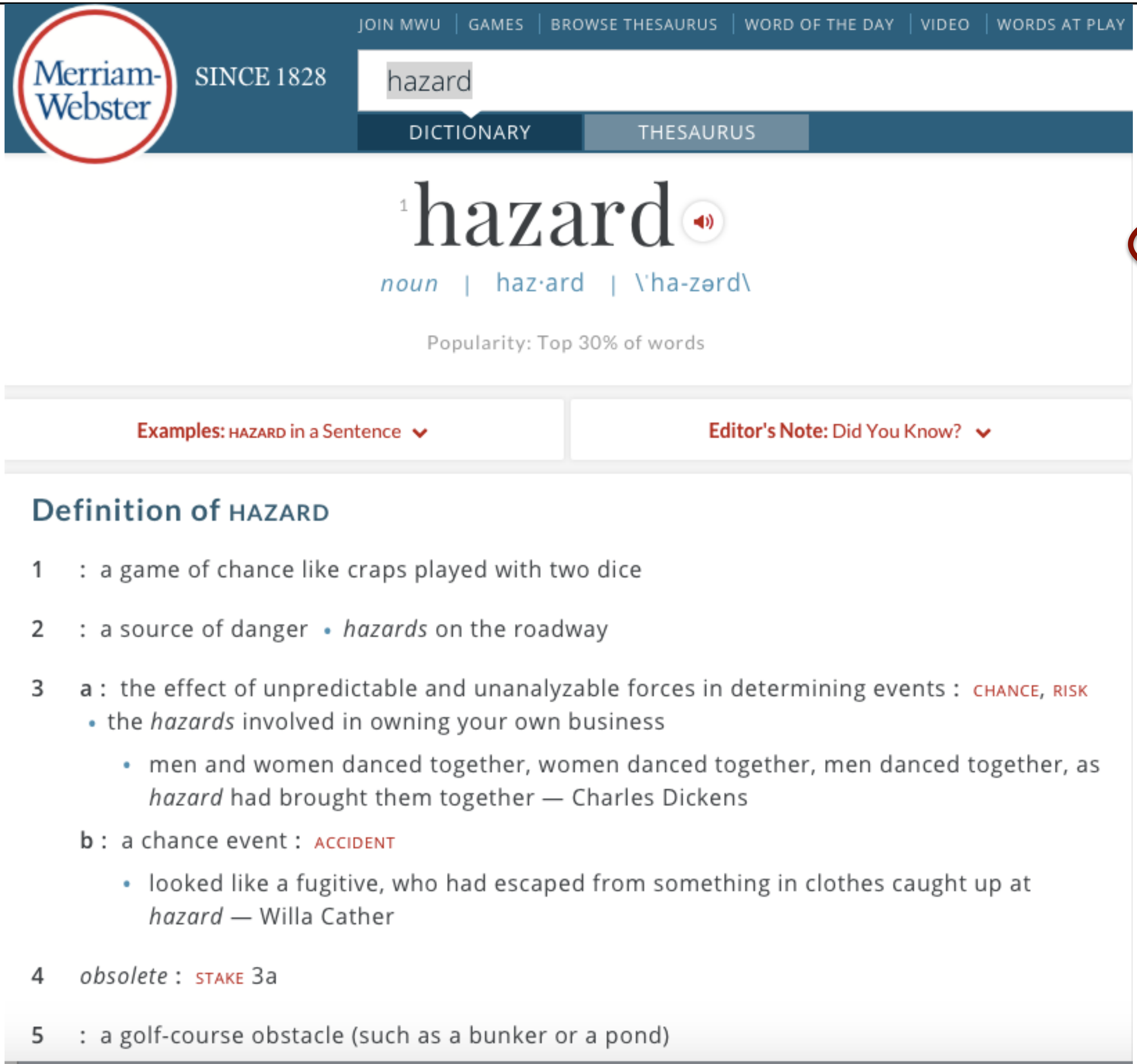

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Hazards, Vulnerabilities and Disasters

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vulnerability

DICTIONARY THESAURUS

vulnerable

adjective | vul·ner·a·ble | \ˈvəl-n(ə-)rə-bəl , ˈvəl-nər-bəl\

Popularity: Top 10% of words | Updated on: 17 Aug 2018

TRENDING NOW: mistrial hogwash probity sequacious inadmissible SEE ALL

Examples: VULNERABLE in a Sentence

Editor's Note: The History of VULNERABLE

Definition of VULNERABLE

1 : capable of being physically or emotionally wounded

2 : open to attack or damage : ASSAILABLE • *vulnerable* to criticism

3 : liable to increased penalties but entitled to increased bonuses after winning a game in contract bridge

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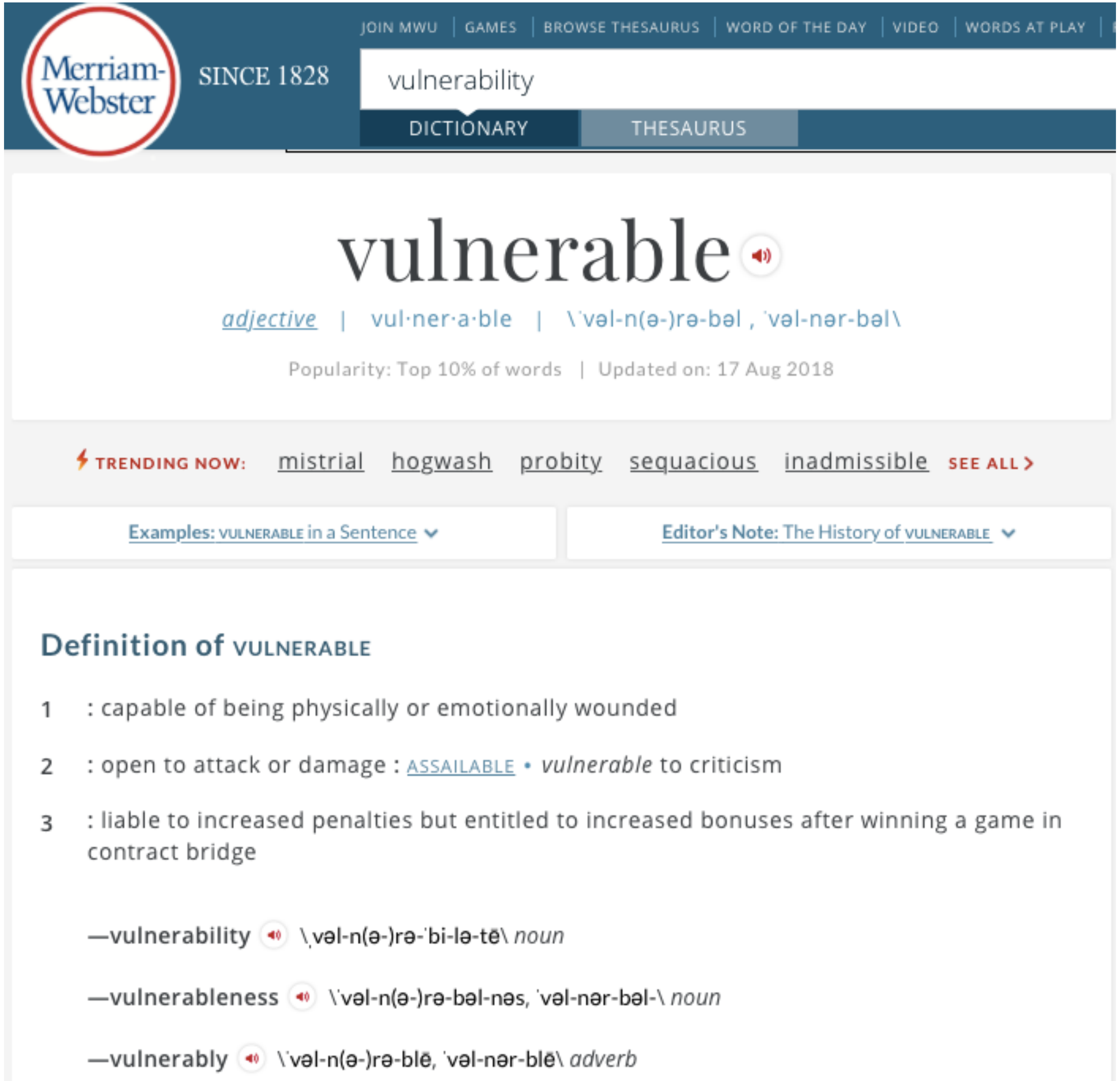

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Definition of vulnerable

1: capable of being physically or emotionally wounded

2: open to attack or damage : assailable
vulnerable to criticism

3: liable to increased penalties but entitled to increased bonuses after winning a game in contract bridge

Definition:

Vulnerability is the inability of a system to withstand the effects of a hostile environment.

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Vulnerability is the inability of a system to withstand the effects of a hostile environment.

Social vulnerability describes the extent to which a community could be affected by stress, change or a hazard. Social vulnerability depends on the individual and community levels of access to resources to prepare for, cope with and recover from disasters. A large number of factors may contribute to social vulnerability including, but not limited to, gender, race, socioeconomic status, age, language, and access to information.

Definition:

A disaster is the loss of lives and property; often as the result of a hazardous event.

Concerning the extent of disaster, we follow Plag et al. (2015) and classify large event as:

- **Extinction Level Events** are so devastating that more than a quarter of all life on Earth is killed and major species extinction takes place.
- **Global Catastrophes** are events in which more than a quarter of the world's human population dies and that place civilisation at serious risk.
- **Global Disasters** are global scale events in which a few percent of the population dies.
- **Major Disasters** are those exceeding $100 billion in damage and/or causing more than 10,000 fatalities.

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Concept of Risk

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risk

DICTIONARY | THESAURUS

[1] risk

noun | \'risk\

Popularity: Top 10% of words

Examples: RISK in a Sentence

Definition of RISK

1 : possibility of loss or injury : PERIL

2 : someone or something that creates or suggests a hazard

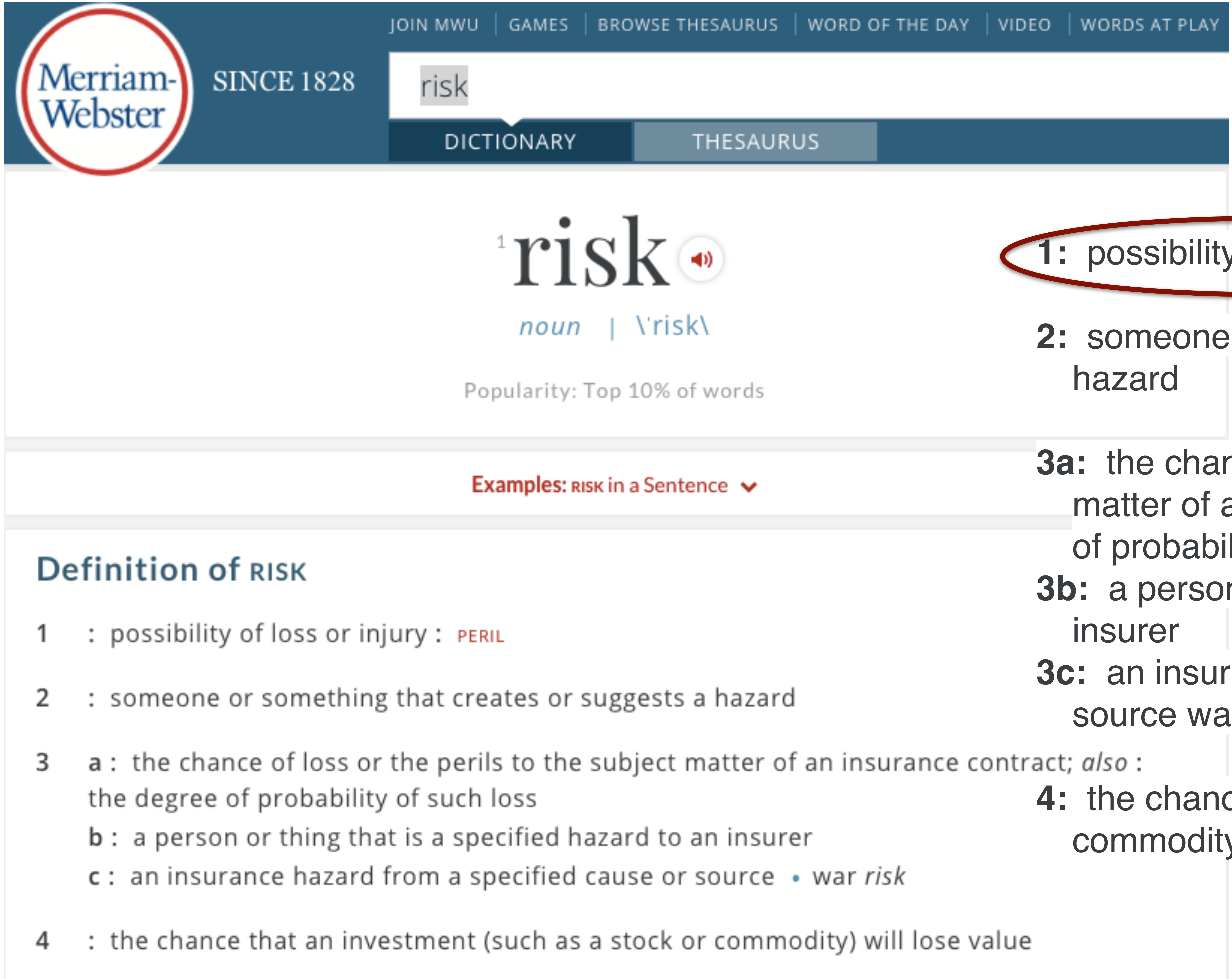
3 a : the chance of loss or the perils to the subject matter of an insurance contract; *also* : the degree of probability of such loss

b : a person or thing that is a specified hazard to an insurer

c : an insurance hazard from a specified cause or source • war *risk*

4 : the chance that an investment (such as a stock or commodity) will lose value

Concept of Risk



1: possibility of loss or injury **:** peril

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3b: a person or thing that is a specified hazard to an insurer

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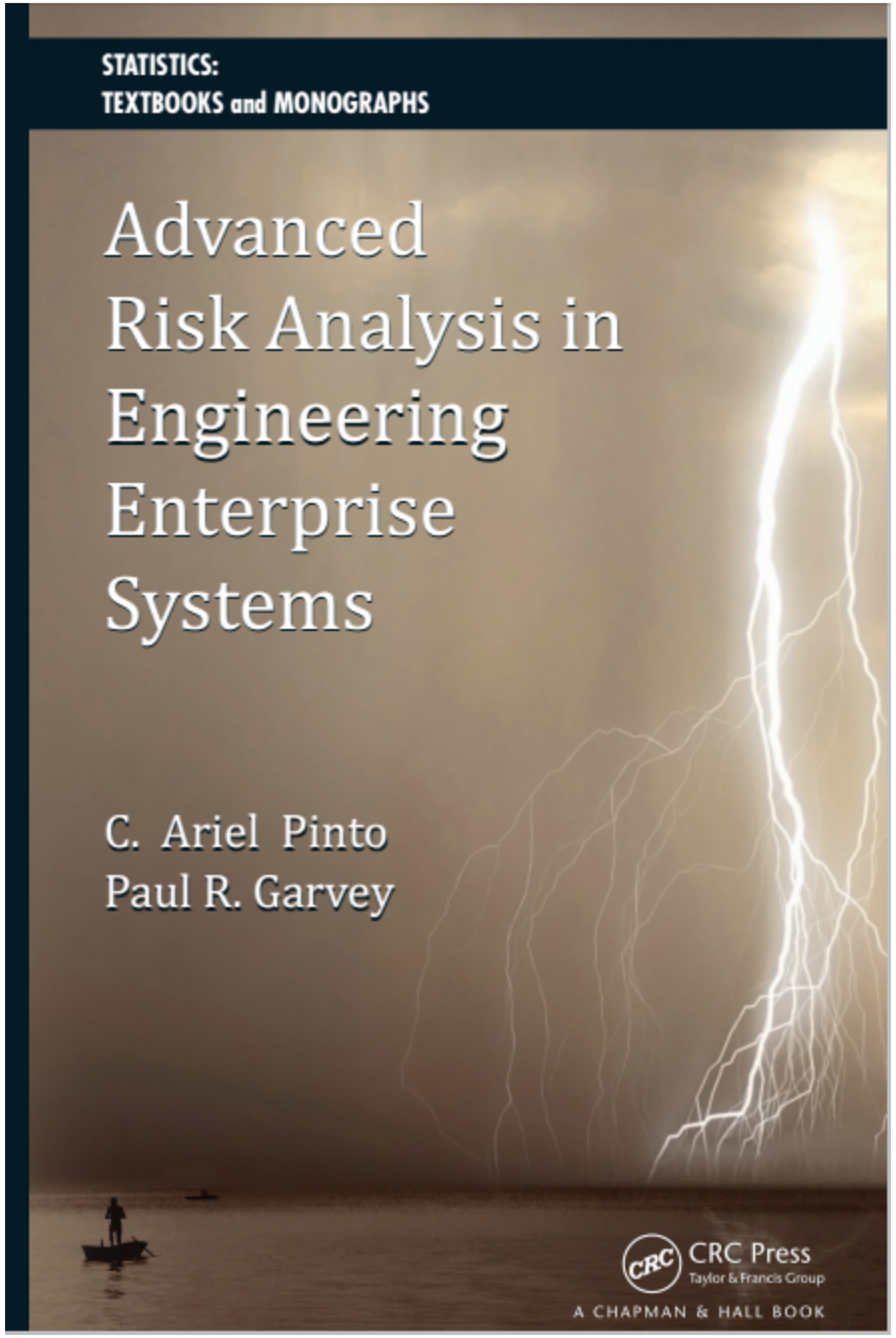

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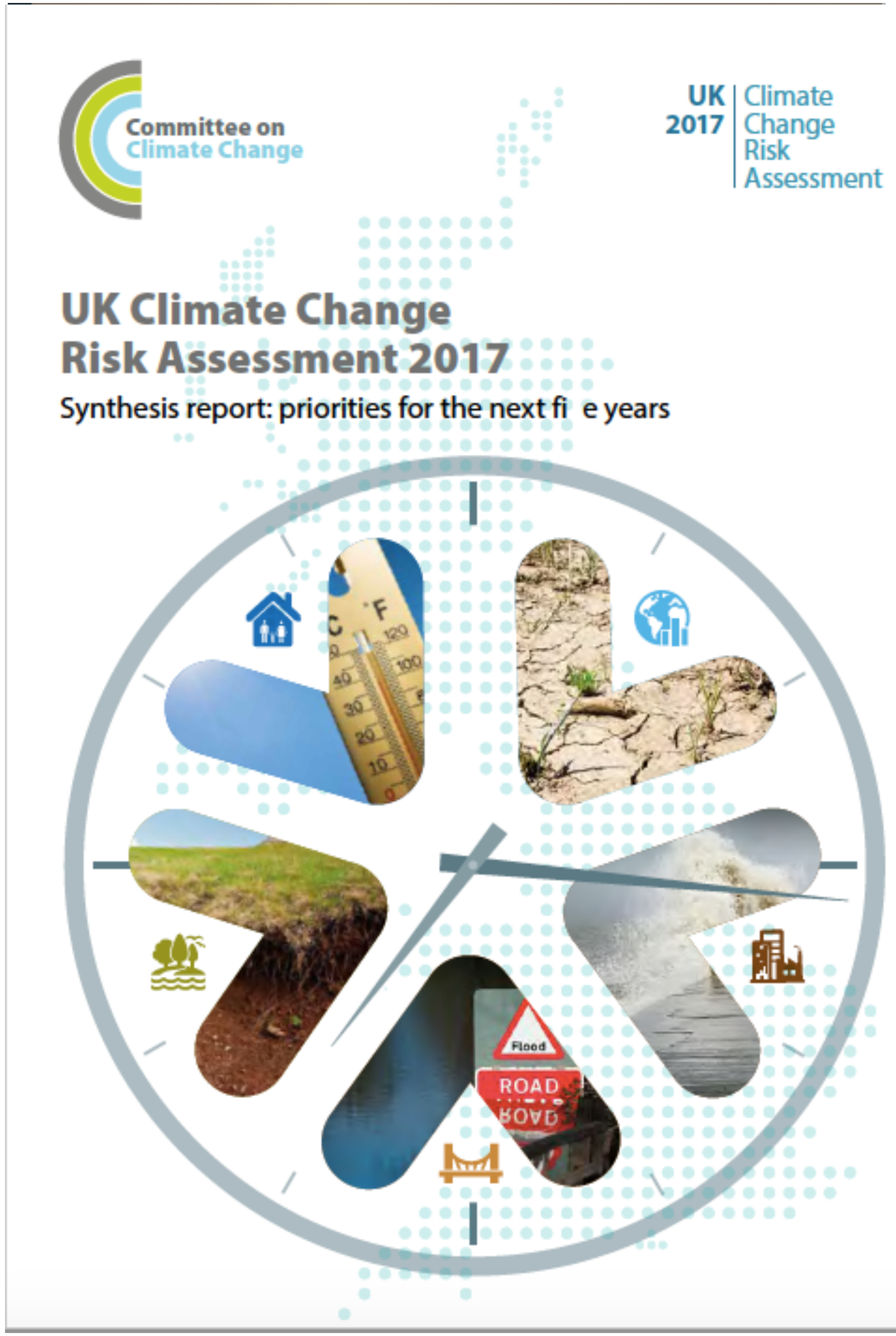

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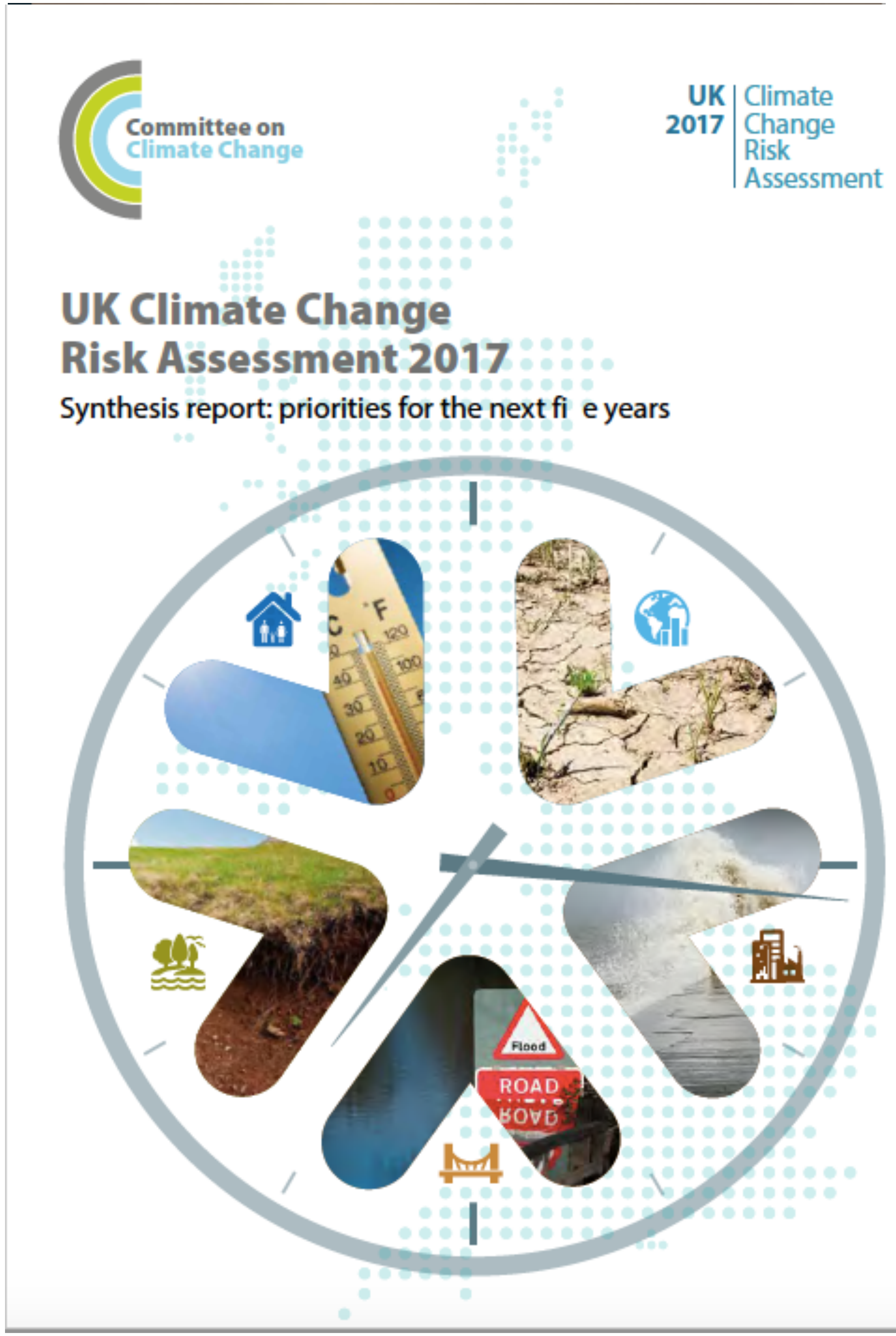

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Risk is the potential for consequences where something of value is at stake and where the outcome is uncertain”

Concept of Risk

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Measuring Risk:

Insurance:
Risk (in $) = Hazard Probability * Vulnerability * Exposed Assets

Concept of Risk

Definition:
Risk is the potential for consequences where something of value is at stake and where the outcome is uncertain”

Measuring Risk:

Insurance:
Risk (in $) = Hazard Probability * Vulnerability * Exposed Assets

Engineering:
Risk = Event rate * vulnerability * consequences

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Measuring Risk:

Plag and Jules-Plag, 2013

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Here we take a risk-based approach that is commonly used for natural hazards and particularly geohazards. For a given hazard h, a given recurrence time interval T, and for a prescribed intensity I, the associated risk $r(I)$ expressed in currency is given by

$$r_h^T(I, x, t) = p_h^T(I, t) \cdot V_h^{a(x,t)}(I, t) \cdot a(x, t) \qquad [1]$$

where x is the location, t time, p the hazard giving the probability that the hazard with intensity I will occur in the considered recurrence interval, V the vulnerability of an asset a for hazard h at intensity I, and a being the asset exposed at location x. To assess the total risk R associated with a hazard, we can use

$$R_h^T(x, t) = \int_0^{I_{\max}} r_h^T(I, x, t)\mathrm{d}i. \qquad [2]$$

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We need to know the “probability density function” for the hazard.

Plag and Jules-Plag, 2013

Concept of Risk

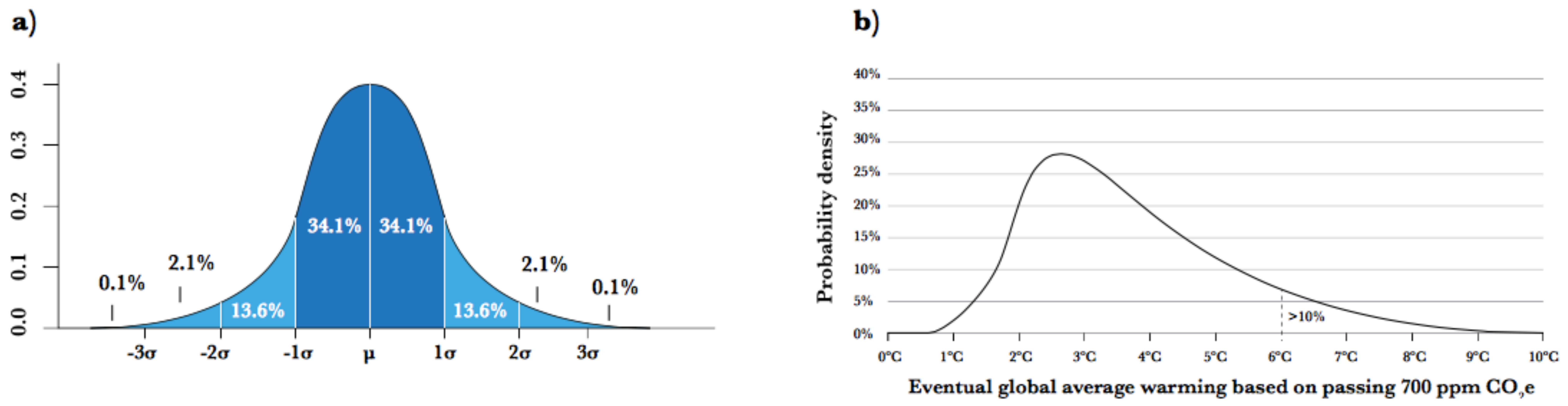
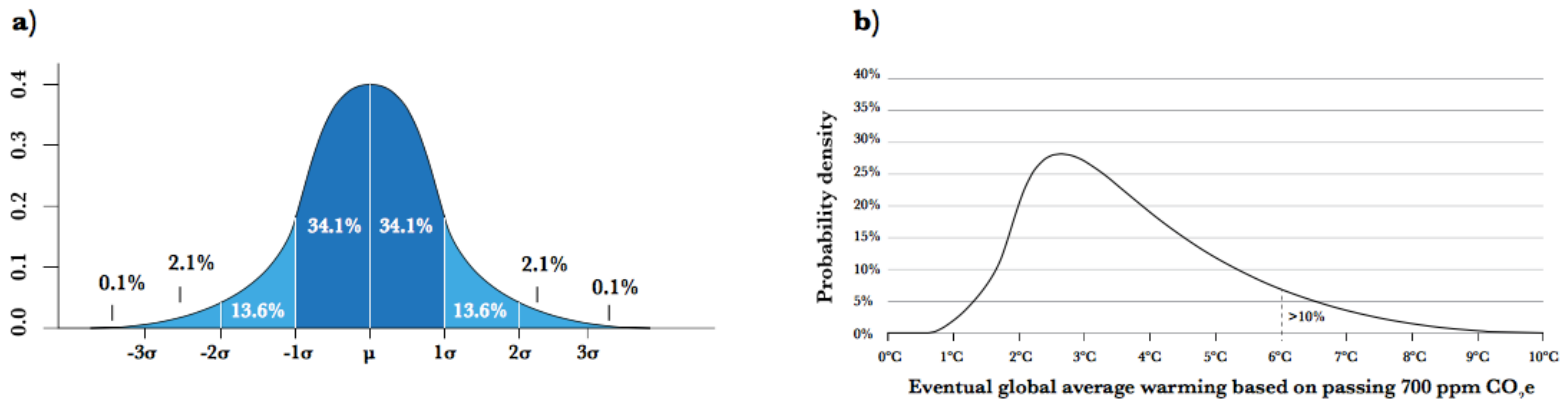


Figure 1: Normal and "fat tail" probability distributions. (a) Normal probability distribution, and (b) an estimate of the likelihood of warming due to a doubling of greenhouse gas concentrations exhibiting a "fat tail" distribution (Credit: Wagner & Weitzman 2015, *Climate Shock: The Economic Consequences of a Hotter Planet*).

Concept of Risk



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THINKING THE UNTHINKABLE

Successful risk management requires thinking "outside the box" to avoid a failure of imagination, but this is a skill rarely found at the senior levels of government and global corporations. Spratt and Dunlop (2018)

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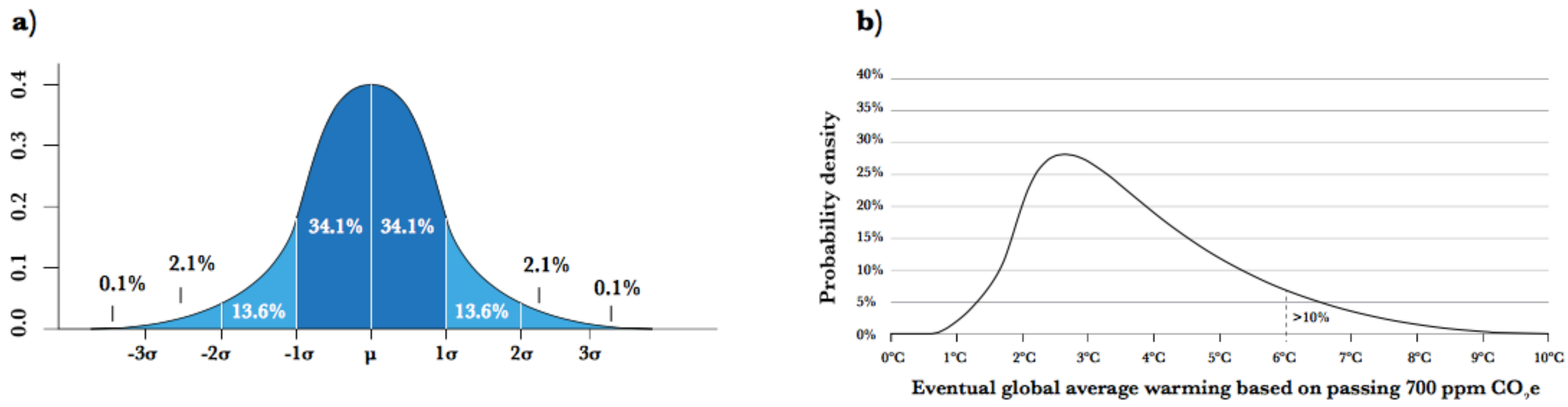

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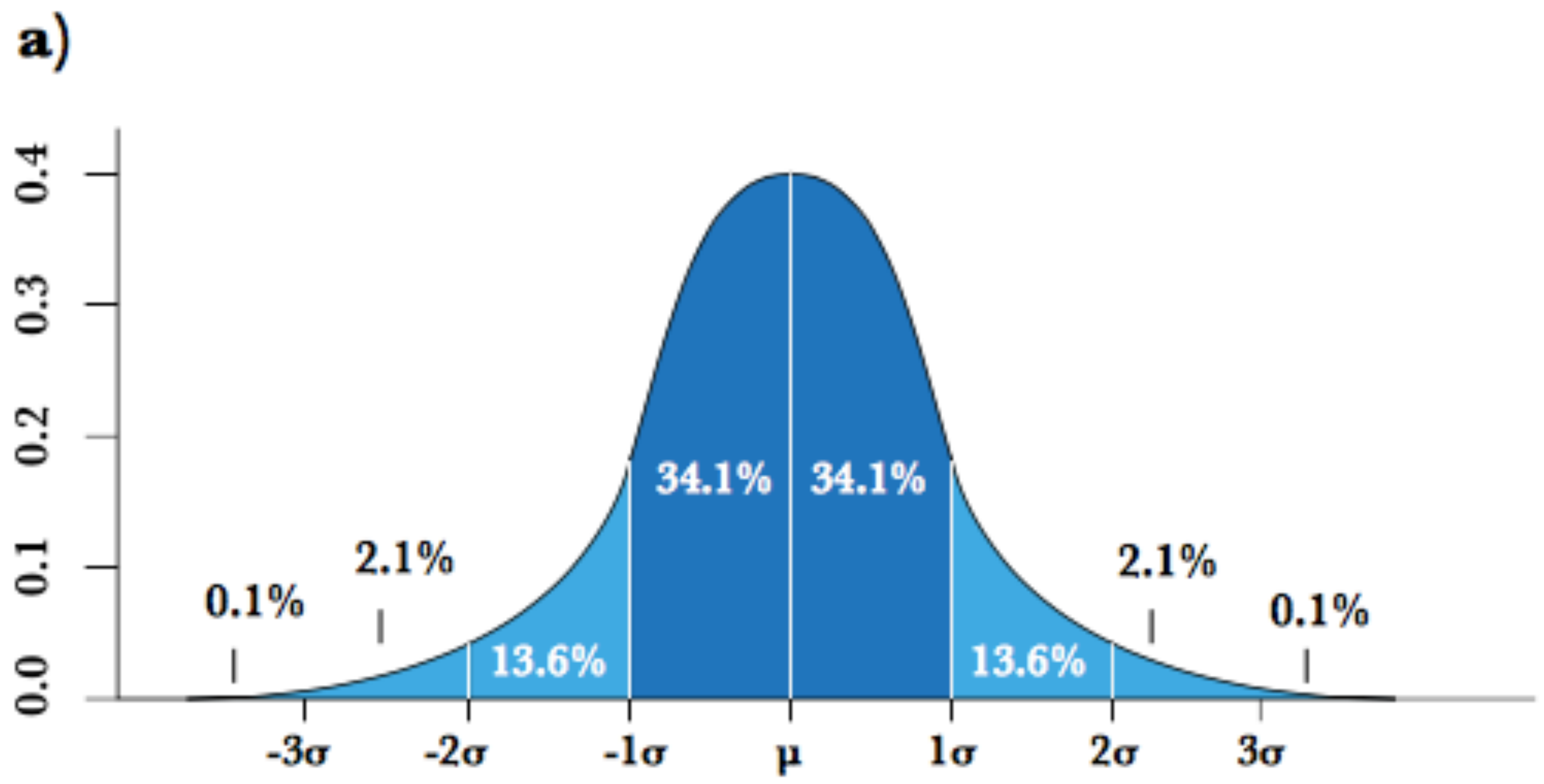
THE UNDERESTIMATION OF RISK



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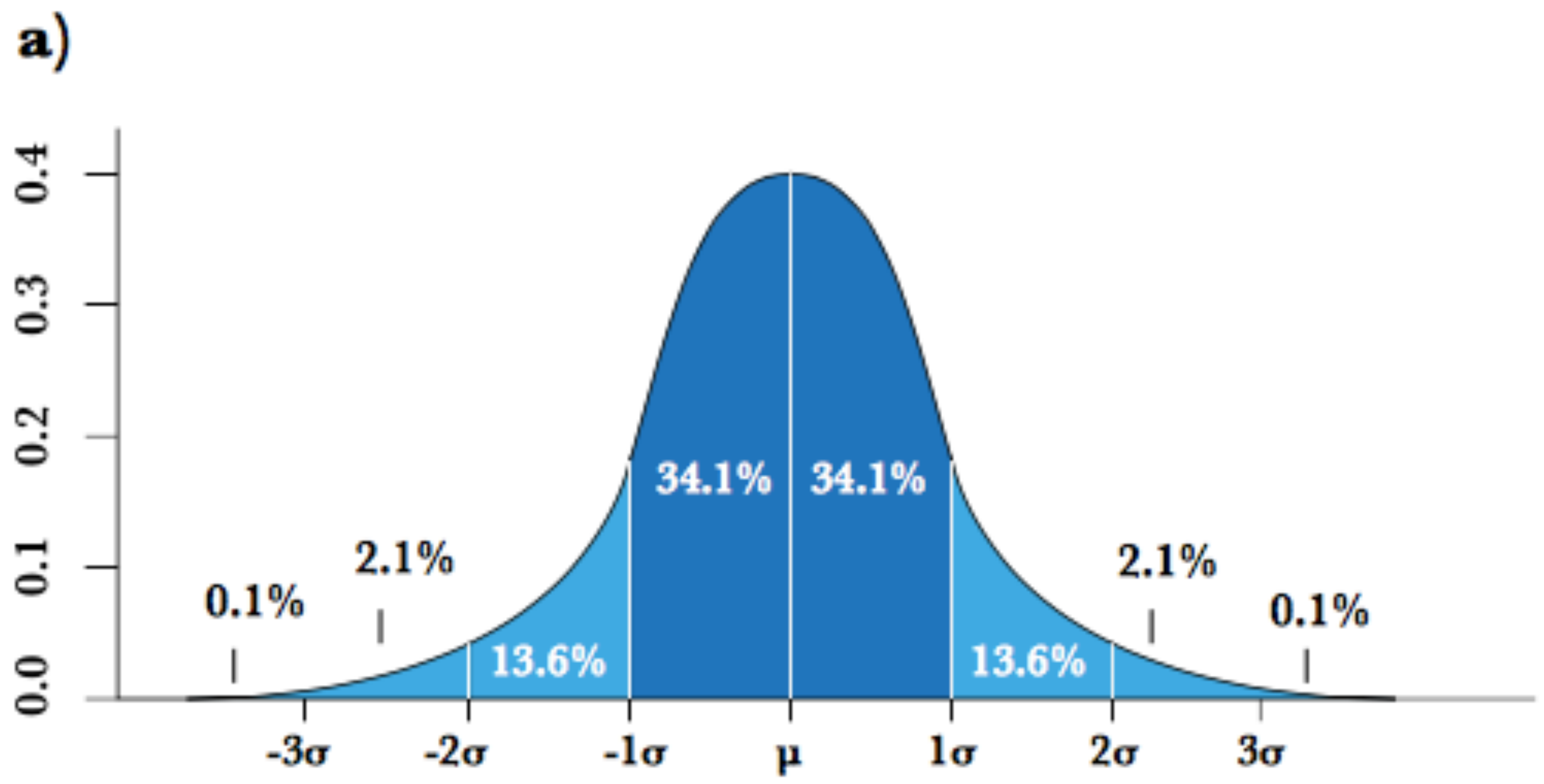

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Disaster Risk Governance

Disaster Risk Governance

Awareness
Preparedness
understanding the hazards and their potential impacts

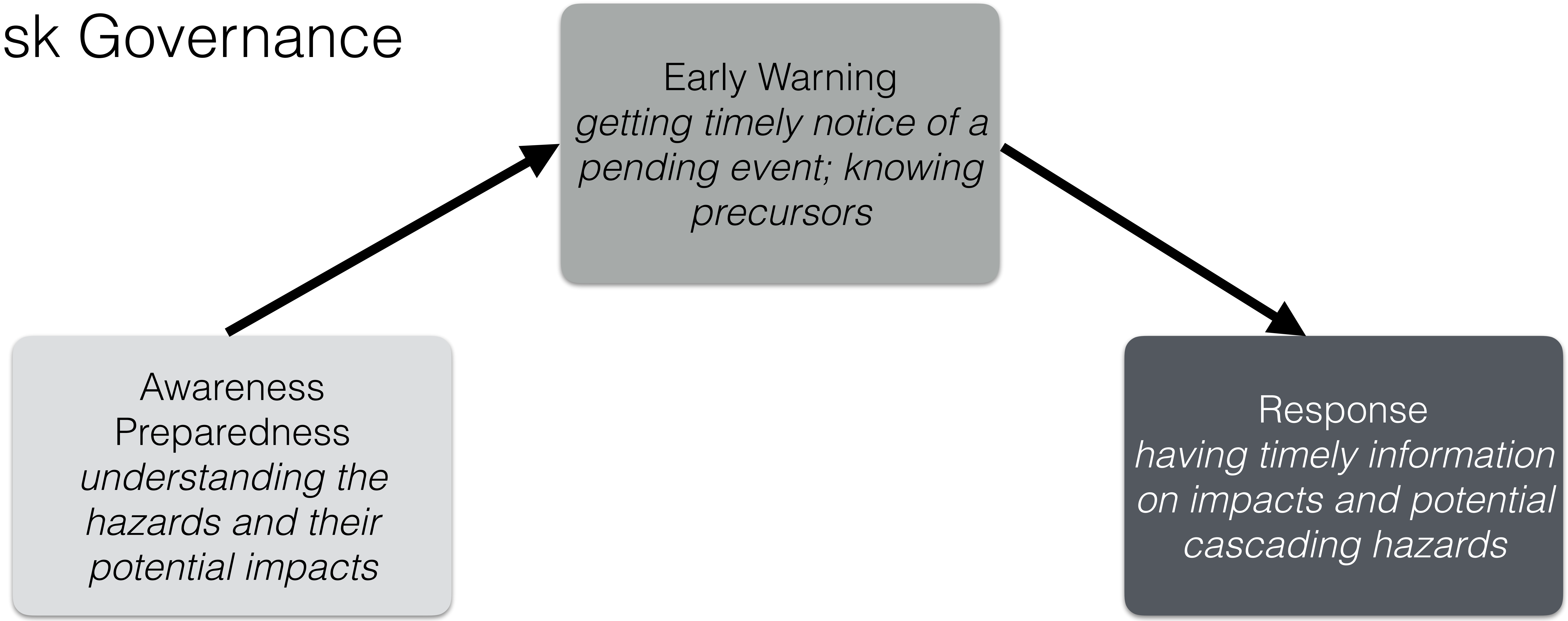
Disaster Risk Governance

Early Warning
getting timely notice of a pending event; knowing precursors

Awareness
Preparedness
understanding the hazards and their potential impacts

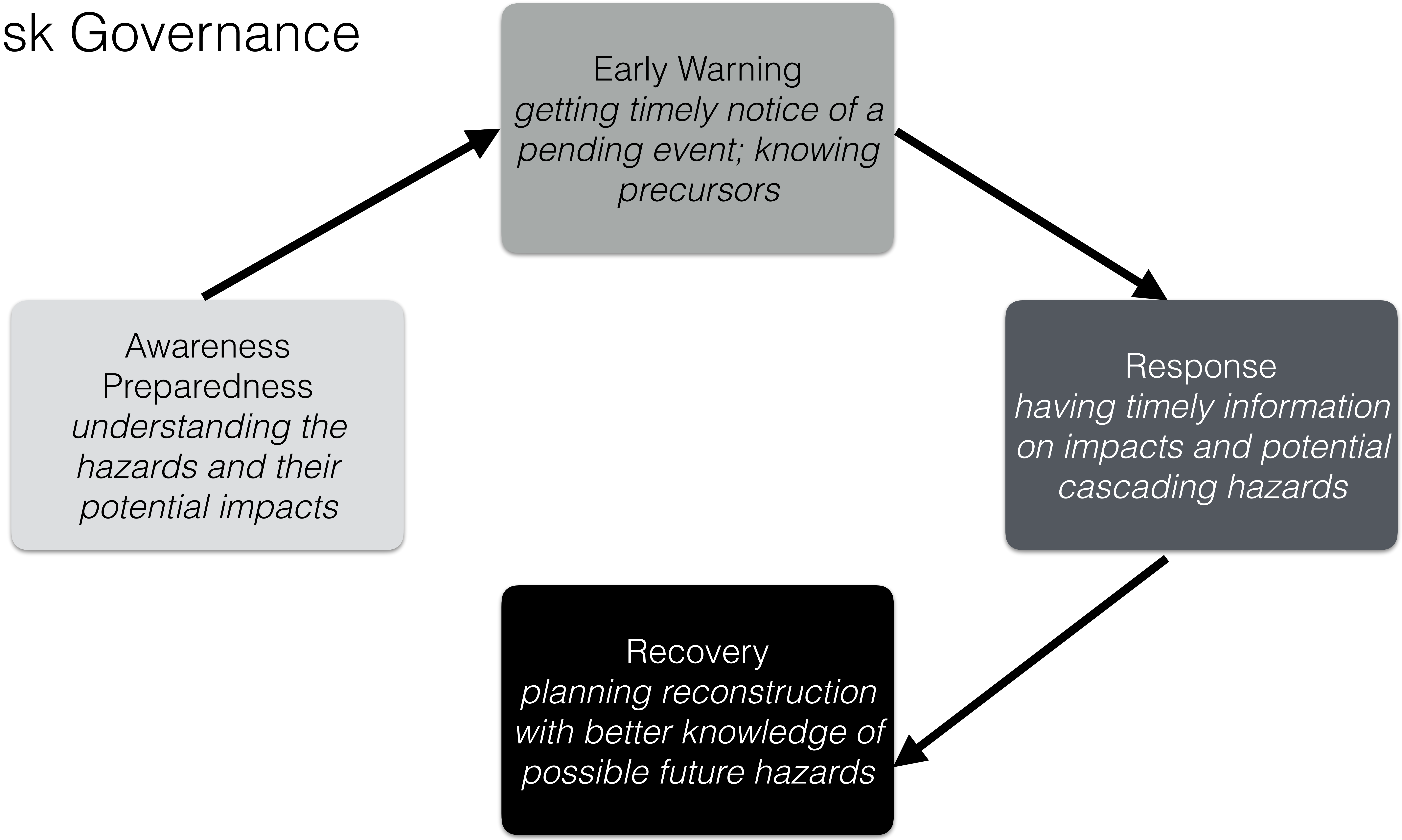
Concept of Risk

Disaster Risk Governance



Concept of Risk

Disaster Risk Governance



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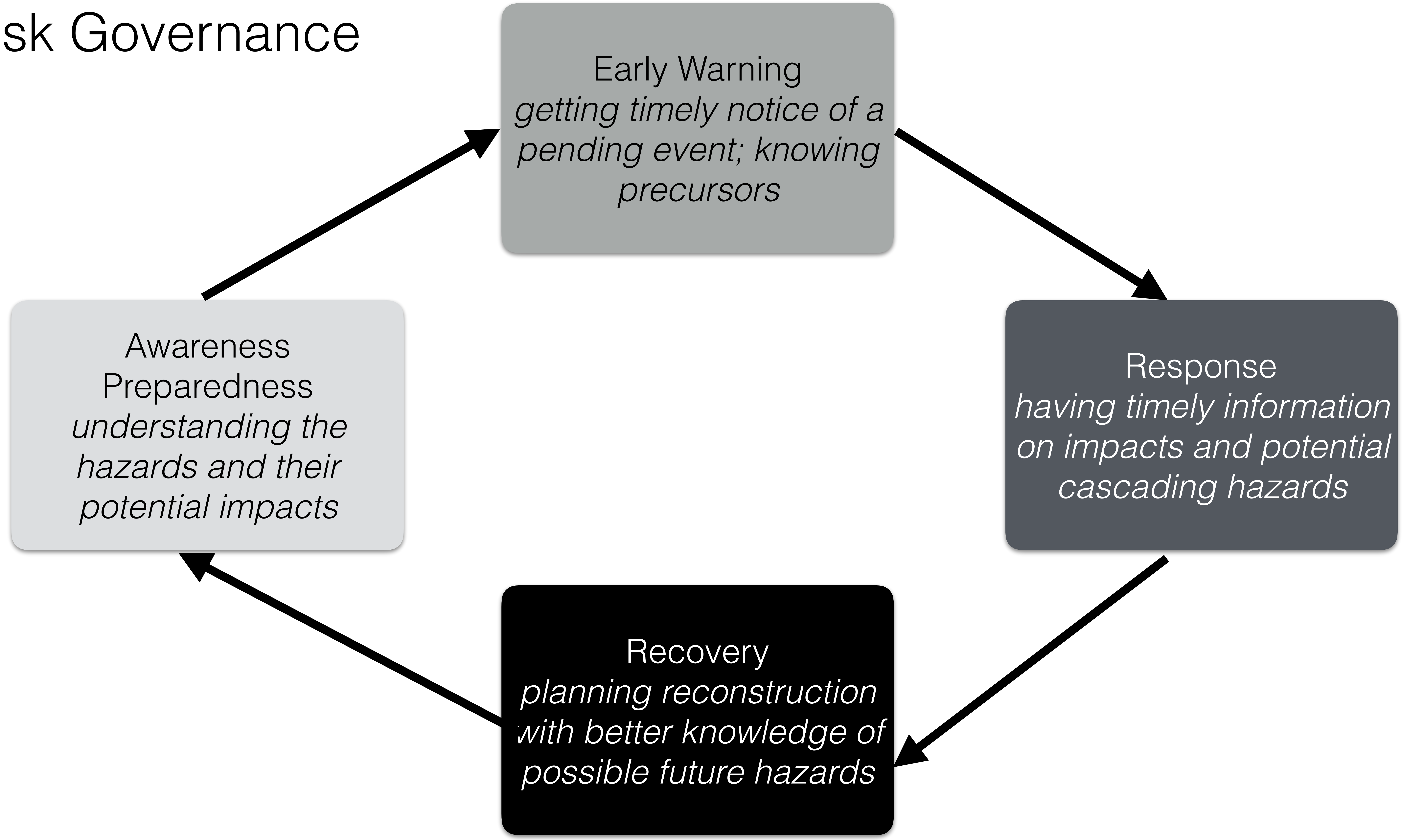

Natural Hazards and Disaster

Class 1: Introduction to the Course and Basic Concepts

- Practicalities
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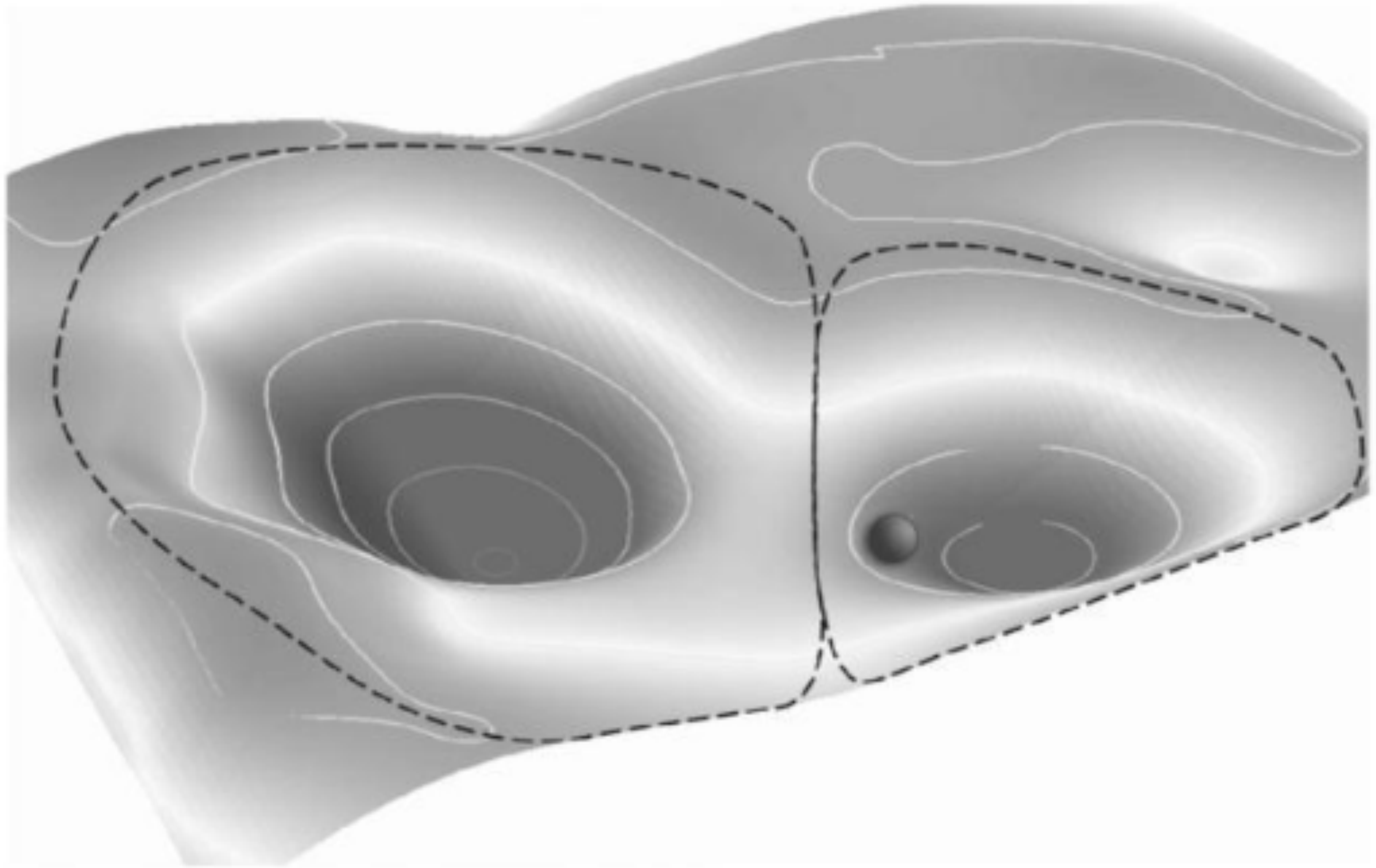

FIGURE 3 The System as a Ball-in-the-Basin Model

The ball is the state of the social-ecological system. The basin in which it is moving is the set of states which have the same kinds of functions and feedbacks, resulting in the ball moving towards the equilibrium. The dotted line is a threshold separating alternate basins. *(From Walker et al , 2004)*

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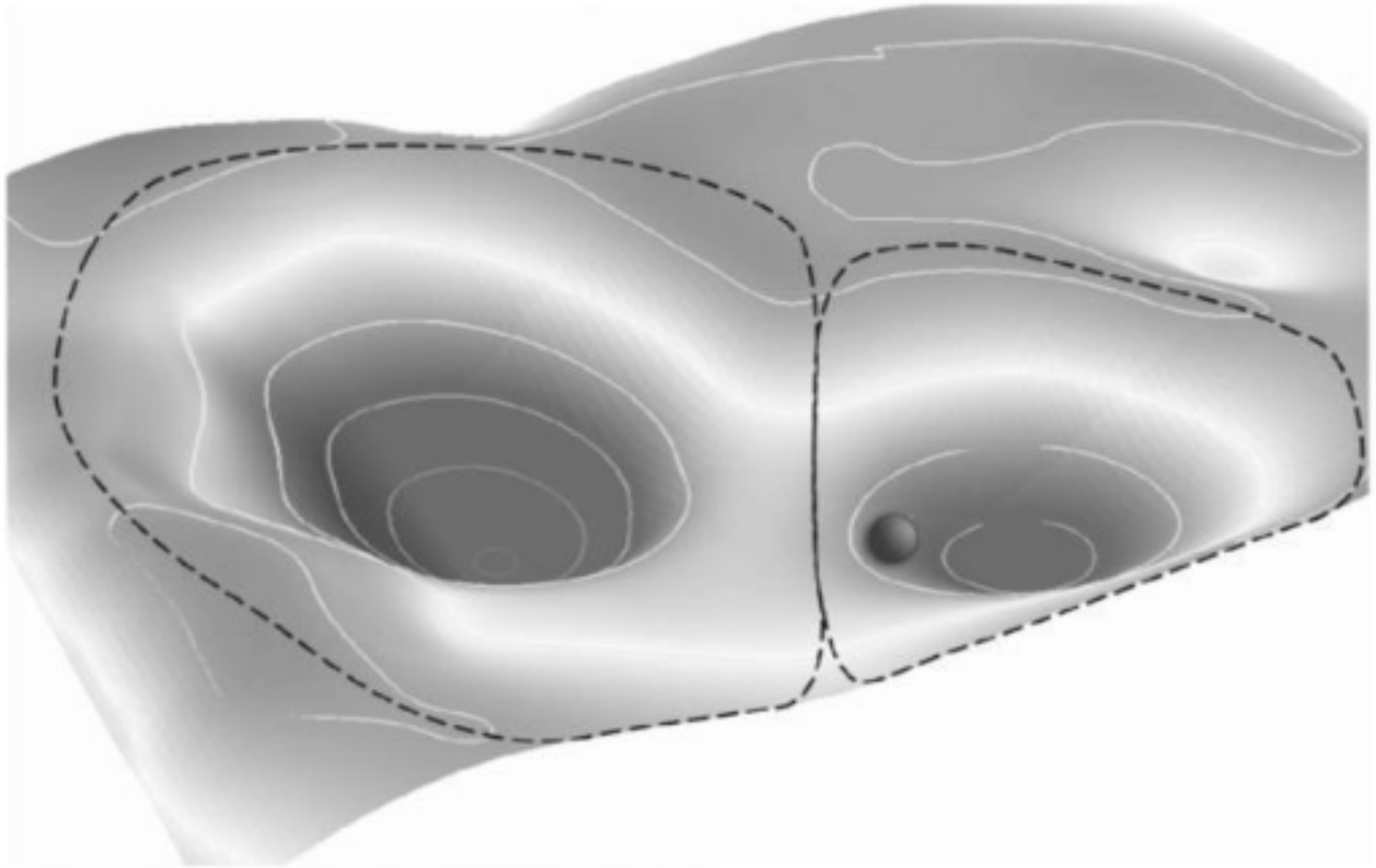

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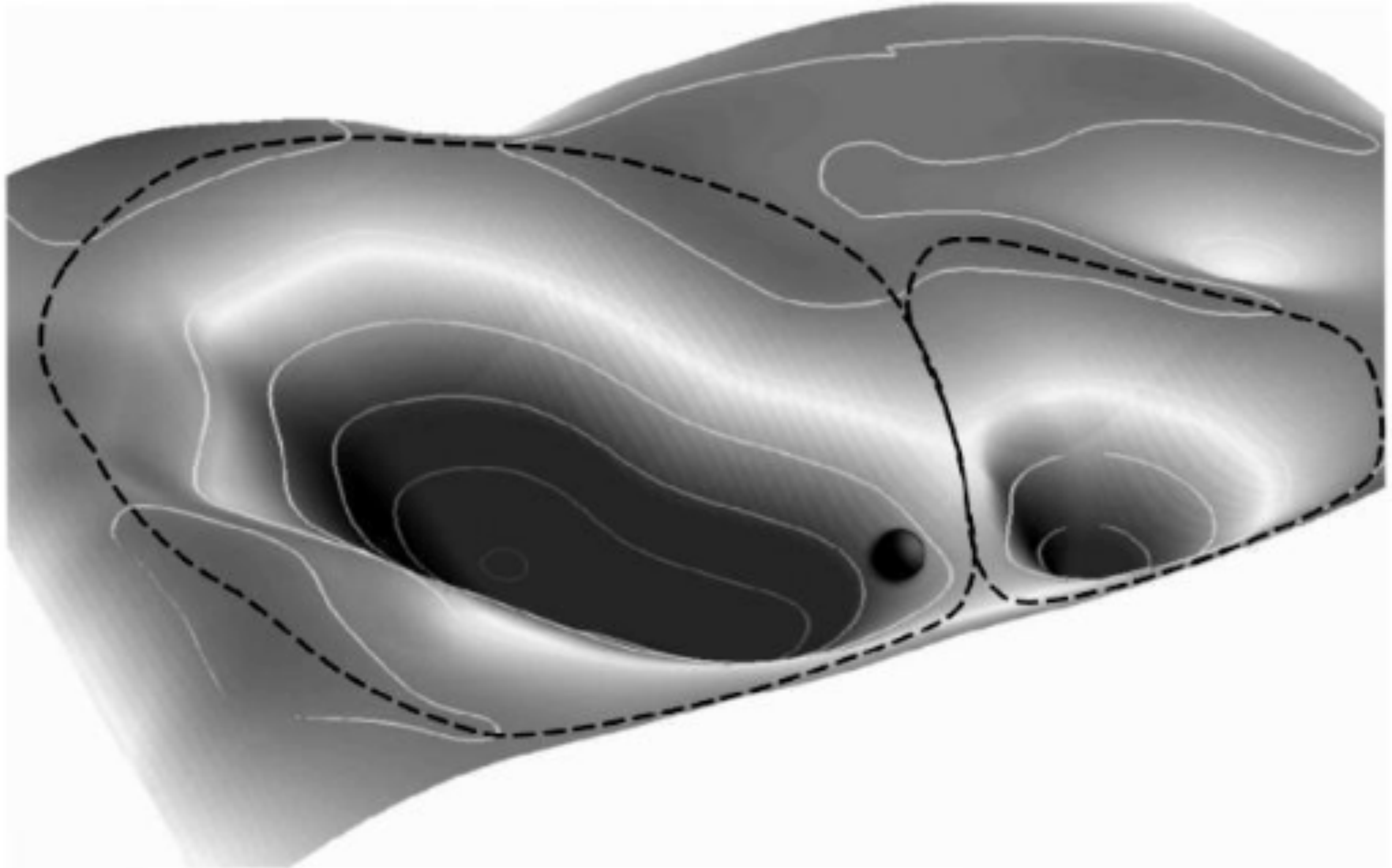
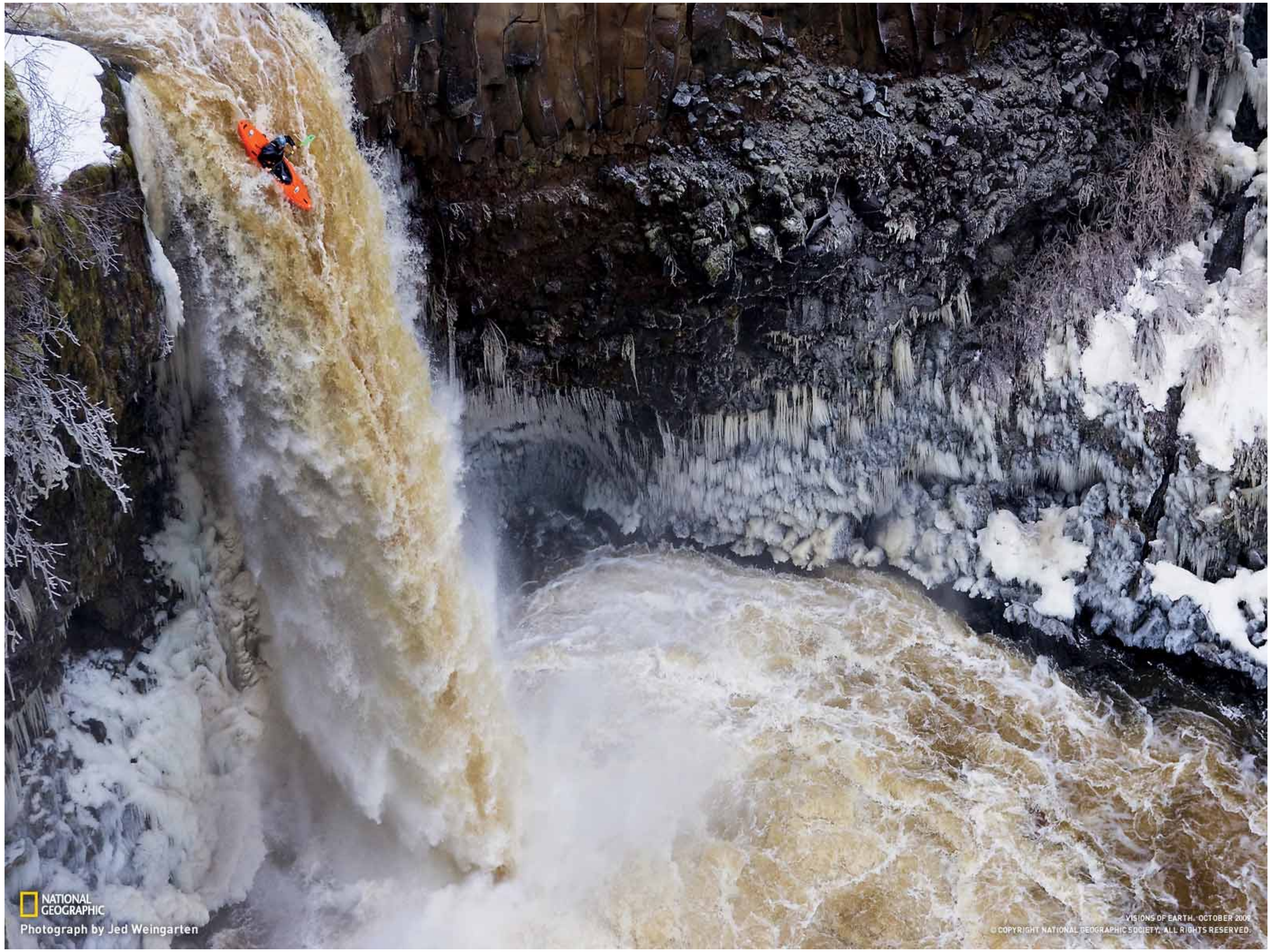


FIGURE 4 The Basin Changes Shape

This this is the same system as in figure 3. The state of the system (position of the ball) has not changed, but as conditions change, so too does the shape of the basin and the behavior of the system. *(From Walker et al , 2004.)*

Thresholds

The threshold is not where the boat goes over the edge, it is far up the river, when the people in the boat lose the option to get to the shore



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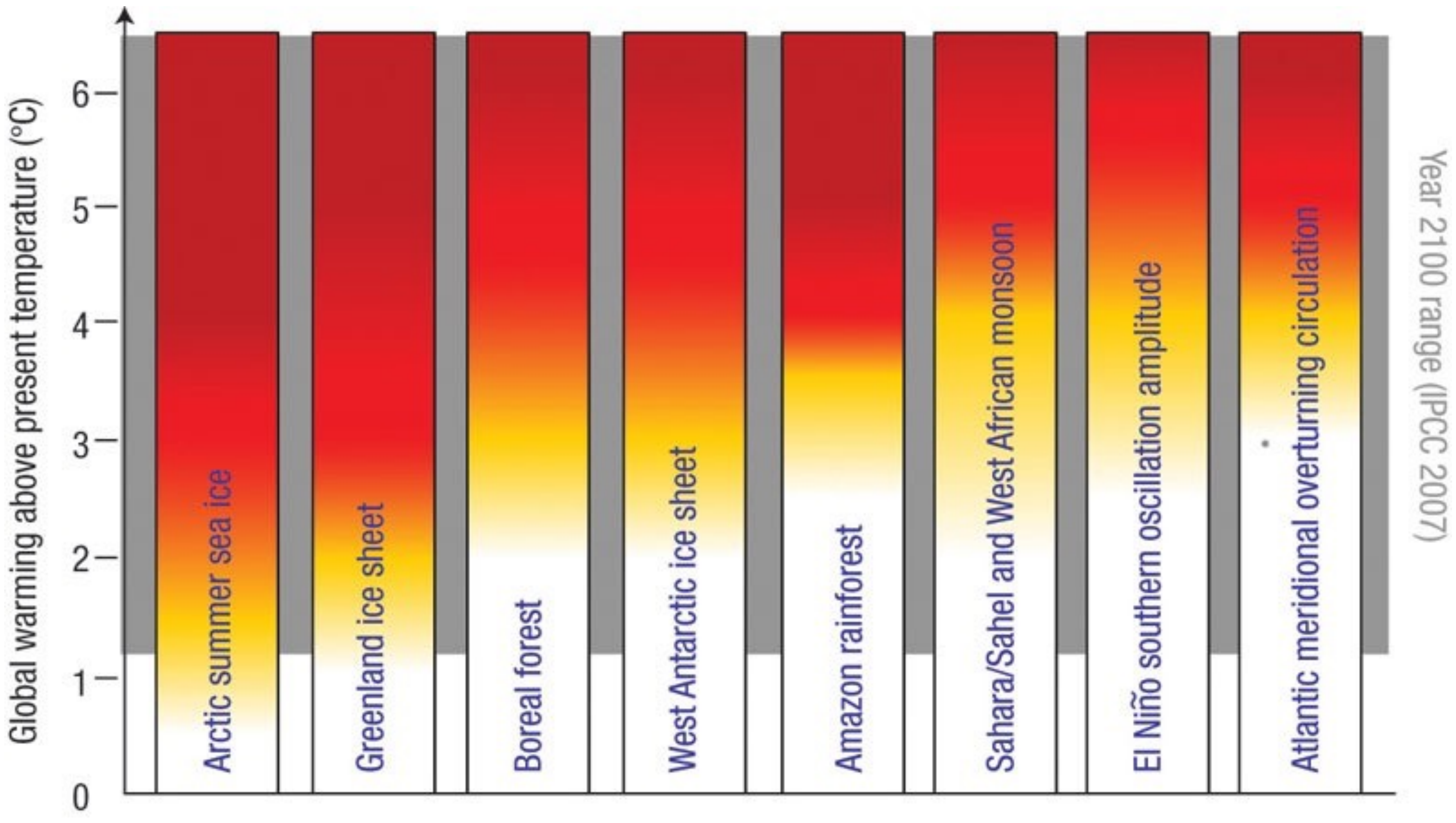

Lenton & Schellnhuber (2007) *Nature Reports Climate Change*

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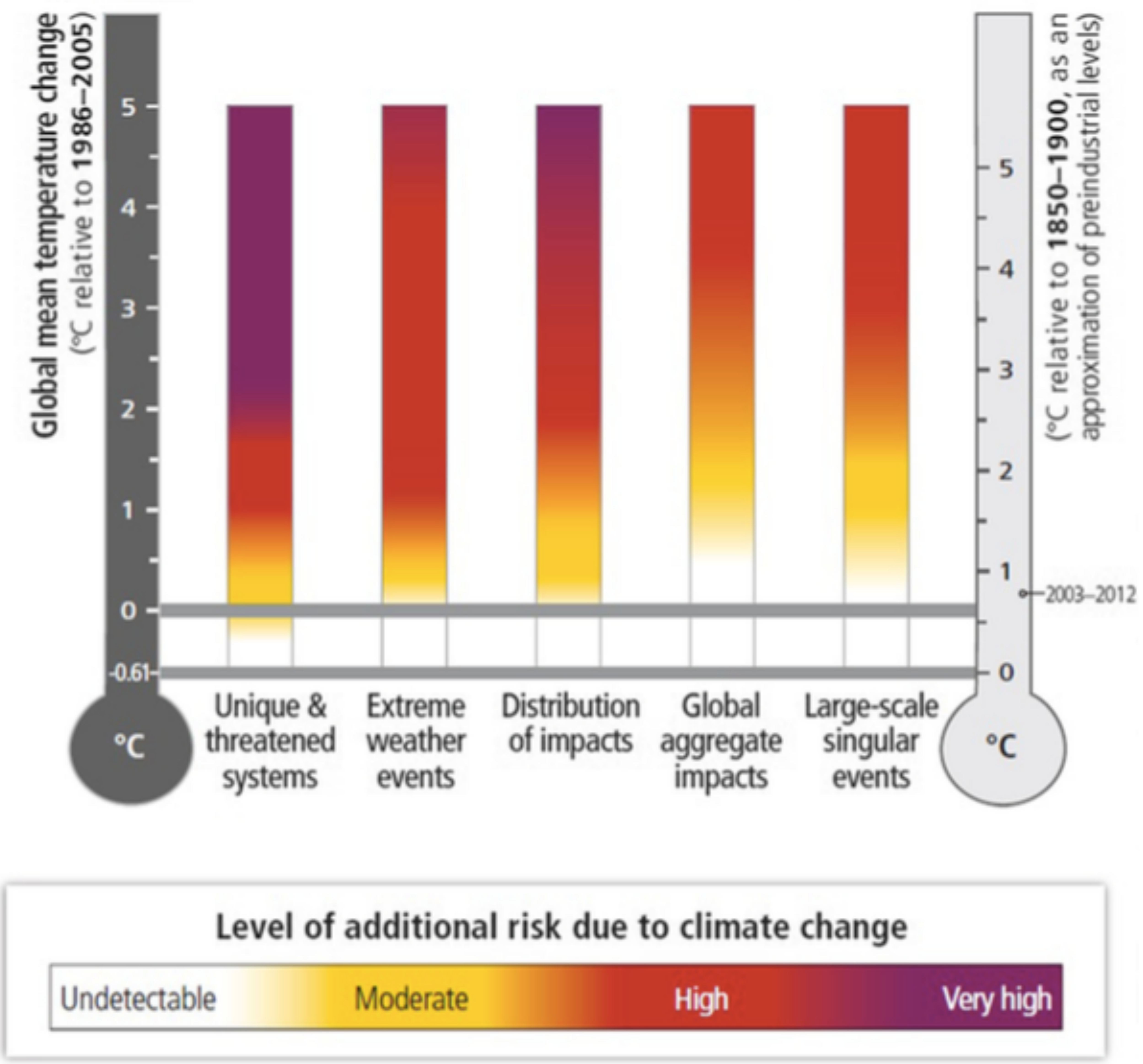

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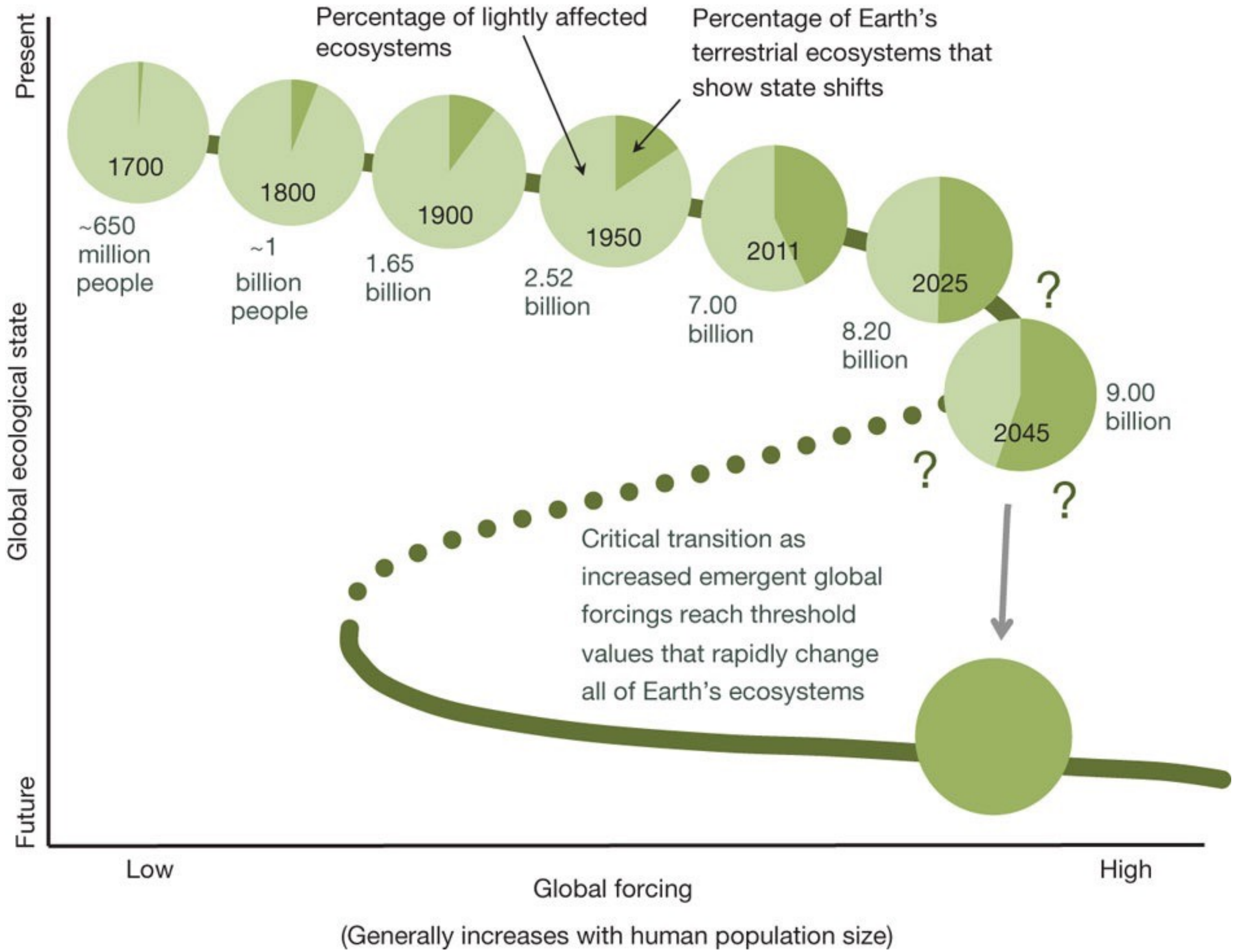

Barnosky et al., 2012, Nature, 486.

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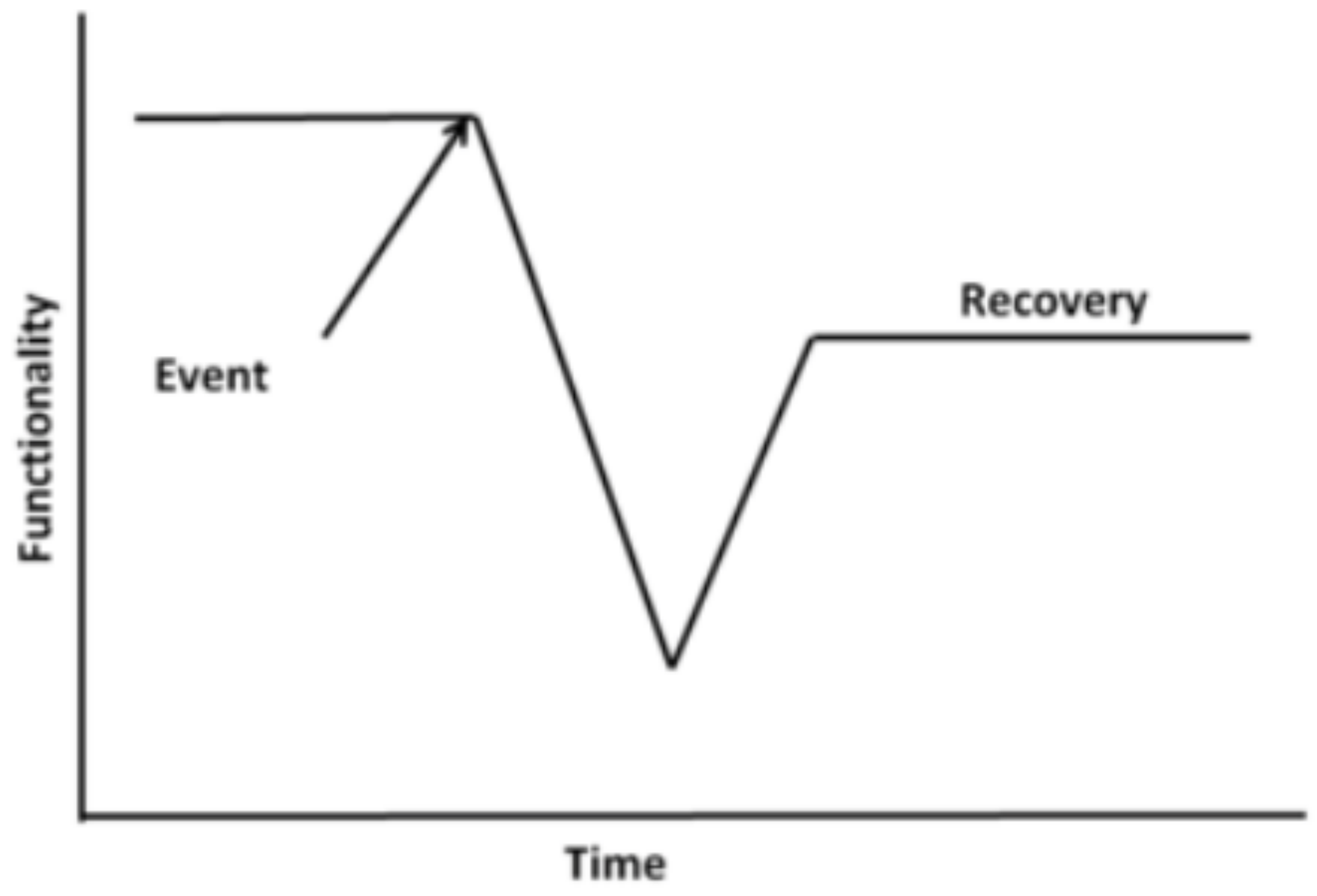
Resilience

"Resilience is the act of rebounding or springing back"
(Oxford English Dictionary, 1973)



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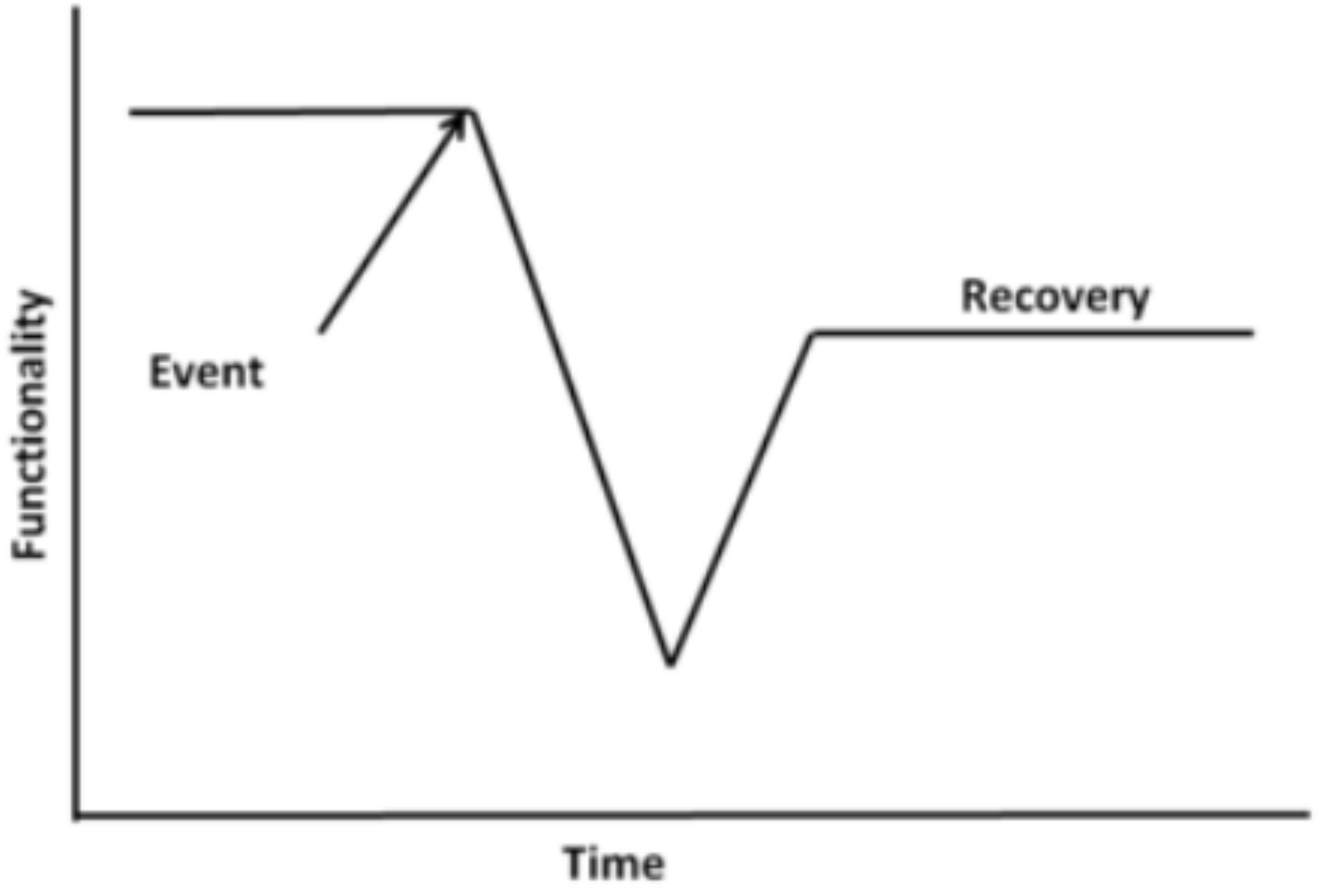
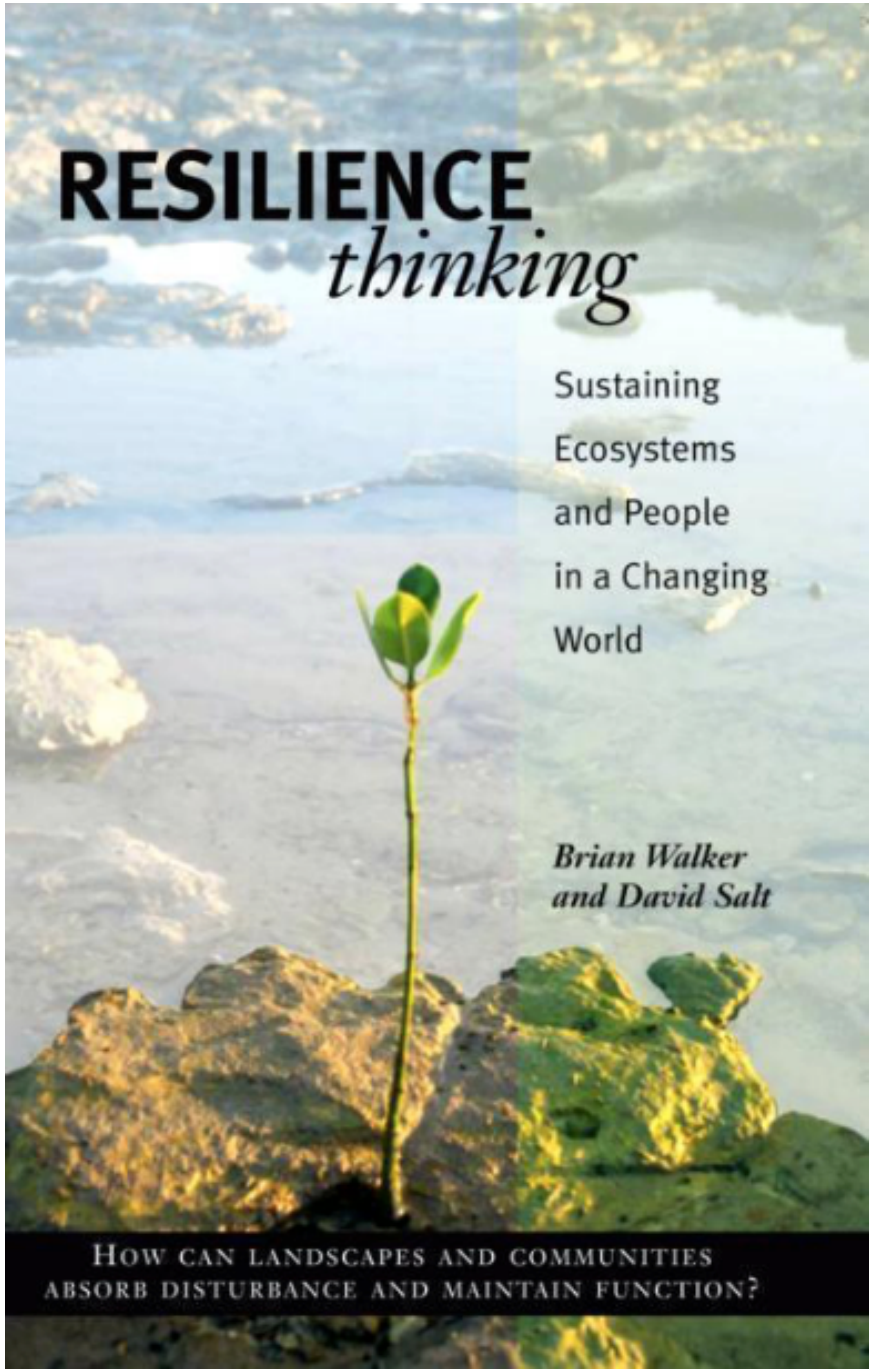


“Resilience is the capacity of a system to absorb disturbance and still retain its basic function and structure.”
Brian Walker PhD. Resilience Thinking: Sustaining Ecosystems and People in a Changing World.



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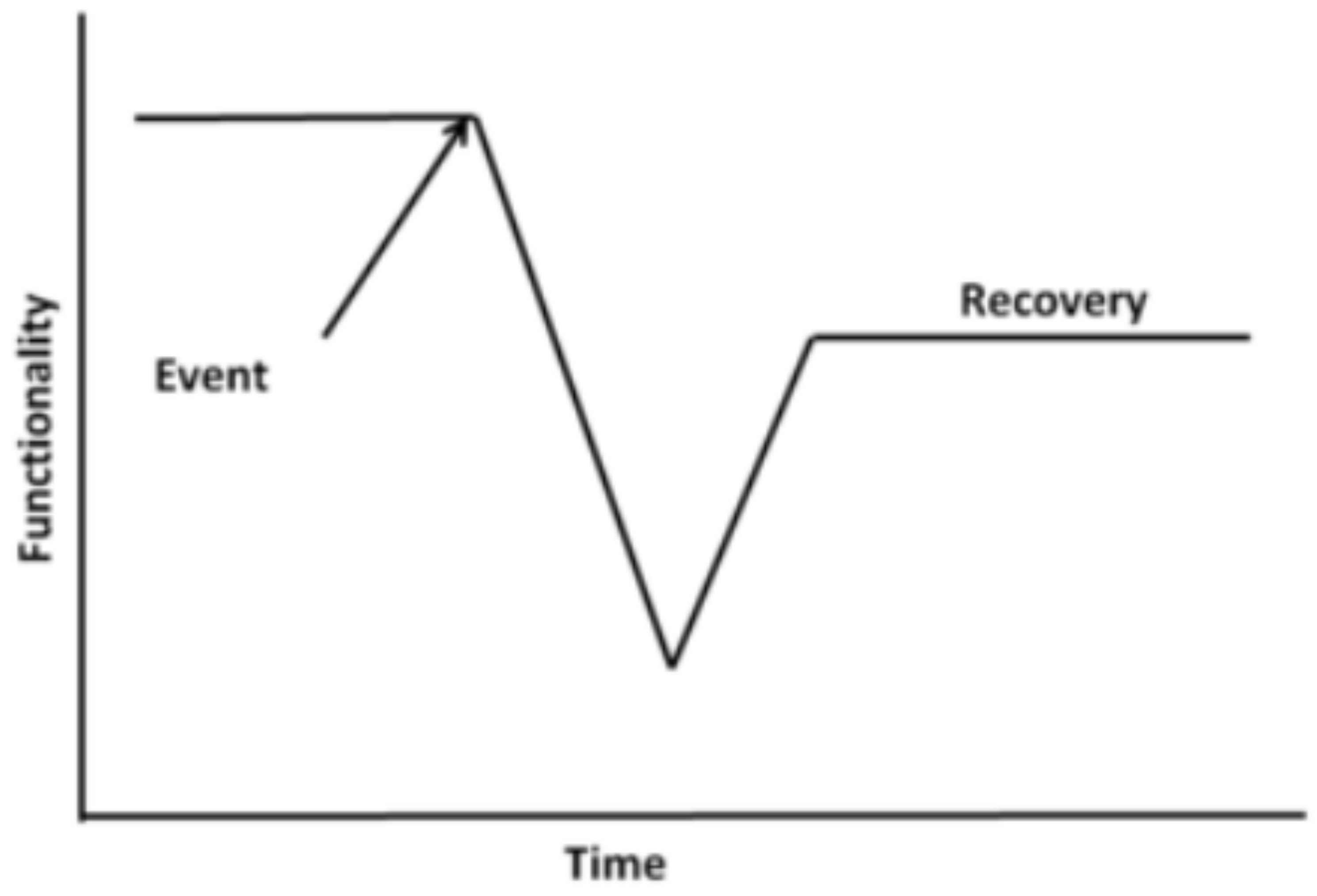

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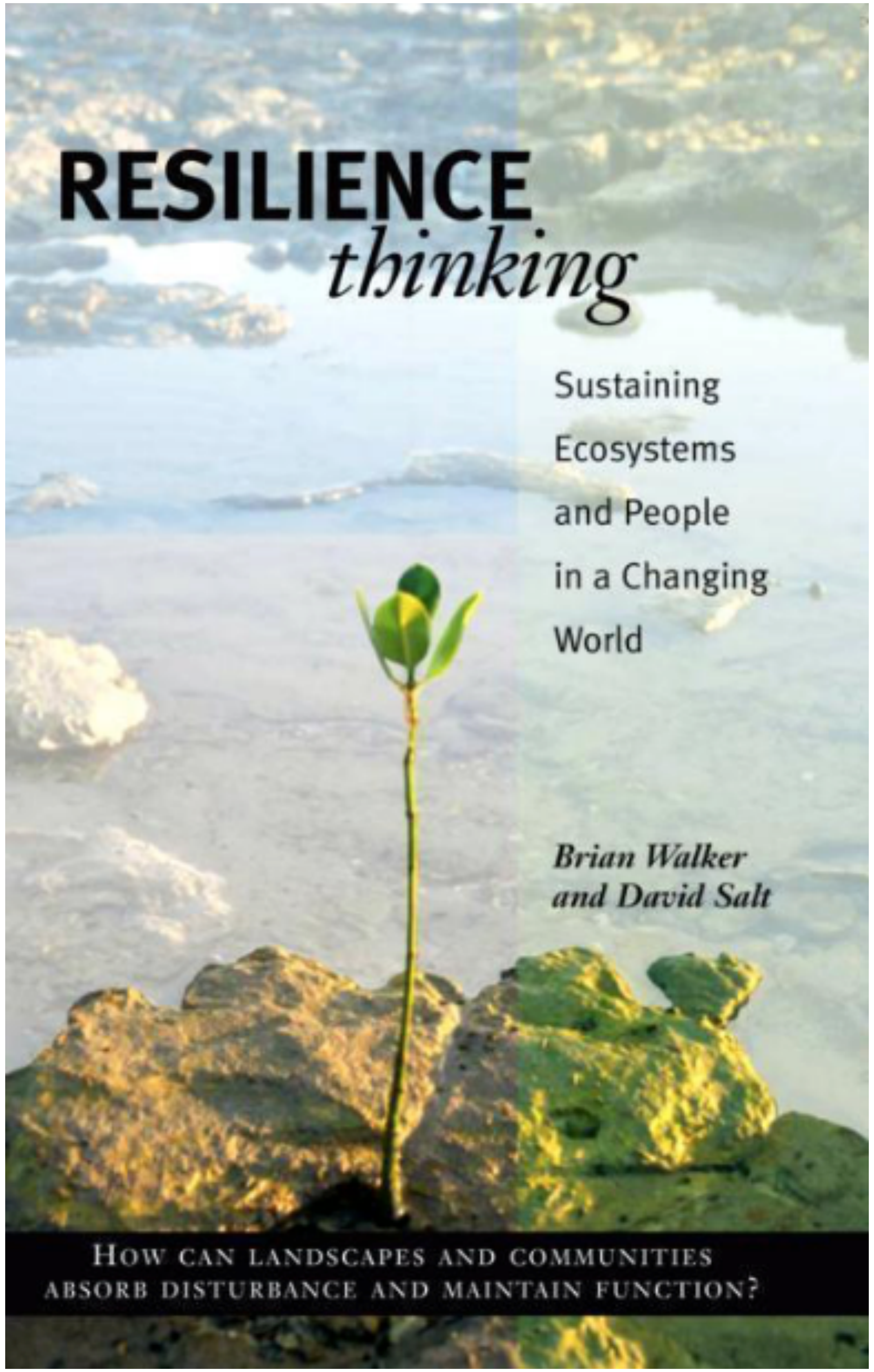
The Stockholm Resilience Centre (2015) explains that "resilience is the capacity of a system, be it an individual, a forest, a city or an economy, to deal with change and continue to develop. It is about how humans and nature can use shocks and disturbances like a financial crisis or climate change to spur renewal and innovative thinking."



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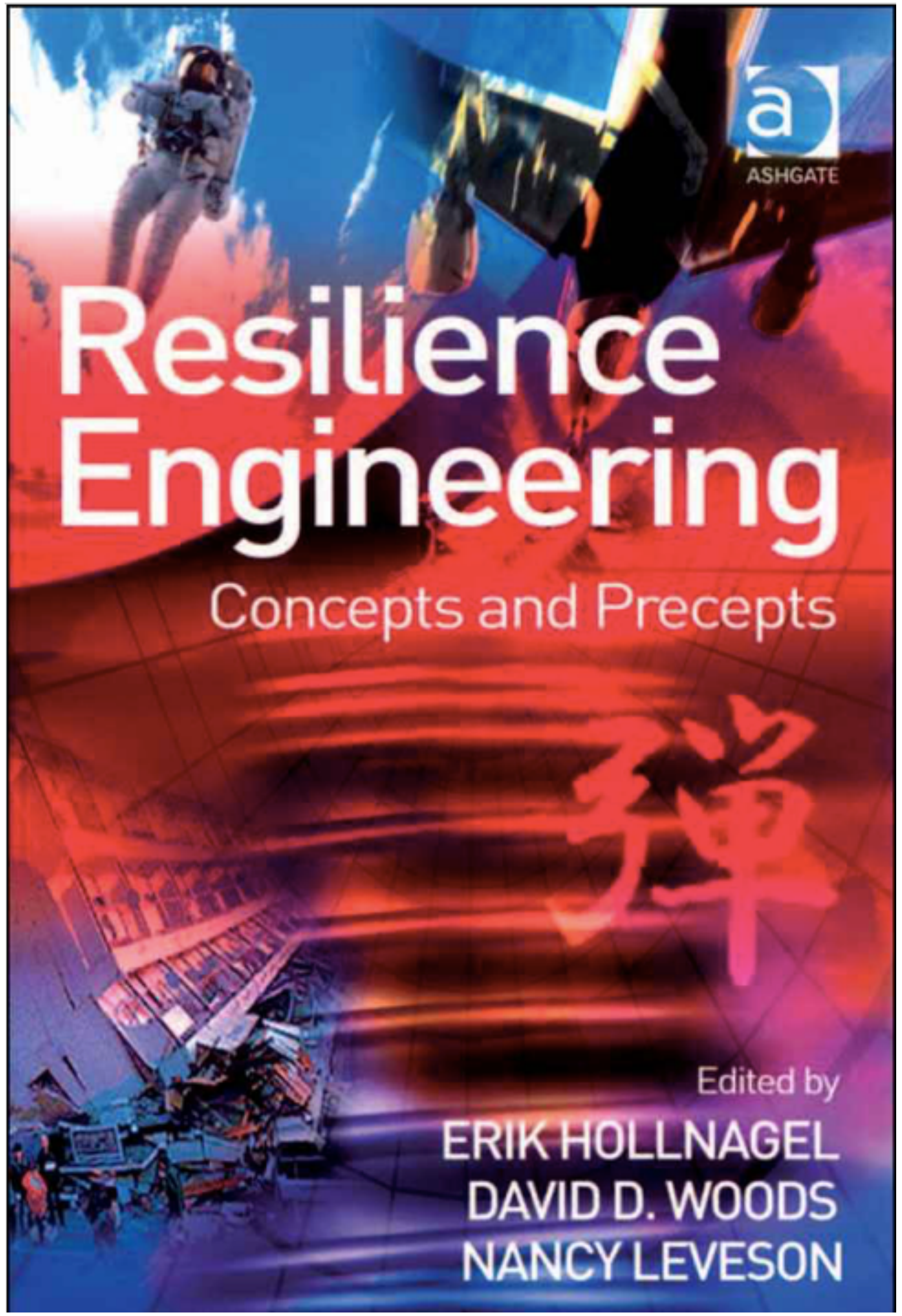
"I want to reserve resilience to refer to the broader capability – **how well can a system handle disruptions and variations** that fall outside of the base mechanisms/model for being adaptive as defined in that system."

Hollnagel in Woods, Professor David D. Resilience Engineering: Concepts and Precepts (Kindle Locations 487-488). Ashgate Publishing Ltd. Kindle Edition.



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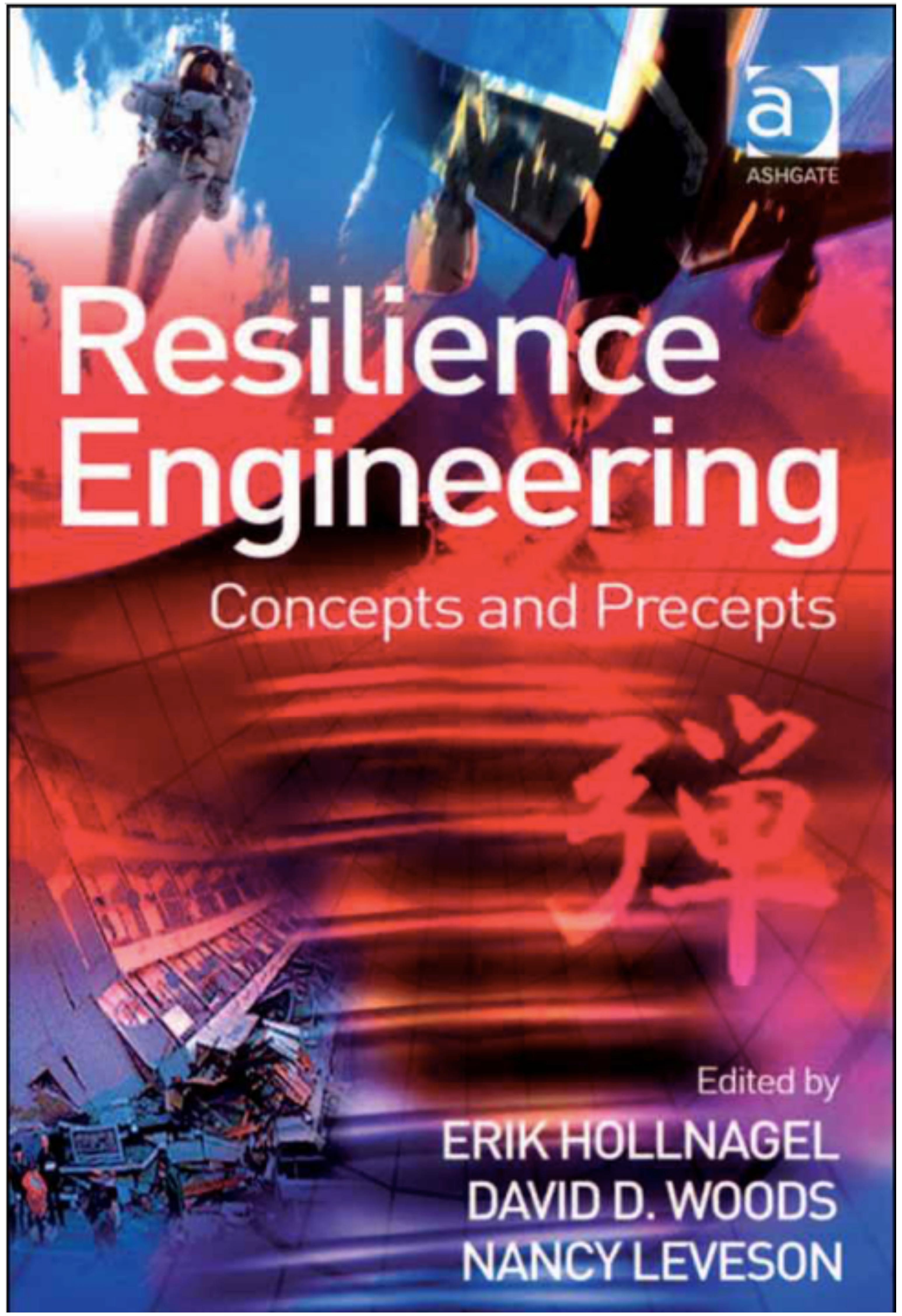
However, we would argue that we should extend the definition a little more broadly, in order to **encompass also the ability to avert the disaster or major upset**, using these same characteristics. Resilience then describes also the characteristic of managing the organisation’s activities to anticipate and circumvent threats to its existence and primary goals. This is shown in particular in an ability to manage severe pressures and conflicts between safety and the primary production or performance goals of the organisation.

Hale & Heijer, in Woods, Professor David D. Resilience Engineering: Concepts and Precepts (Kindle Locations 728-732). Ashgate Publishing Ltd. Kindle Edition.



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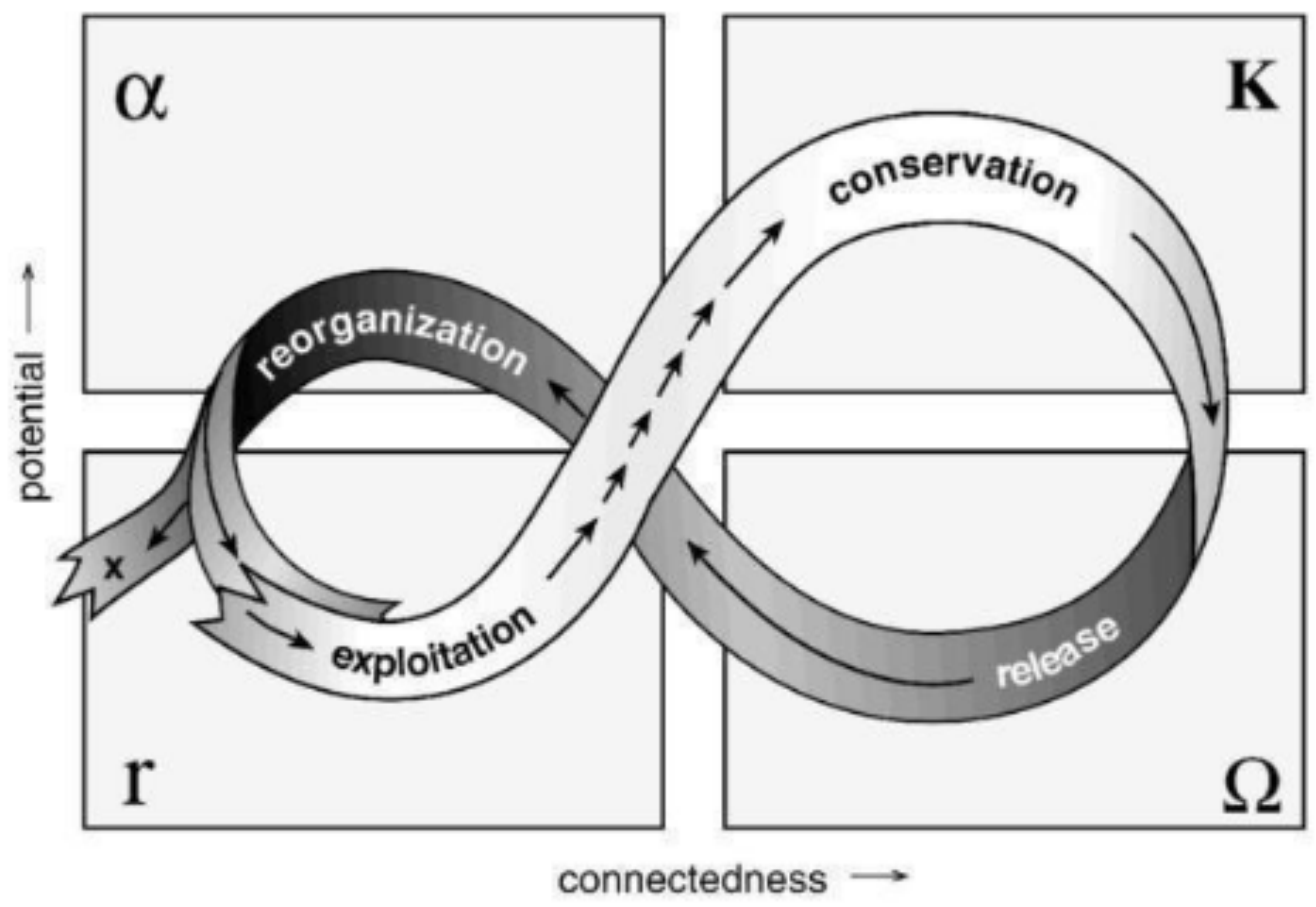
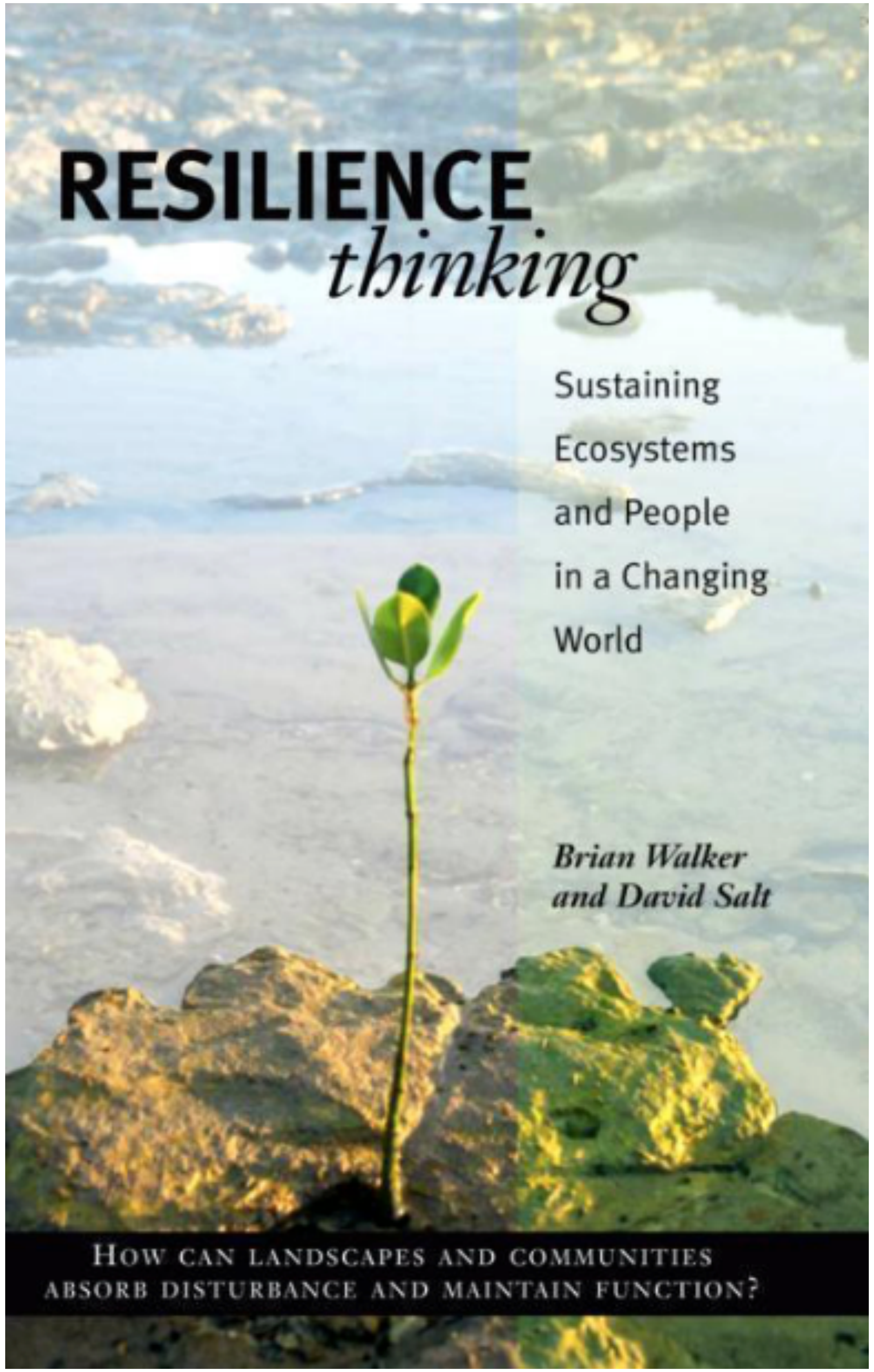


FIGURE 9 The First Version of the Adaptive Cycle

The first versions of the adaptive cycle pictured it as a figure 8 in two dimensions with the axes being connectedness and potential. Potential reflects accumulated growth and storage (biomass that is increasingly inactive like heartwood in trees or leaf litter). The use of the simpler loop, as shown in figure 10, has been adopted because it better reflects the passage from release to reorganization in some systems. However, because the adaptive cycle in the shape of the number 8 (as shown here in figure 9) was the original version it has iconic value, and it is often seen as a symbol of studies on resilience and adaptive cycles. *(From Gunderson and Holling, 2002)*



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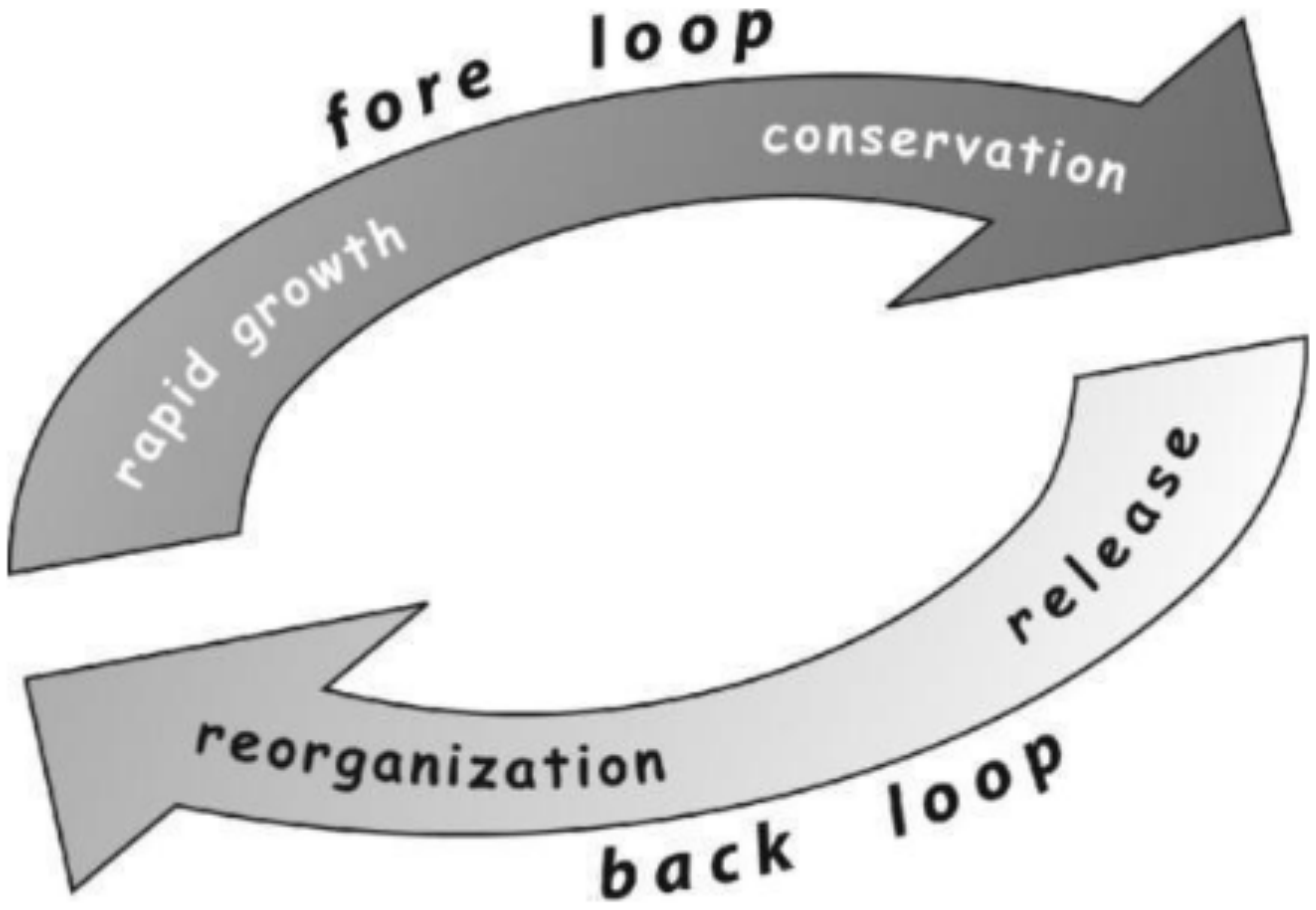
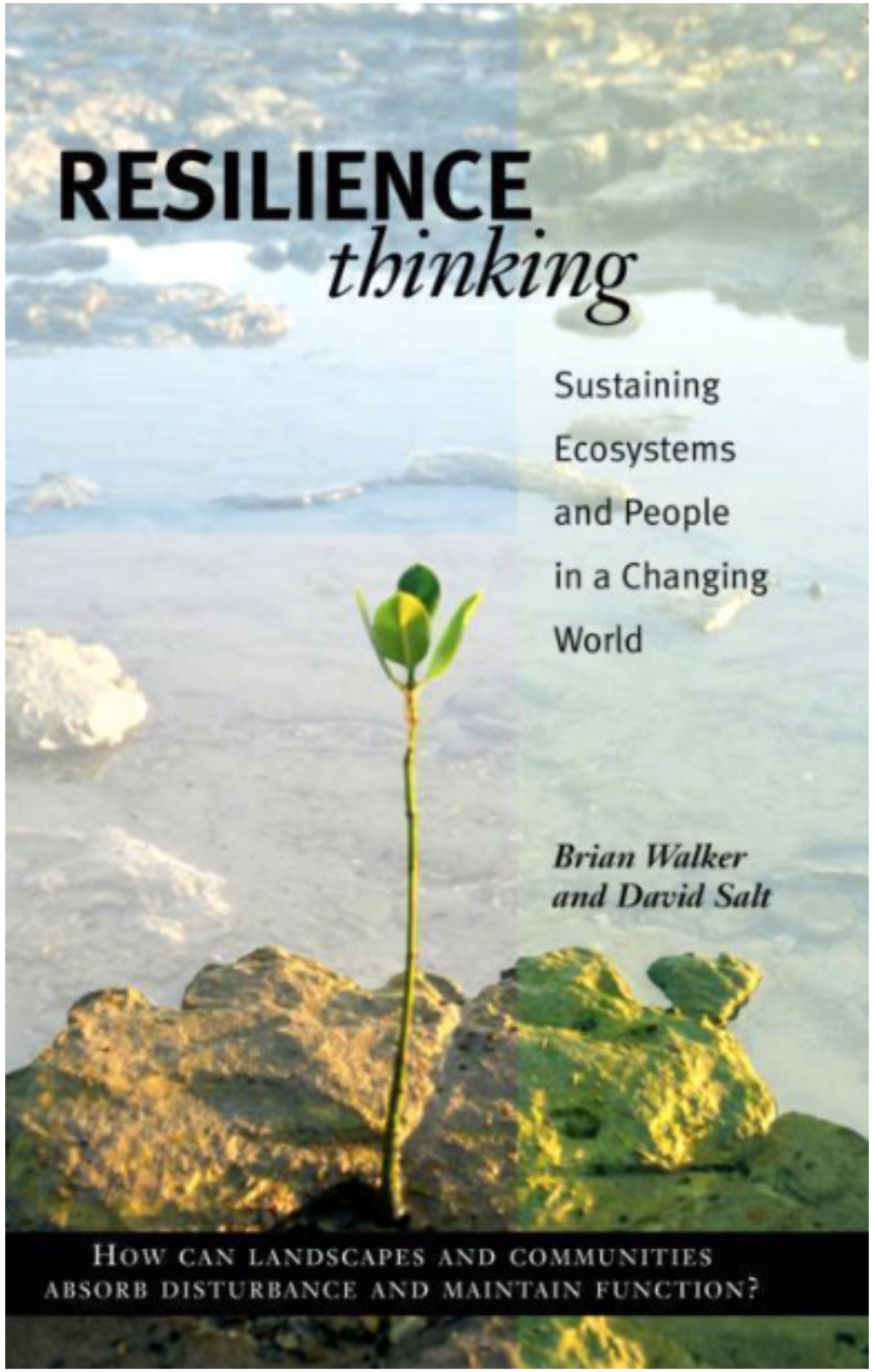


FIGURE 10 A Simple Representation of the Adaptive Cycle

The rapid growth and conservation phases are referred to as the fore loop with relatively predictable dynamics and in which there is a slow accumulation of capital and potential through stability and conservation. The release and reorganization phases are referred to as the back loop, characterized by uncertainty, novelty, and experimentation and during which there is a loss (leakage) of all forms of capital. The back loop is the time of greatest potential for the initiation of either destructive or creative change in the system.



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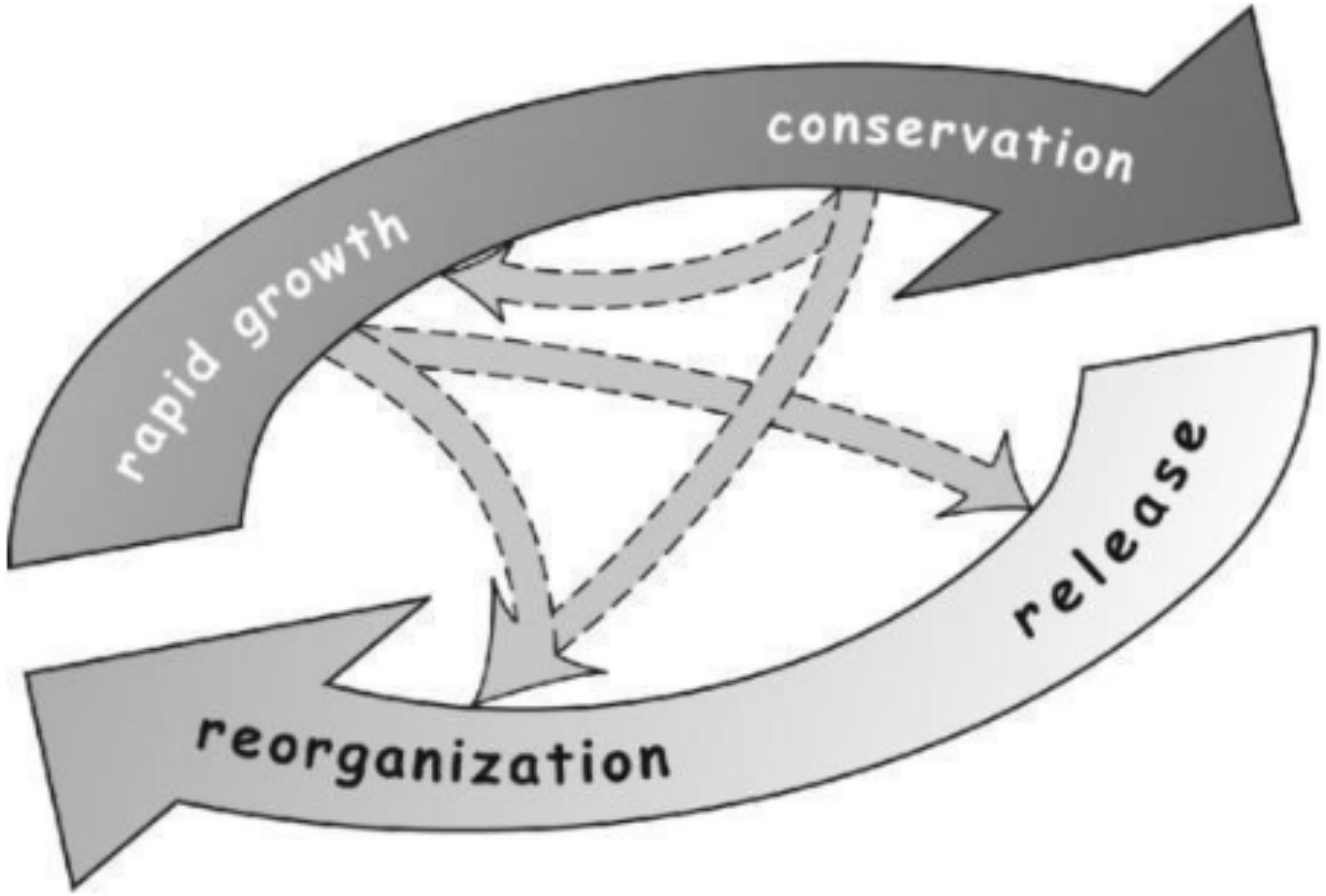
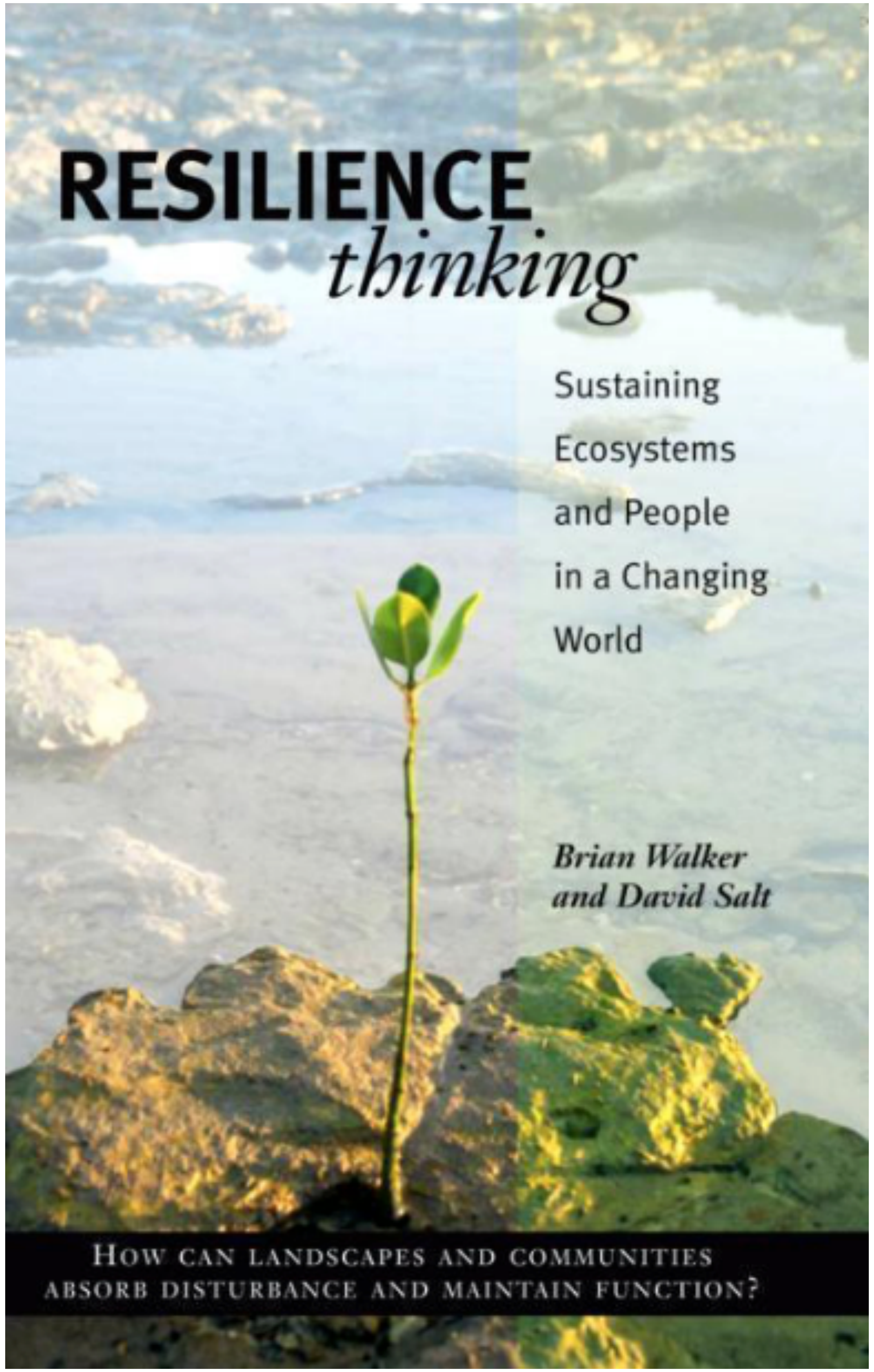


FIGURE 11 Variants of the Adaptive Cycle



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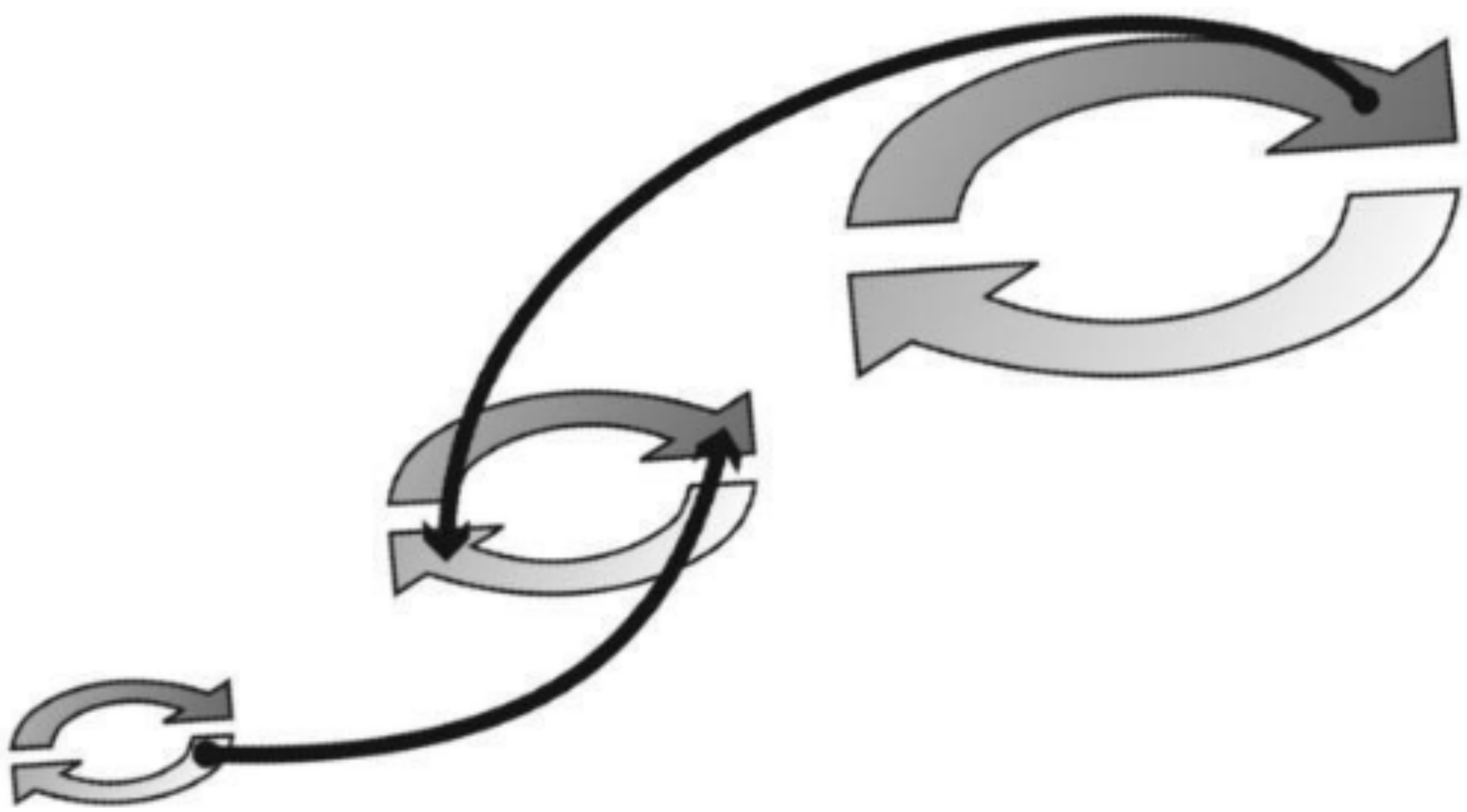
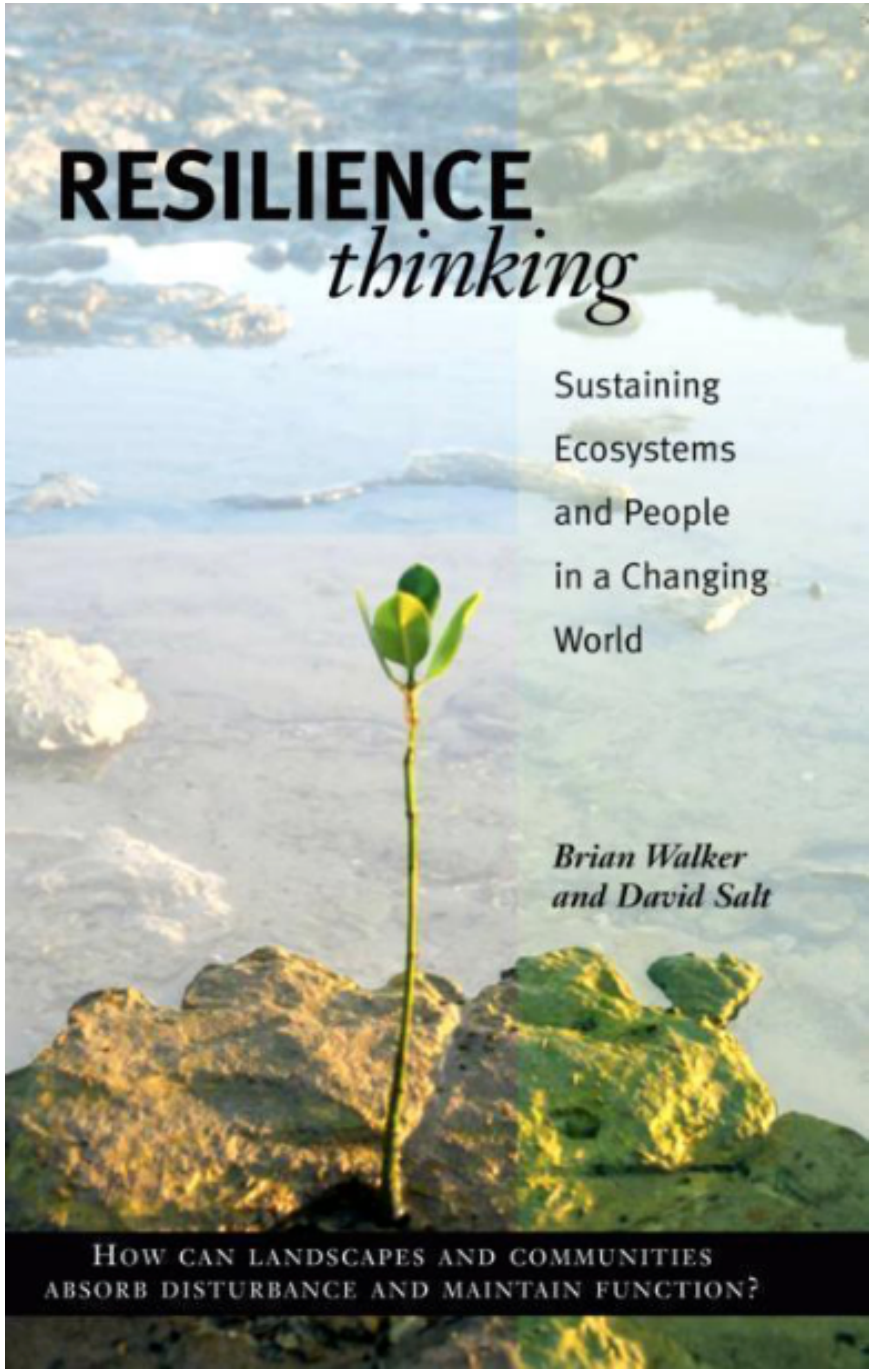


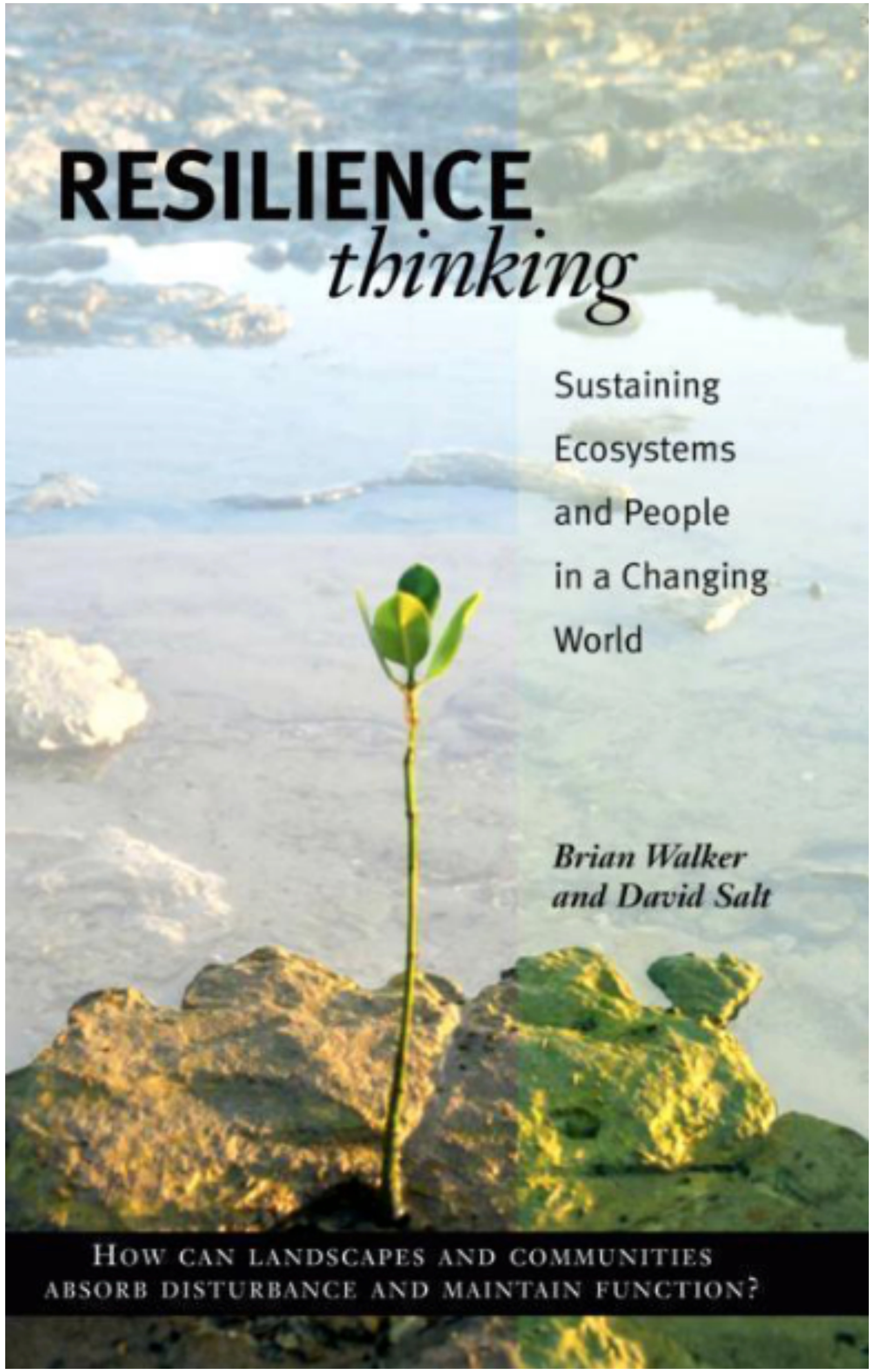
FIGURE 13 Panarchy Refers to Hierarchies of Linked Adaptive Cycles



Thresholds and Resilience Thinking

Thresholds (chapter 3) and the adaptive cycle metaphor are both central to resilience thinking. Adaptive cycles describe how many systems behave over time, and how resilience varies according to the phase where the system lies. Thresholds represent transitions between alternate regimes. While the **two concepts** can sometimes be related in the pattern of a particular system's dynamics, this not always the case. They are **different models used for different purposes**, and it is not always possible to equate the dynamics of a basin of attraction with the dynamics of an adaptive cycle. Where they do coincide, however, alternate regimes generally represent a new adaptive cycle, indicating that the system has new structures and feedbacks.

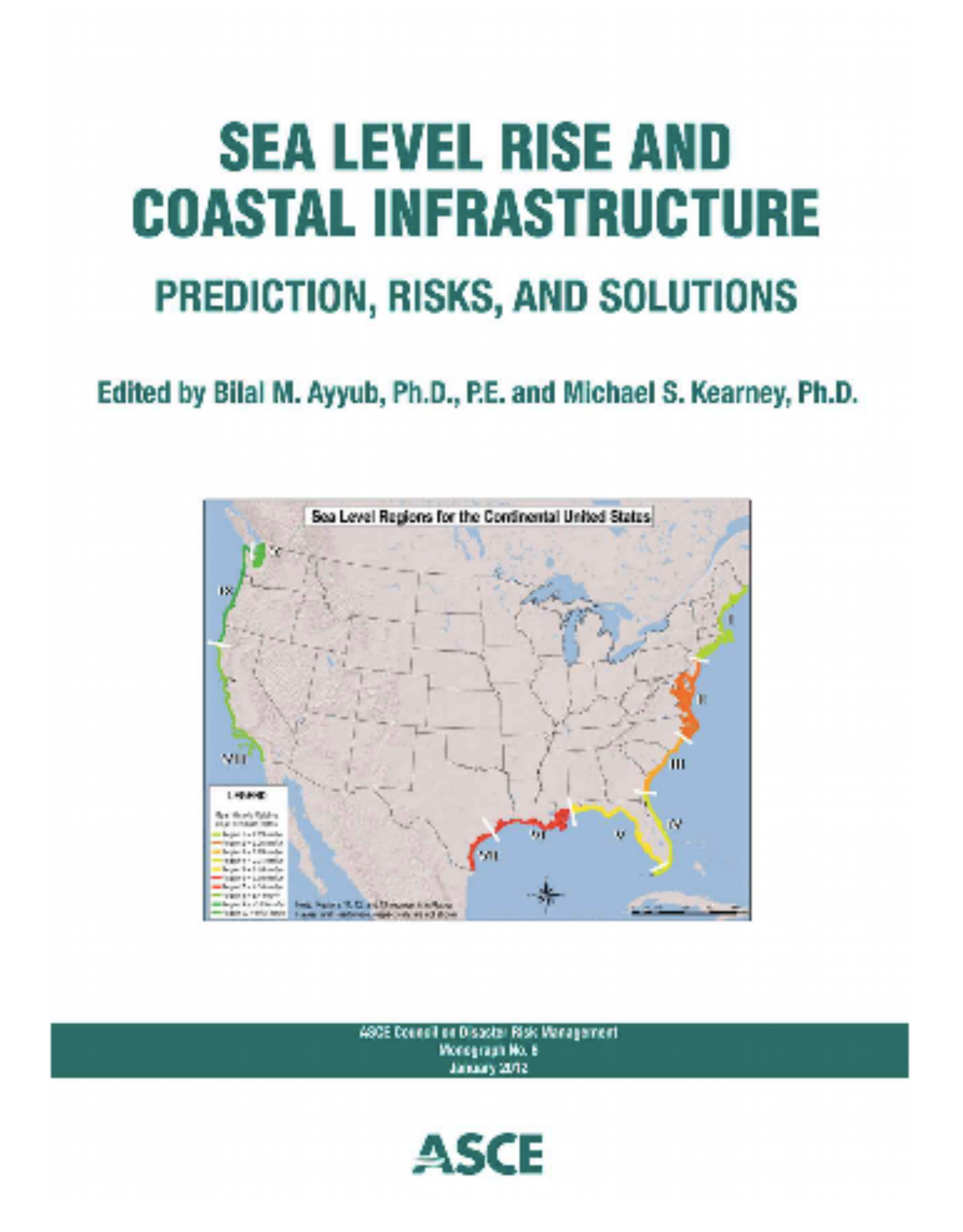
Brian Walker PhD. Resilience Thinking: Sustaining Ecosystems and People in a Changing World (Kindle Locations 1168-1170). Kindle Edition.



Resilience

Resilient systems bend under stress but do not break, so they are able to weather storms more effectively and recover more quickly. Adaptive systems are characterized by redundancy, diversity, efficiency, strength, interdependence, adaptability, and collaborativeness (Godschalk 2003). They are designed so that the failure of one part does not cause the whole system to collapse.

Ayyub, Bilal M.. Sea Level Rise and Coastal Infrastructure: Prediction, Risks, and Solutions (Council on Disaster Risk Management (CDRM) Monograph) (Kindle Locations 2359-2361). American Society of Civil Engineers. Kindle Edition.



Resilience

Content:

http://stockholmresilience.org/download/18.10119fc11455d3c557d6928/1459560241272/SRC+Applying+Resilience+final.pdf