

IBDP Environmental Systems and Societies (2026)

Topic 1 Foundation

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Ava SP



Door

Overview of ESS Foundation

Perspective

How do different perspectives develop?

How do perspectives affect the decisions we make concerning environmental issues?

~ 3 hours

Systems

How can the systems approach be used to model environmental issues at different levels of complexity and scale?

~ 5 hours

Sustainability

What is sustainability and how can it be measured?

To what extent are challenges of sustainable development also ones of environmental justice?

~ 8 hours

1.2 Systems

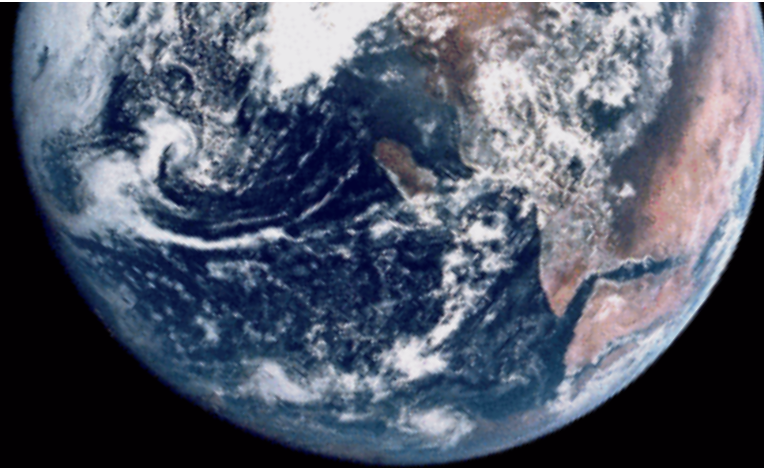
1.2.1 Systems are sets of interacting or interdependent components.	1.2.10 Positive feedback loops occur when a disturbance leads to an amplification of that disturbance, destabilizing the system and driving it away from its equilibrium.
1.2.2 A systems approach is a holistic way of visualizing a complex set of interactions, and it can be applied to ecological or societal situations.	1.2.11 Positive feedback loops will tend to drive the system toward a tipping point.
1.2.3 In system diagrams, storages are usually represented as rectangular boxes and flows as arrows, with the direction of each arrow indicating the direction of each flow.	1.2.12 Tipping points can exist within a system where a small alteration in one component can produce large overall changes, resulting in a shift in equilibrium.
1.2.4 Flows are processes that may be either transfers or transformations.	1.2.13 A model is a simplified representation of reality; it can be used to understand how a system works and to predict how it will respond to change.
1.2.5 Systems can be open or closed.	1.2.14 Simplification of a model involves approximation and, therefore, loss of accuracy.
1.2.6 The Earth is a single integrated system encompassing the biosphere, the hydrosphere, the cryosphere, the geosphere, the atmosphere and the anthroposphere.	1.2.15 Interactions between components in systems can generate emergent properties.
1.2.7 The concept of a system can be applied at a range of scales.	1.2.16 The resilience of a system, ecological or social, refers to its tendency to avoid tipping points and maintain stability.
1.2.8 Negative feedback loops occur when the output of a process inhibits or reverses the operation of the same process in such a way as to reduce change. They are stabilizing as they counteract deviation.	1.2.17 Diversity and the size of storages within systems can contribute to their resilience and affect their speed of response to change (time lags).
1.2.9 As an open system, an ecosystem will normally exist in a stable equilibrium, either in a steady-state equilibrium or in one developing over time (for example, succession) and will be maintained by stabilizing negative feedback loops.	1.2.18 Humans can affect the resilience of systems through reducing these storages and diversity.

1.2.1 Introduction to Systems

1.2.1 Learning Objectives

1. Outline the components of an environmental system
2. Define transfer and transformation in terms of environmental systems
3. Construct a system diagram of a lake
4. Evaluate the use of models (diagrams) to represent environmental systems
5. Describe system equilibria and feedback loops

A system is a collection of inter-related components and their relationships, which together create a unified, complex whole, giving rise to emergent properties.



The Earth is a closed system

Gaia Hypothesis:

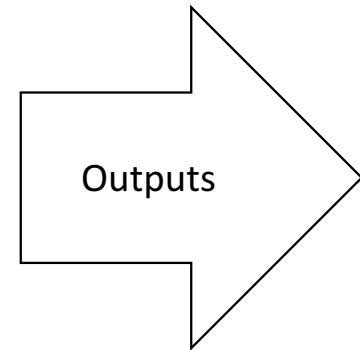
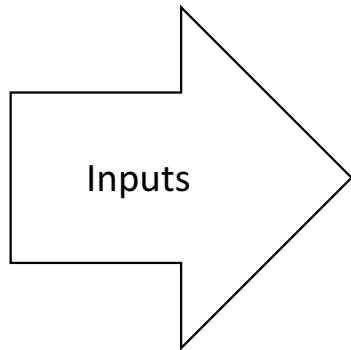
“living organisms interact with their inorganic surroundings on Earth to form a synergistic and self-regulating complex system that helps to maintain and perpetuate the conditions for life on the planet”

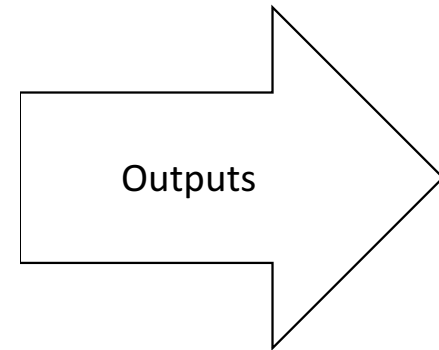
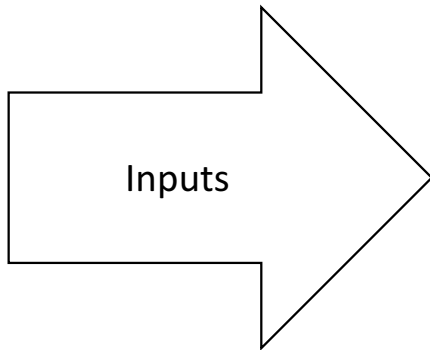
Biosphere as a system

The biosphere is a big system consisting of many different systems “spheres”

- The anthroposphere refers to the parts of Earth that are created or modified by humans.
 - This includes cities, towns, roads, machines, ports, energy systems, mines, and agricultural land used for crops and livestock.
 - The anthroposphere reduces the natural biosphere by degrading land and damaging habitats.
- Atmosphere (air)
- Geosphere
 - Lithosphere (rocks)
 - Pedosphere (soil)
- Hydrosphere
- Cryosphere

Components of a system





Input: what the tree takes in?

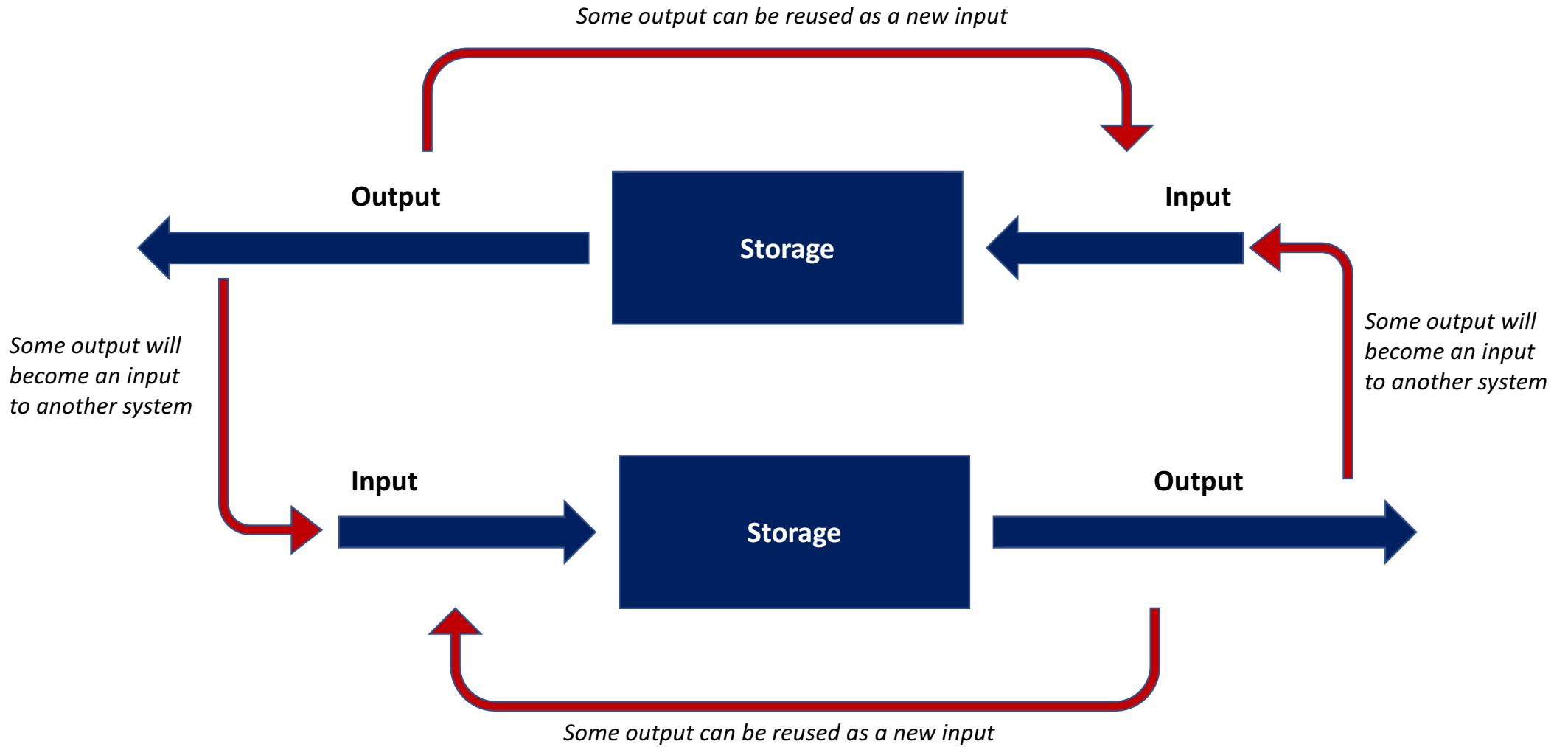
Storage: Tree

Output: what the tree gives out?

What is stored here?

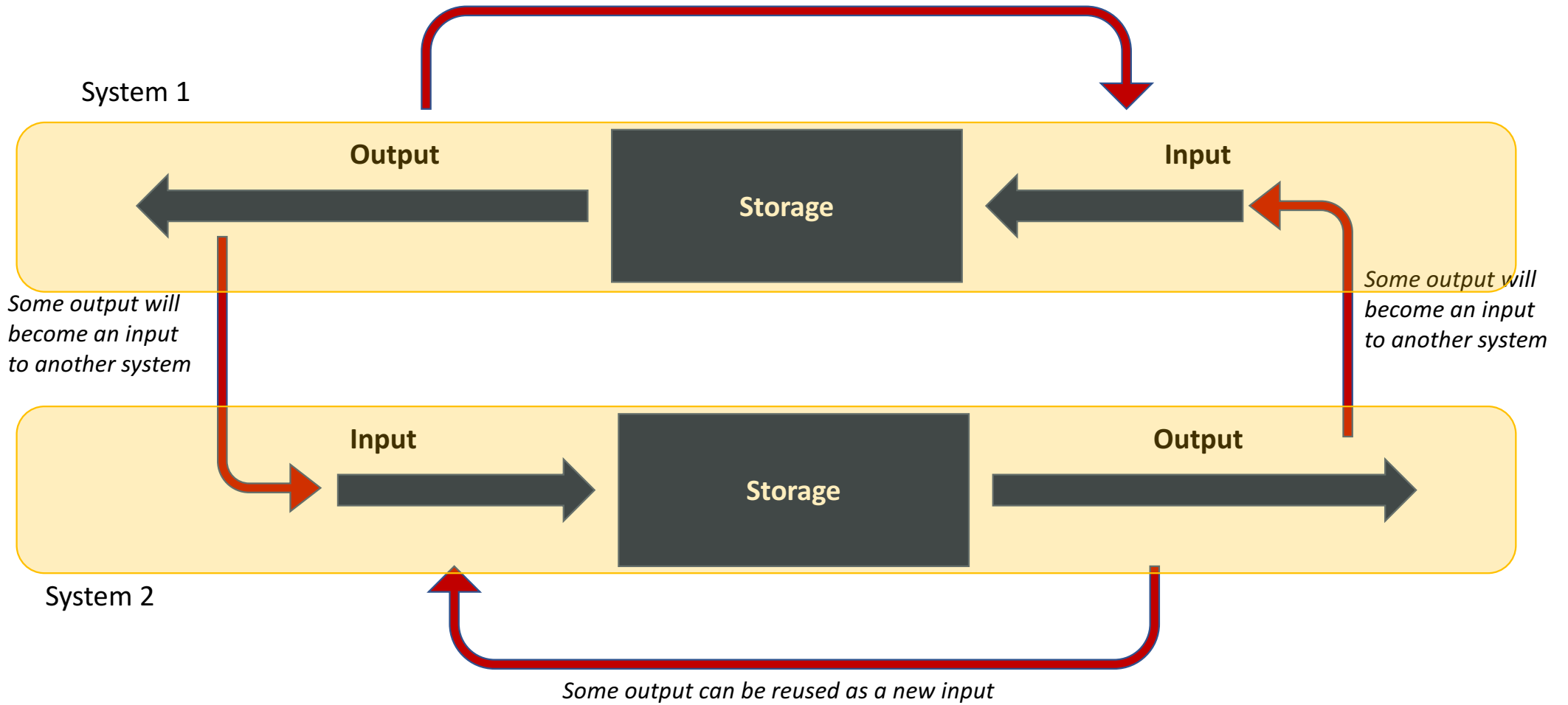


Systems...



Systems...

Some output can be reused as a new input



Activity 1: Input, output, storages between and within these two systems?

System 1

System 2

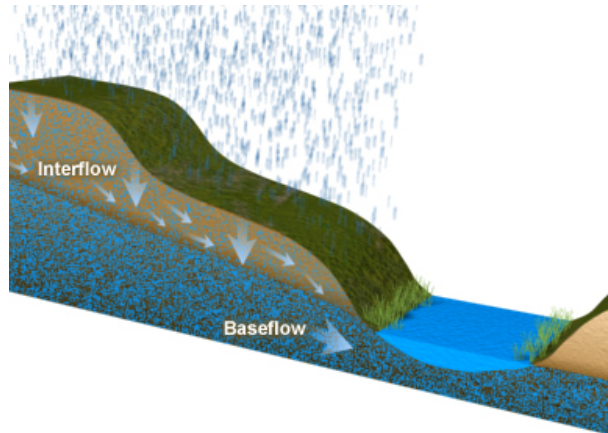


Flows within and between systems

Flow of energy and matter can be:

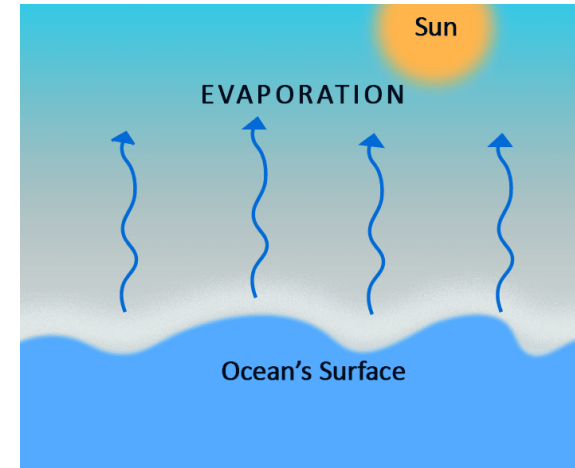
Transfer

change in location / place



Transformation

change in energy or/and change in chemical nature and state



Activity 2: What are the flows?



Types of Flows: Transfer vs. Transformation

- Transfers = flow through the system, involving a change in location
- Transformation = lead to interactions in the system, changes of state or forming new end products

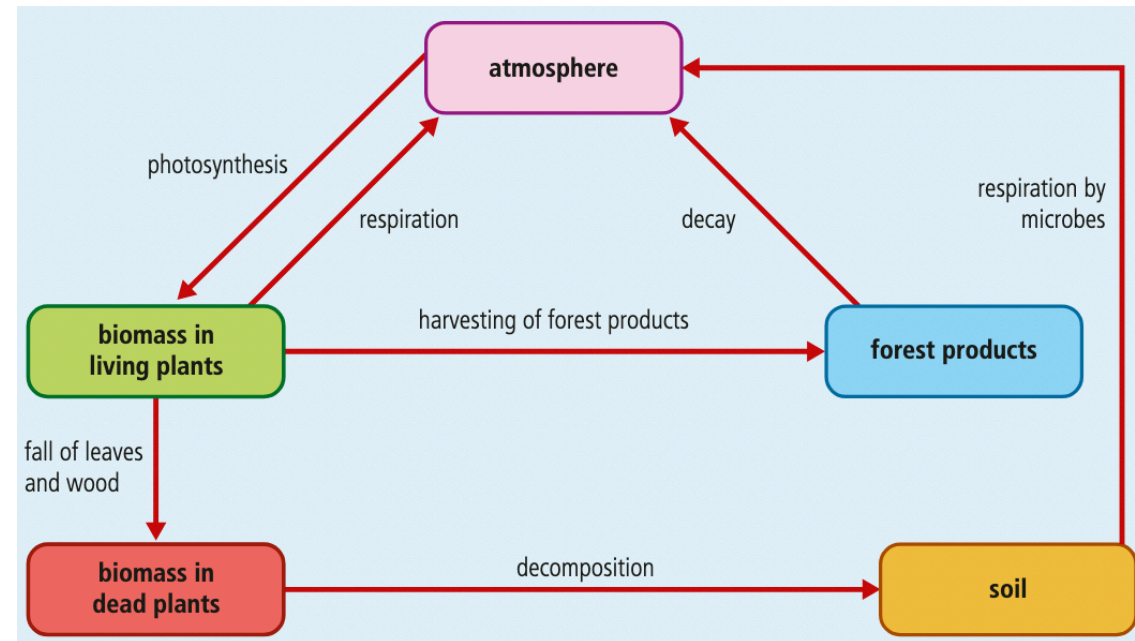
For example, in a lake water system:

- Runoff from mountain, rivers flowing into lake = input
- Evaporation = output
- Detritus entering lake = transfer
- Decomposition of detritus = transformation



A System Approach

- Sizes of boxes and arrows can be used to indicate the magnitude
- **Flow** of energy and matter can be:
 - Transferred = change in location / place
 - Transformed = change in energy or/and change in chemical nature and state

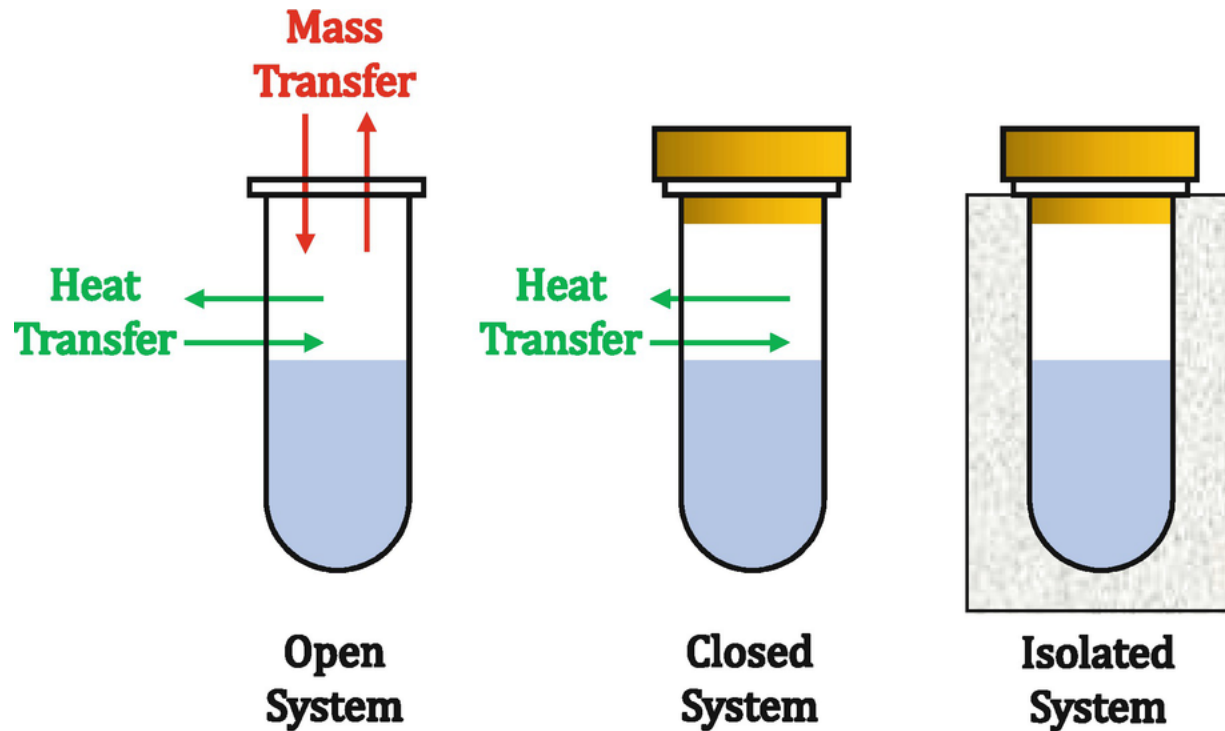


Systems can be open or closed

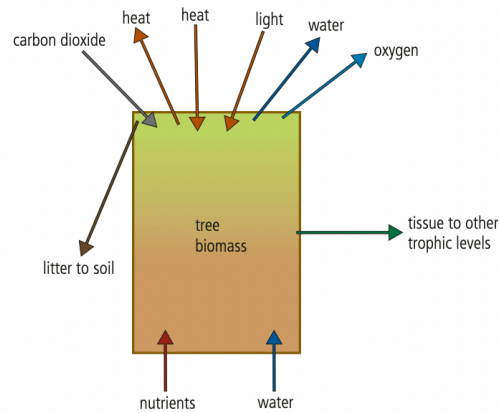
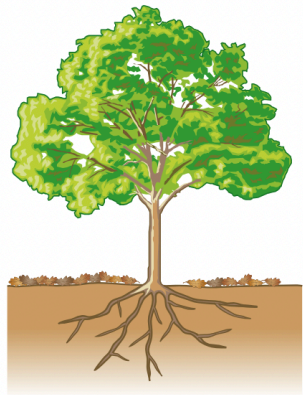
- An open system exchanges both energy and matter across its boundary, while a closed system exchanges only energy across its boundary.
- Almost all systems are open; only the global geochemical cycles approximate to closed systems.
- Biosphere 2 is an example of a closed system, and a local ecosystem is an example of an open system.
- Various scales of systems:
 - Ecosystem – the Amazon rainforest
 - Biome – Tropical Rainforest
 - The entire planet – Gaia hypothesis

Types of Systems

What are open, closed and isolated systems?



A System Approach



Coral Reef
Ecosystem -Most diverse aquatic
ecosystem in the world

Open or closed?



A System Approach

Coral Reef
Ecosystem -Most diverse aquatic
ecosystem in the world

Open systems

exchange matter and energy with the
surroundings

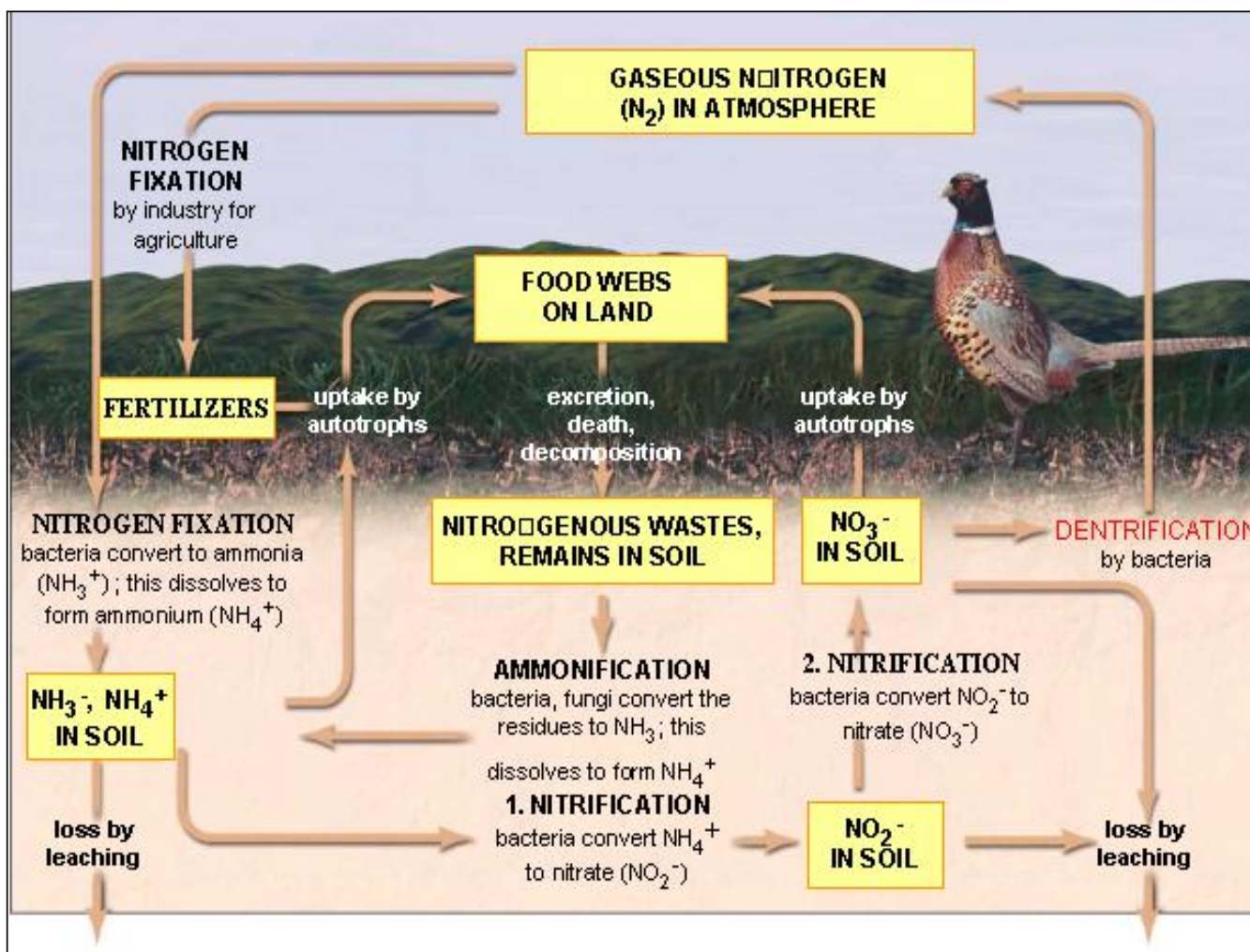


Closed systems exchange energy but not matter.
– the Earth is the only closed system in nature

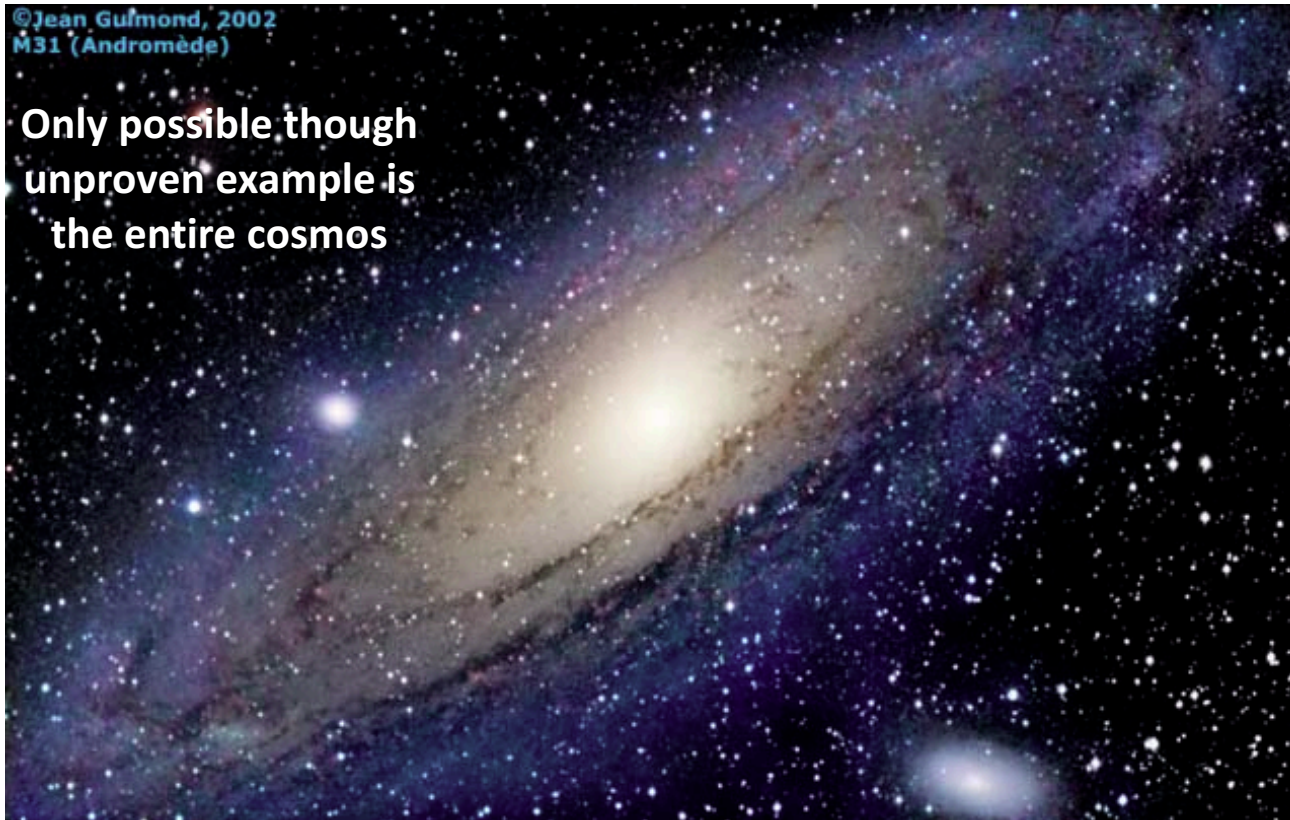


Biosphere II Built as self sustaining closed system in 1991 in Tuscon, AZ
Experiment failed when nutrient cycling broke down

Nutrient cycles (overall) approximate closed systems as well

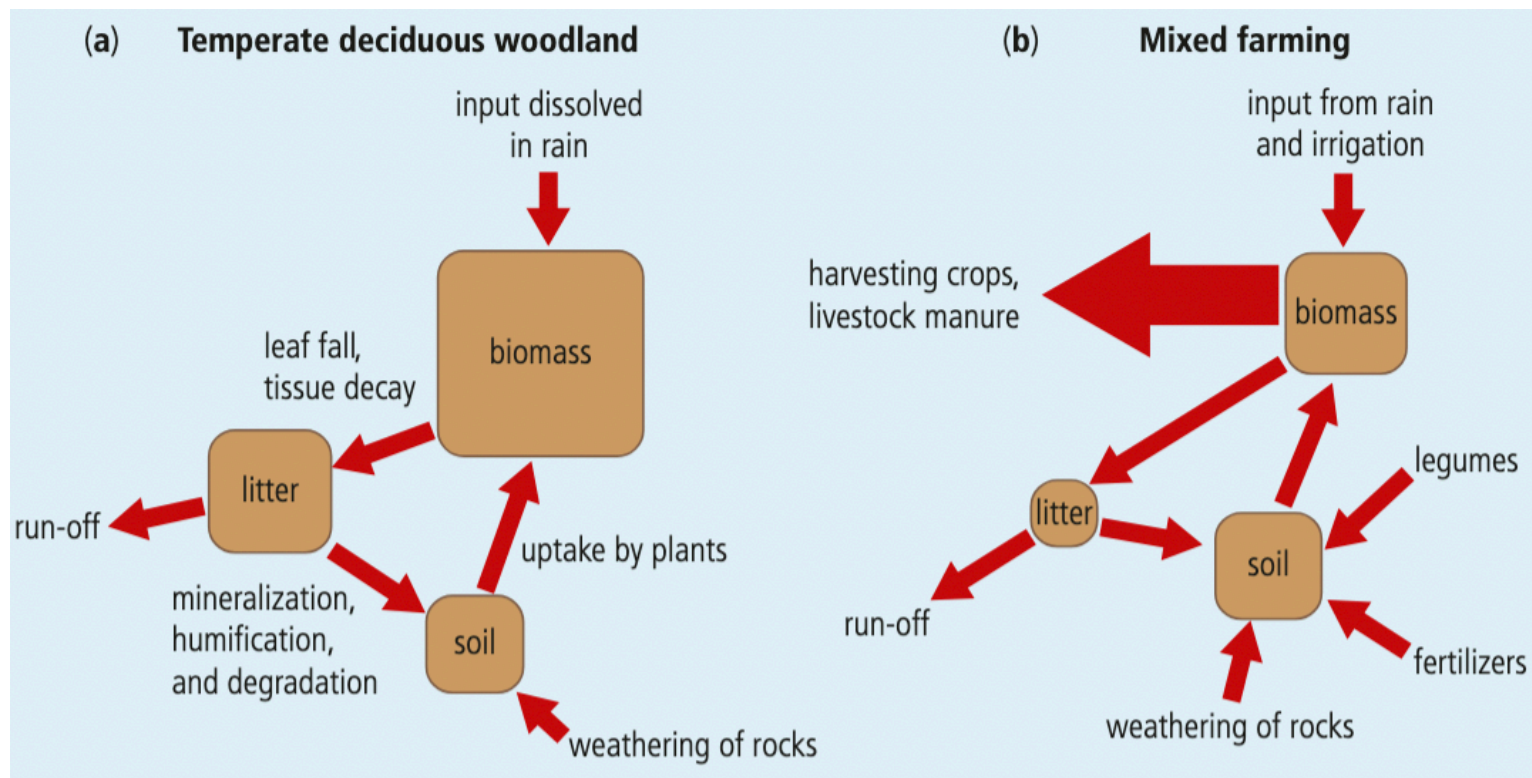


Isolated systems exchange neither matter nor energy with the surroundings



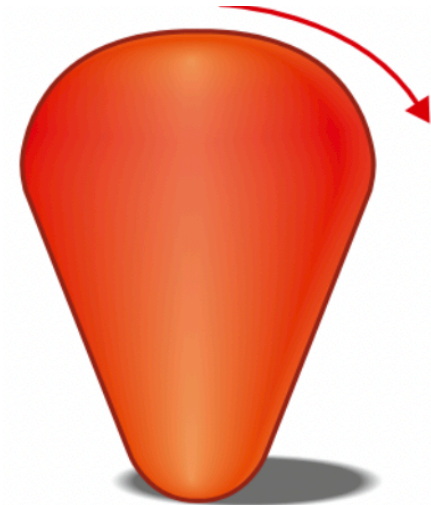
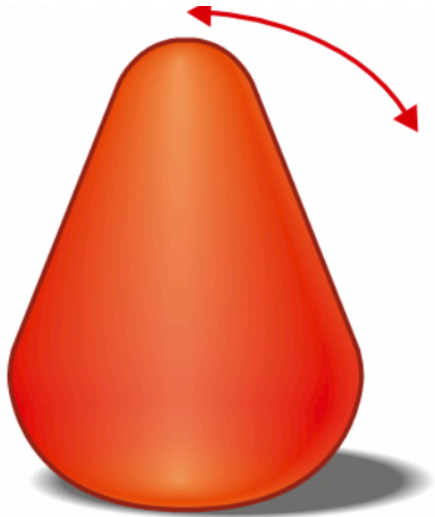
Activity 4

Illustrate a simple system diagram in woodland or a mixed farming land



System Equilibria

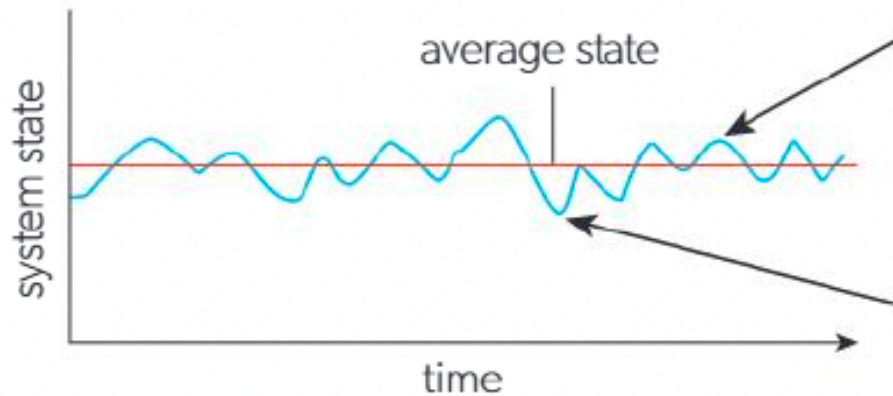
Stable Vs Unstable Equilibria



Equilibrium

- Open systems tend toward steady-state equilibrium, maintaining balance within limits despite ongoing changes.
- Examples:
 - Water tank: inflow = outflow → level stays constant.
 - Economic markets: continuous capital flows but overall stability.
 - Ecological populations: births = deaths → stable numbers.
 - Mature forest ecosystem: energy & matter inputs = outputs → long-term balance.
 - Human body temperature regulation: sweating to cool, shivering to warm.
- Equilibrium is maintained by negative feedback mechanisms.

Maintaining steady-state equilibrium

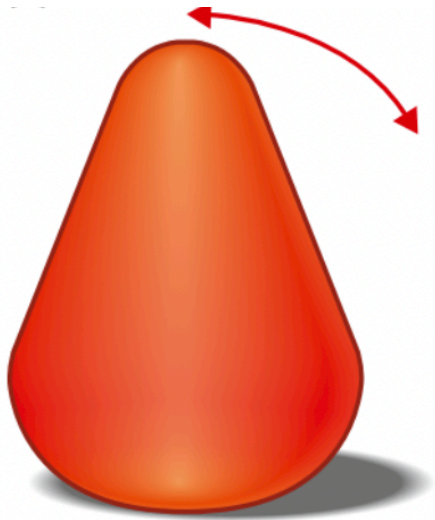


Too many products, a negative feedback loop returns the state to the "average state"

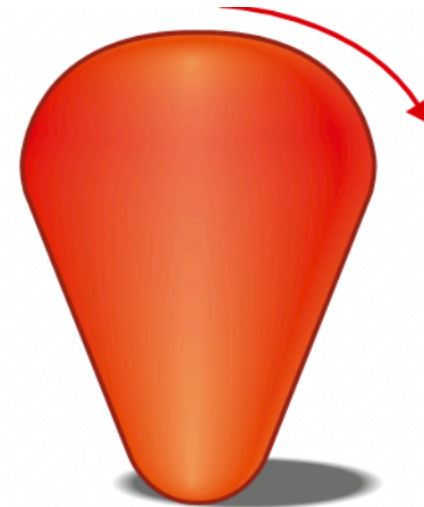
Too little products, a negative feedback loop returns the state to the "average state"

Stable Vs Unstable Equilibria

Stable equilibrium



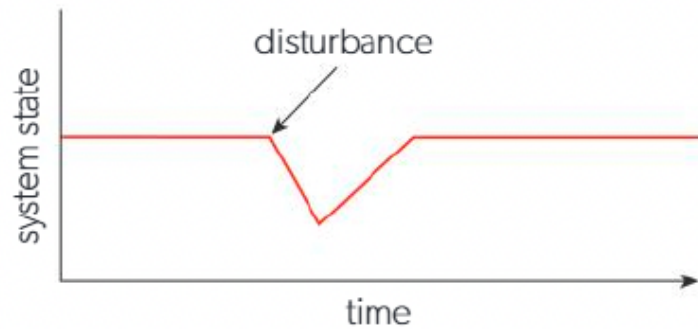
Unstable equilibrium



Stable Vs Unstable Equilibria

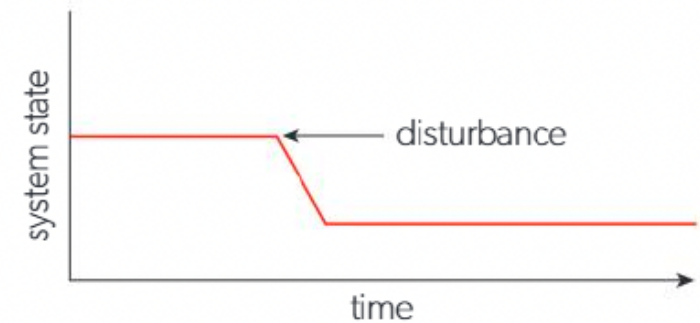
Stable equilibrium

system returns to original state after disturbance (e.g., body temperature regulation).



Unstable equilibrium

system shifts to a new state after disturbance.



The use system models

A model is a simplified representation of reality, used to understand systems and predict changes. Systems follow rules, but humans don't always know them fully, so models help explore scenarios.

Pros and cons of environmental models

Strengths of models:

- Simpler to work with than reality.
- Useful for predicting effects of input changes.
- Applicable to similar situations.

Limitations:

- They cannot capture the full complexity of real systems.
- Assumptions and simplifications may limit accuracy.

1.2.2 Feedback Loops, Tipping Point and Resilience

1.2.2 Learning Objectives

1. Describe, using named examples, the negative and positive feedback loops
2. Outline the meaning of system's tipping point
3. Describe the factors affecting a system's resilience
4. Evaluate the use of environmental models

Feedback Loop Mechanism

- Systems are influenced by both internal and external information, leading to responses:
 - Example 1: Feeling cold (information) → putting on clothes or turning on heating (response).
 - Example 2: Feeling hungry (information) → eating or not eating (response).

Types of Feedback Loop

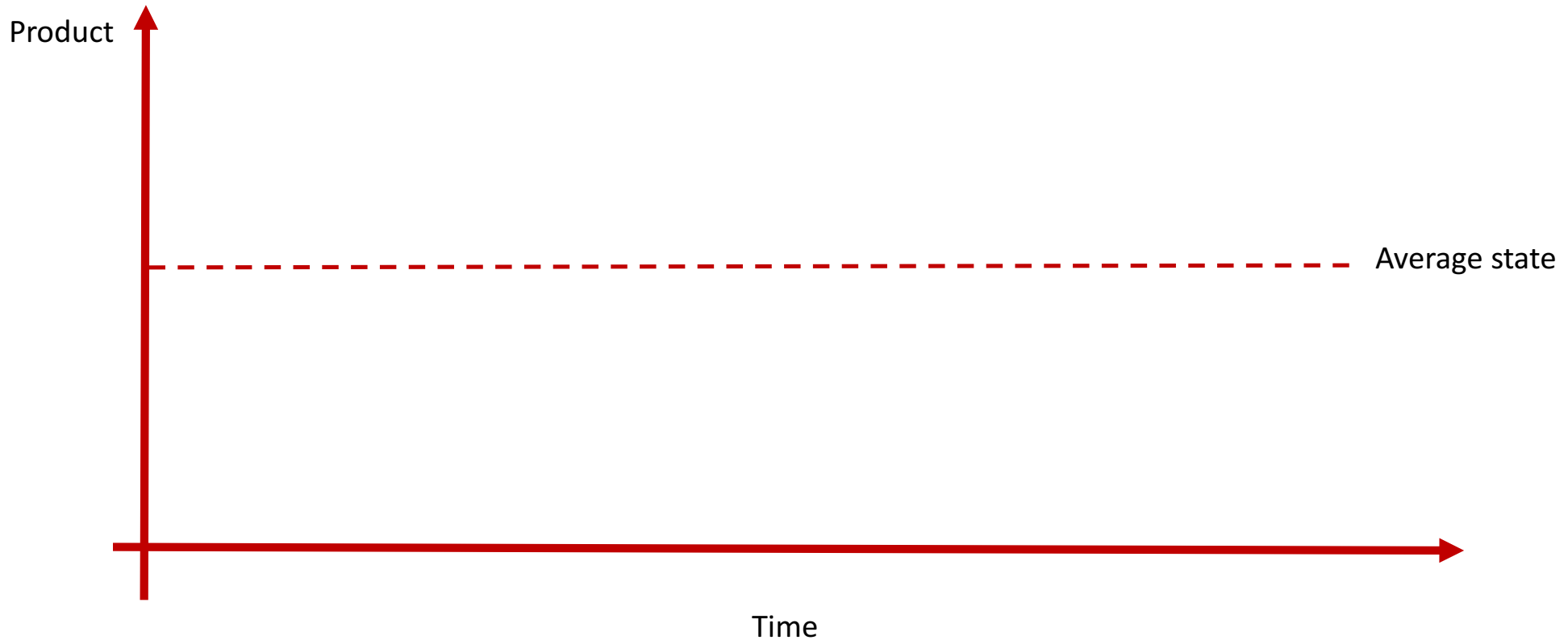
Negative Feedback

- Helps maintain stability by counteracting changes
- Reducing impacts or changes

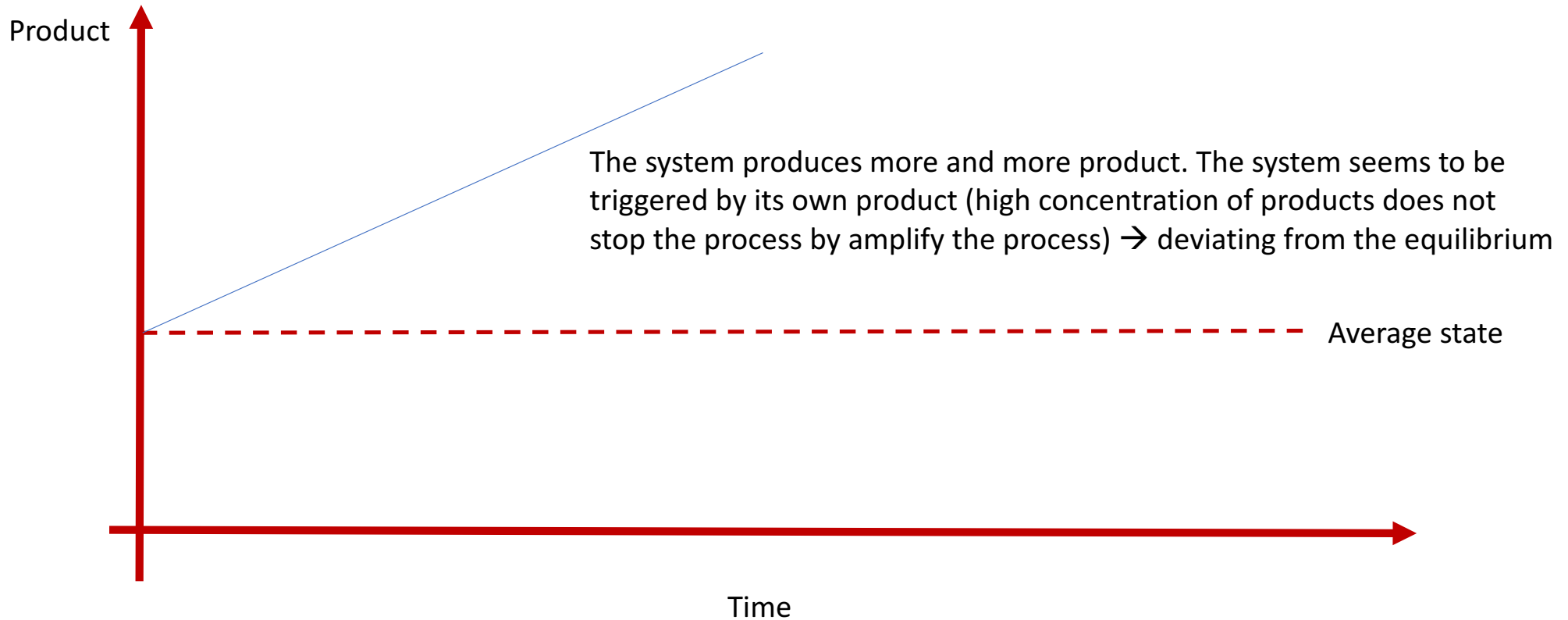
Positive Feedback

- Reinforces changes, often leading to instability.
- Amplifying impacts or changes

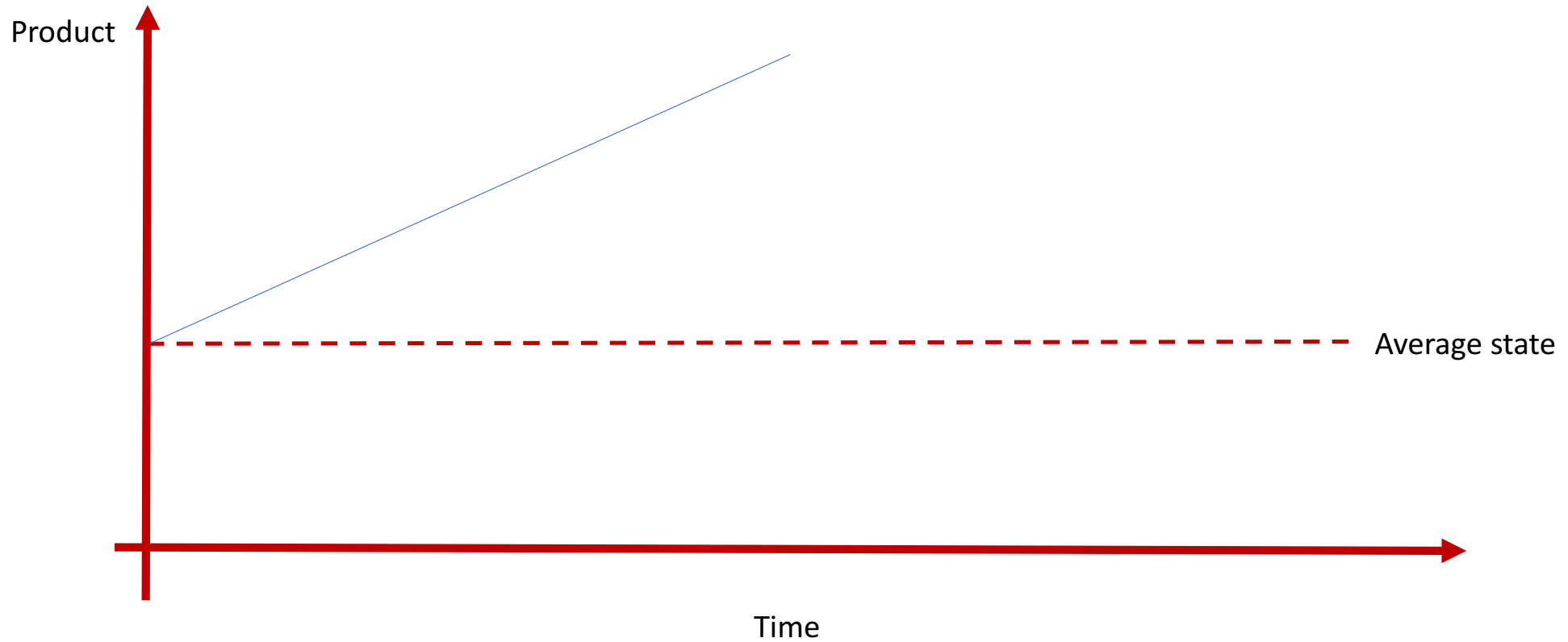
Effects of Positive Feedback Loop on Equilibria



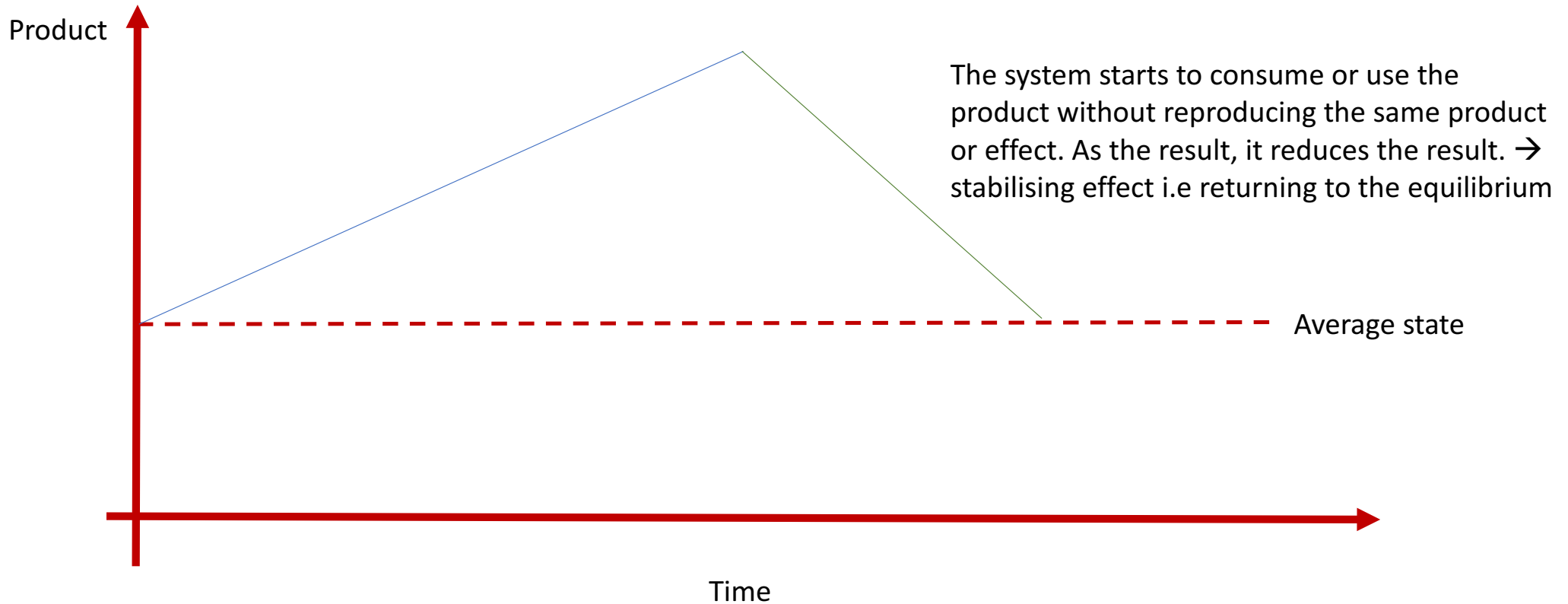
Effects of Positive Feedback Loop on Equilibria



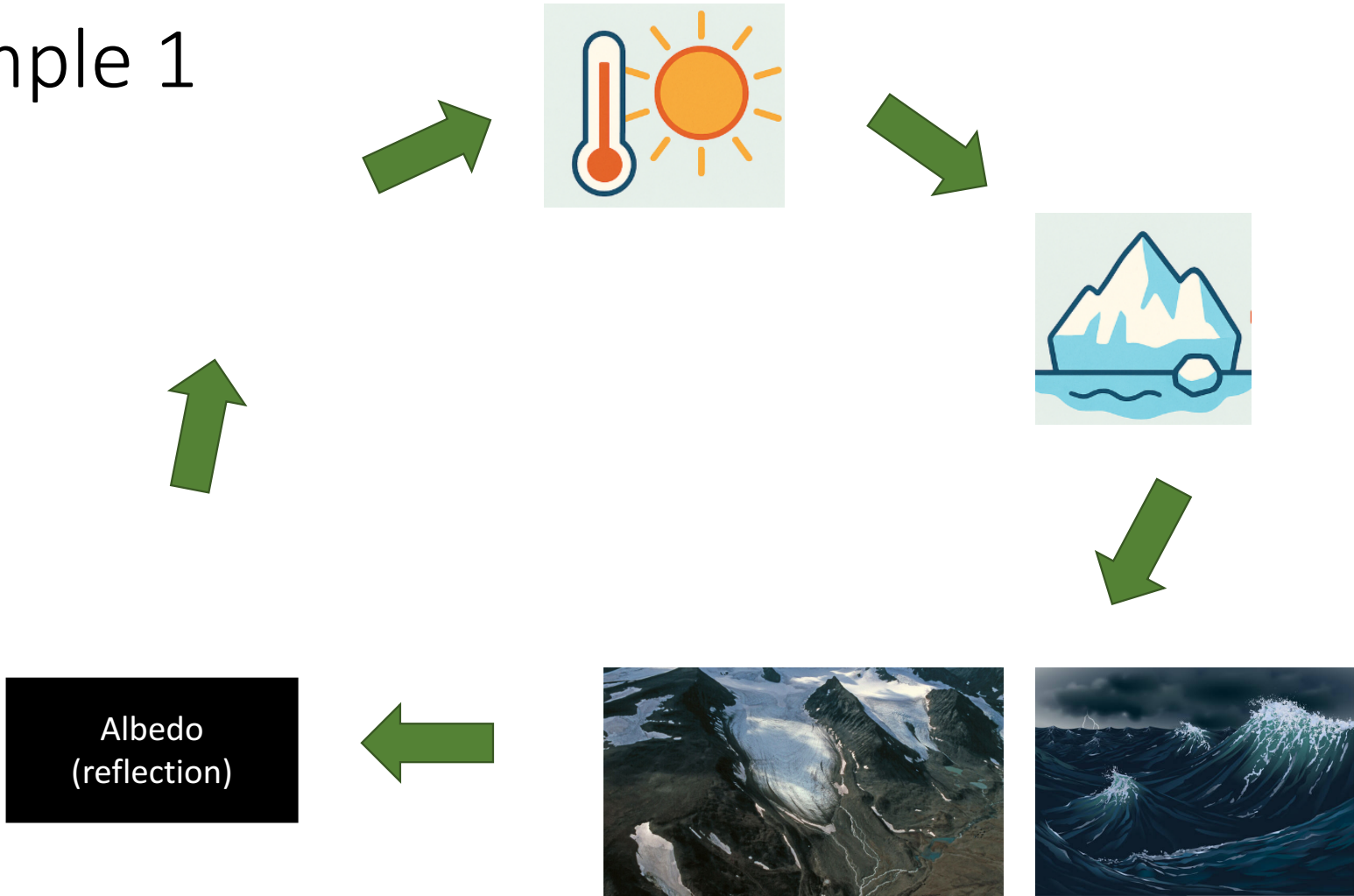
Effects of Negative Feedback Loop on Equilibria



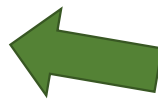
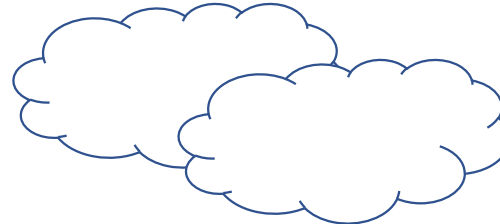
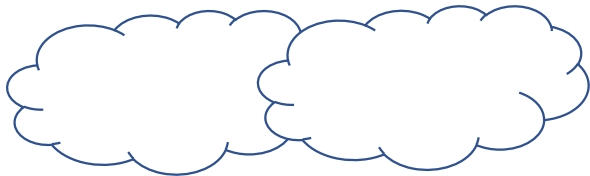
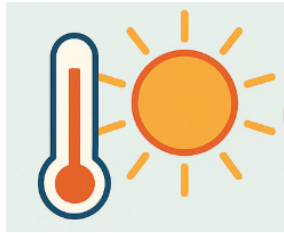
Effects of Negative Feedback Loop on Equilibria



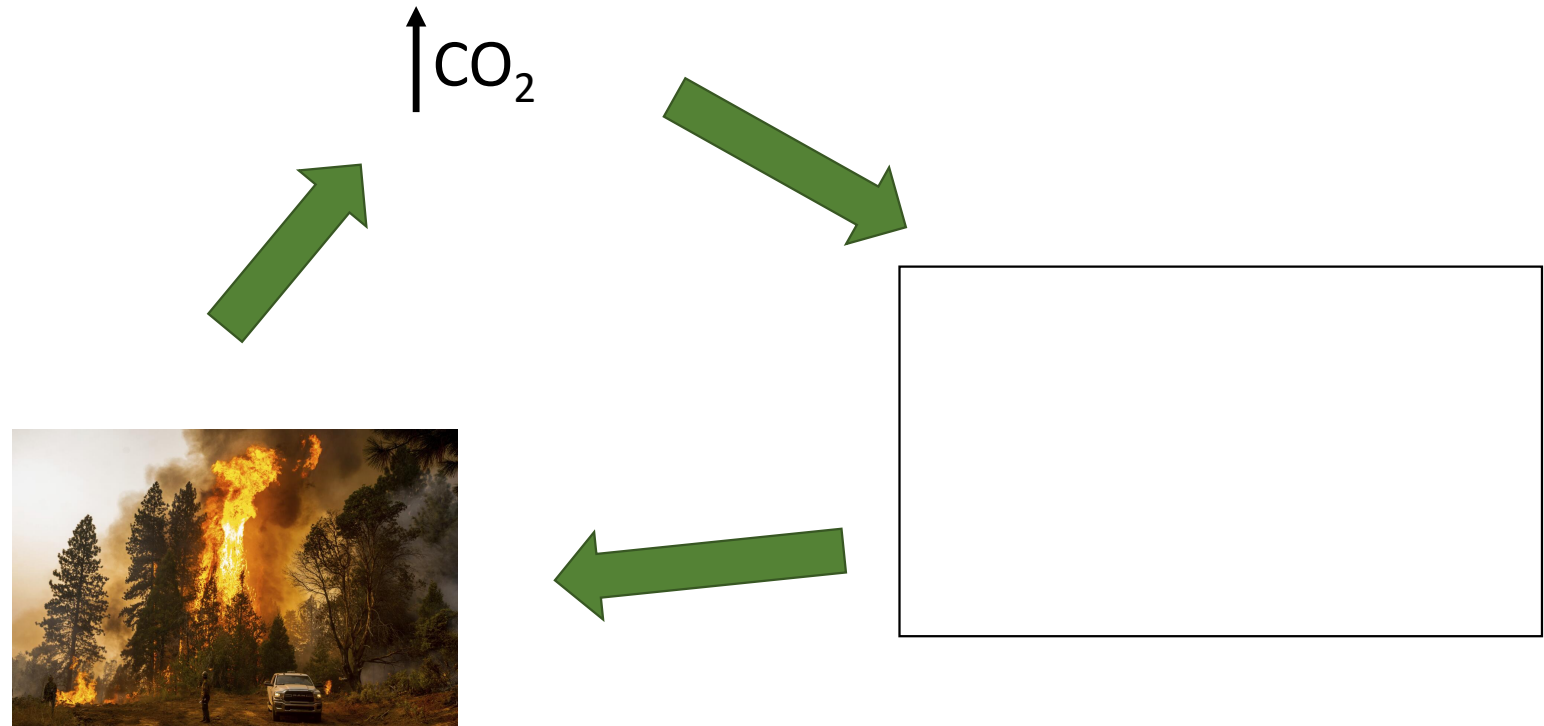
Example 1



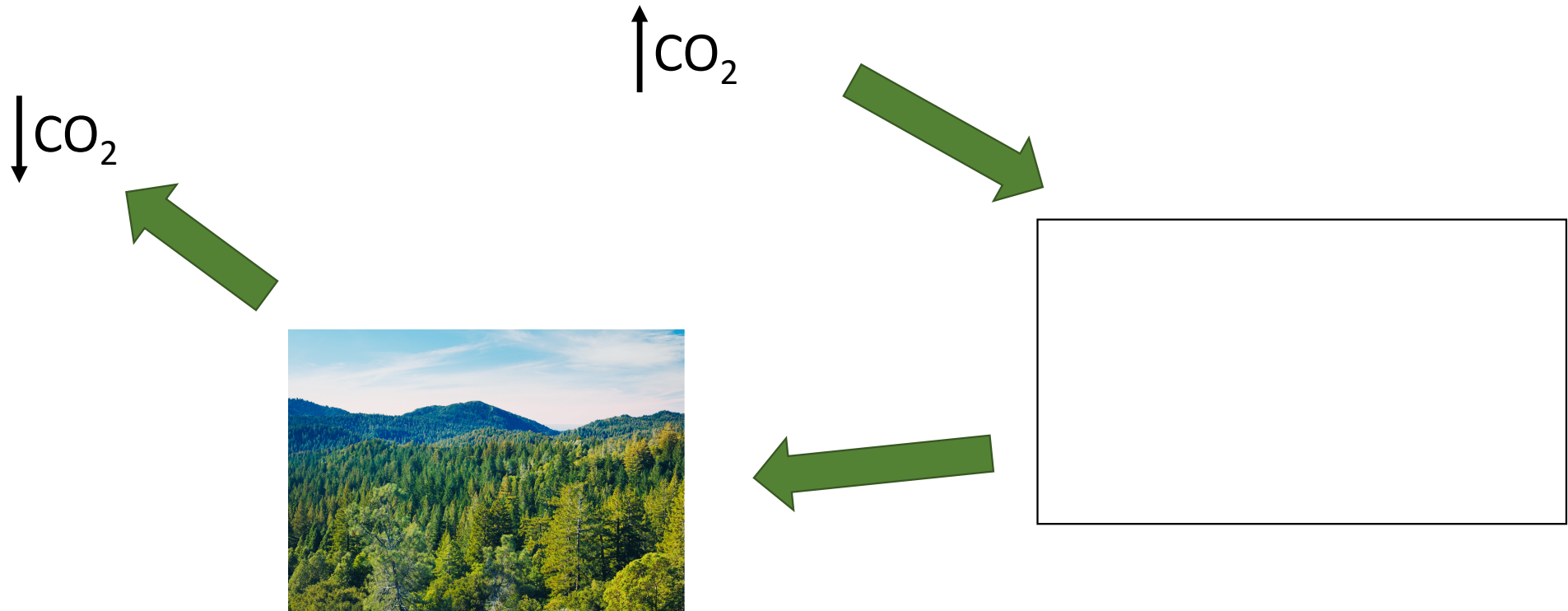
Example 2



Example 3



Example 4



Type of Feedback Loop

Negative Feedback

- Helps maintain stability by counteracting changes.
- Rising global temperatures → ice caps melt → more water vapour forms clouds → more reflection of sunlight → cooling effect.
- Predator-prey dynamics (Lotka–Volterra model): prey populations increase → predator numbers rise → prey decline → predator numbers fall → prey recover.

Positive Feedback

- Reinforces changes, often leading to instability.
- Hypothermia: body cooling reduces metabolism, leading to further cooling until death.
- Global warming: melting ice exposes darker ground, lowering albedo, causing more heat absorption and further warming.

Tipping Point

Tipping Point

- In many systems, small changes may appear insignificant at first. However, once these changes push the system beyond a critical threshold—called a *tipping point*—the system can shift into a very different state.
- Positive feedback loops then reinforce the transformation, driving the system toward a new equilibrium.

Characteristics of Tipping Point

- There is a threshold beyond which a fast shift of ecological states occurs.
- The threshold point cannot be precisely predicted.
- The changes are long-lasting.
- The changes are hard to reverse.
- There is a significant time lag between the pressures driving the change and the appearance of impacts, creating great difficulties in ecological management.

Example of the effect of crossing tipping point



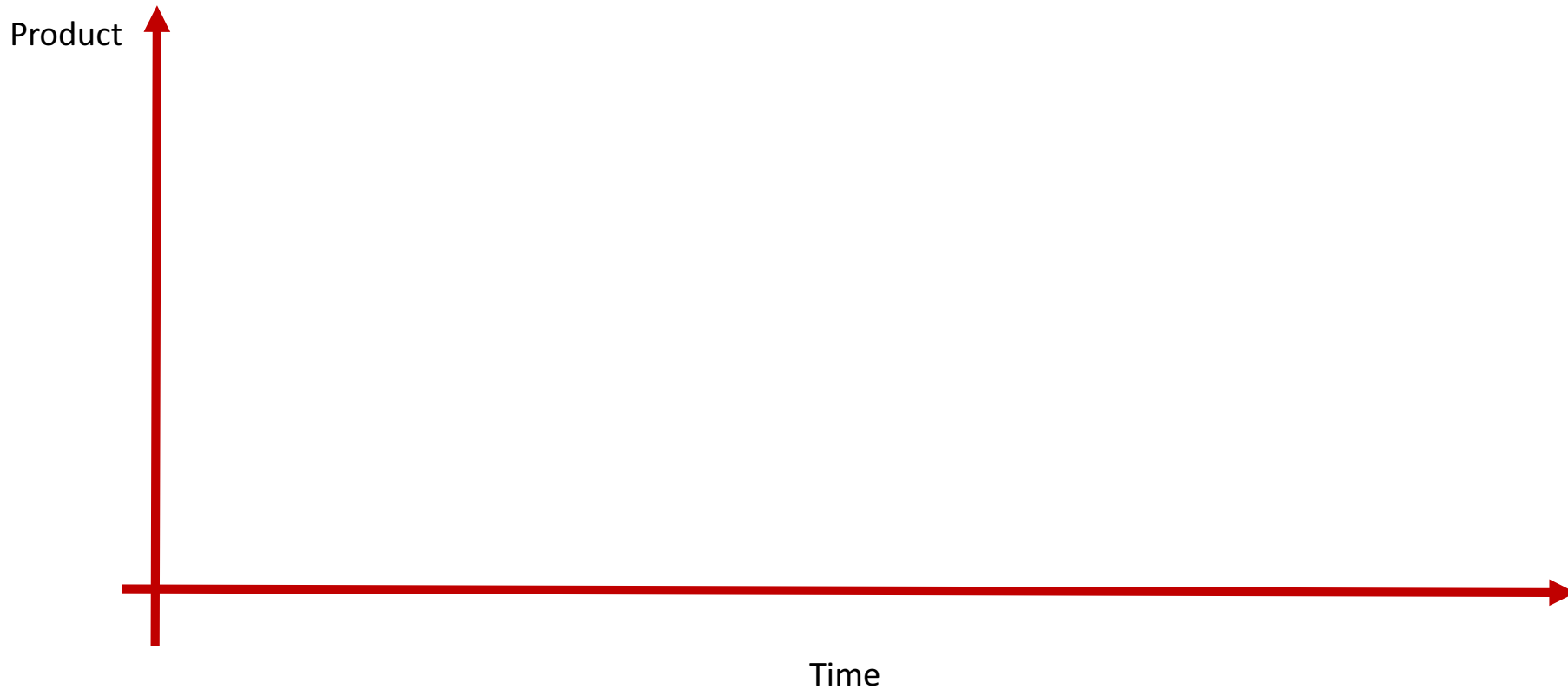
Eutrophication due to excess nutrient
(phosphate and nitrates) entering
water bodies



Coral reef dying due to low pH in the
ocean (too acidic)

Positive Feedback Loop can help
to return to the equilibrium

How a system can recover? (very difficult to achieve)

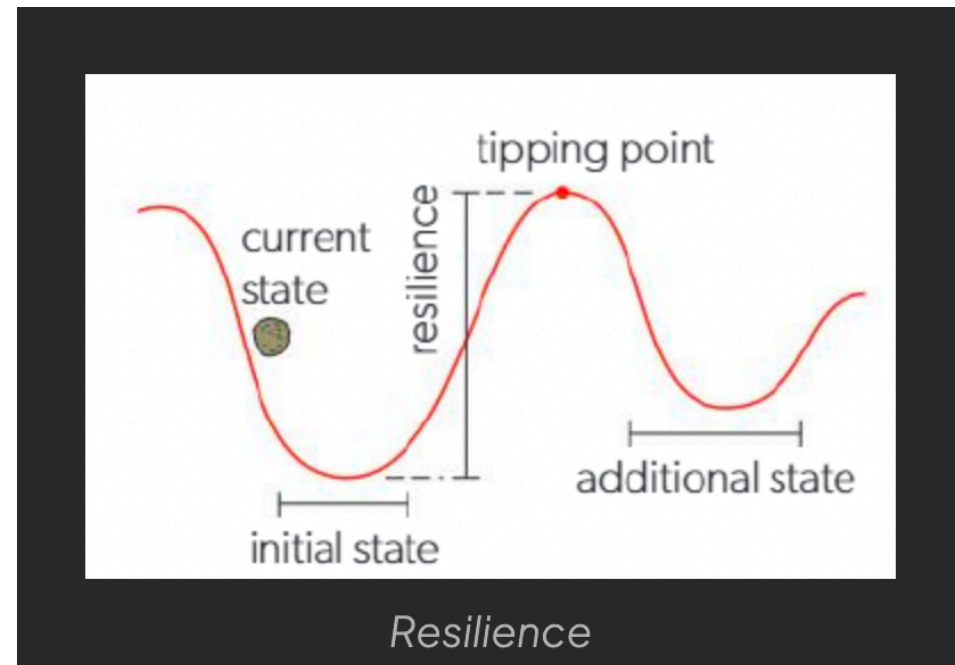


Resilience

Ecosystems are typically complex, with many feedback loops, flows, and storages. Greater complexity often contributes to stability, as multiple pathways can compensate if one fails.

Resilience

- Resilience describes how well a system recovers after disturbance. A resilient system returns to its original state, while a less resilient one shifts into a new state.
- Resilience is generally desirable: it maintains stability in societies, individuals, and ecosystems.
 - For example, Australian eucalypt forests, though fire-prone, are resilient. Their flammable oils and litter promote fire, but the trees regenerate quickly due to protected buds, while competitors are eliminated. However, if non-fire-adapted species replace eucalypts, the outcome can be devastating.

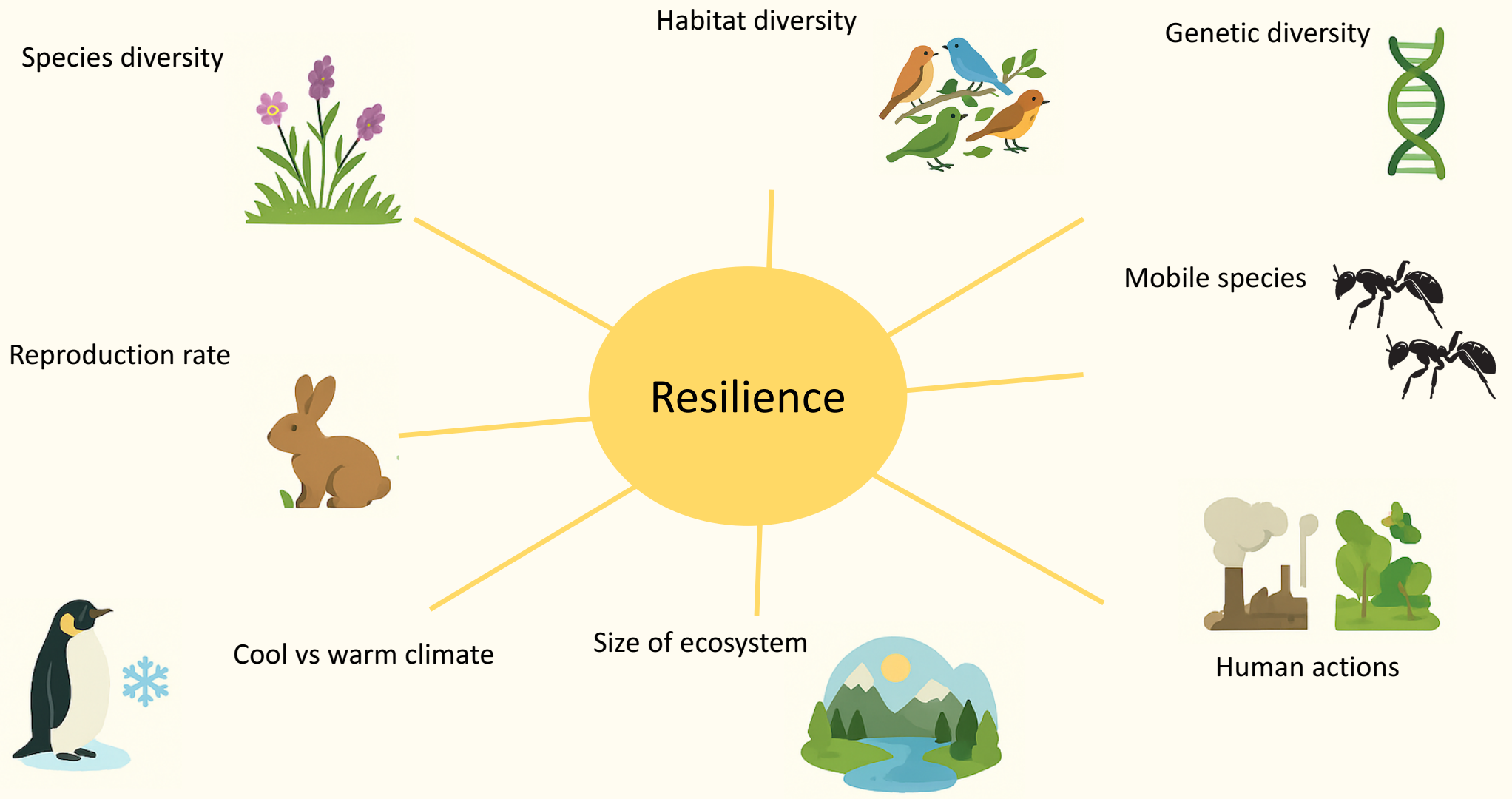


Factors Influencing Resilience

- Biodiversity
 - Habitat and niche
 - Species diversity
 - Genetic diversity
- Mobile species
- Size of ecosystems
- Climate
- Reproduction rate of a species.
- Human actions

Discuss

**Choose 1 factor and
outline how it can
increase resilience of
system**



Resilience

High species diversity and ecological complexity enhance resilience.



Greater biodiversity increases the likelihood that one species can replace another if lost.



High genetic diversity within species provides resistance to diseases.



Fast-reproducing species recover more quickly.



Mobile species that can shift ranges are more resilient.



Climate plays a role: regeneration is slow in the Arctic but rapid in tropical forests.



Larger ecosystems are more resilient than smaller, fragmented ones (e.g., lakes vs. puddles).



Human actions can either improve resilience (e.g., reducing pollutants, managing invasives) or weaken it (e.g., monocultures, habitat fragmentation, reduced genetic diversity).



End of 1.2