Class 3

Degradation of the Earth's Life-Support System

Content:

- Crossing the Planetary Boundaries
- The Life-Support System: Ecosystem Services, Essential Biogeochemical Cycles and Feedback Loops

Leaving the "Safe Operating Space"

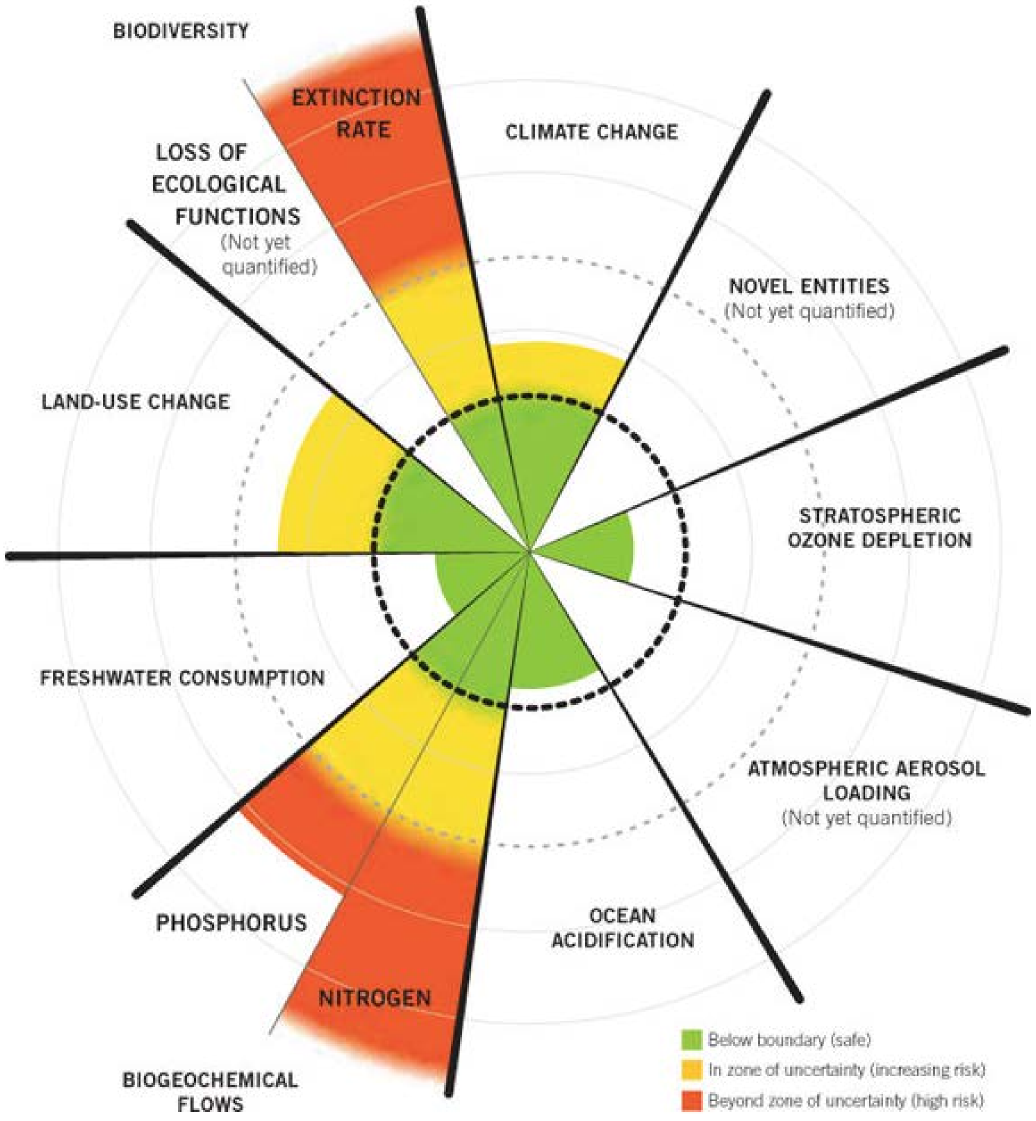


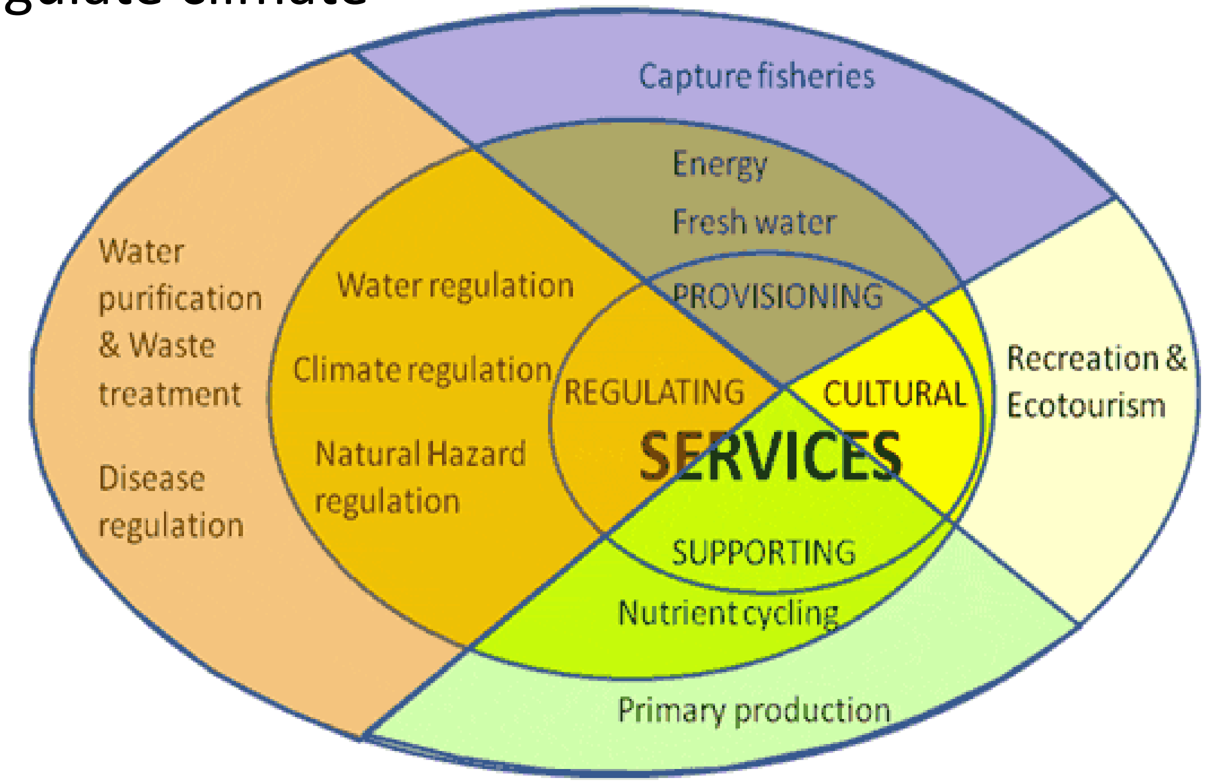
Table 2–1. The Nine Planetary Boundaries*

Earth System Process	Parameters	Proposed Boundary	Current Status	Pre-industrial Value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per meter squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tons per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tons per year)	11	8.5–9.5	–1

Rockstrom and Klum, 2015

We rely on ecosystem services

- Natural resources are “goods” produced by nature
- Earth’s natural systems provide “services” to us
- **Ecosystem services**: arise from the normal functioning of natural services and allow us to survive = the set of ecosystem functions that are useful for humans
  - Purify air and water, cycle nutrients, regulate climate
  - Pollinate plants
  - Receive and recycle wastes



Guide to the Millennium Assessment Reports

Full Reports

The Working Group assessment reports are between 500–800 pages in length, with a volume of summaries of about 120 printed pages.
Learn more

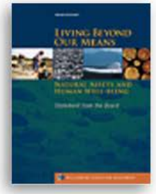
- **Current States & Trends**
- **Scenarios**
- **Policy Responses**
- **Multiscale Assessments**

Synthesis Reports

The first set of assessment reports consists of an overall synthesis and 5 others that interpret the MA findings for specific audiences.
Learn more

- **Overall synthesis**
- **Biodiversity**
- **Desertification**
- **Business & Industry**
- **Wetlands and Water**
- **Health**

Statement of the MA Board



The MA Board of Directors has developed an interpretation of the key messages to emerge from the assessment, entitled *Living Beyond Our Means: Natural Assets and Human Well-Being*.

- **Learn more**
- **Download the Statement**
- **About the MA Board of Directors**

A Framework for Assessment

In late 2003, the MA and Island Press published *Ecosystems and Human Well-being: A Framework for Assessment*. This volume lays out the assumptions, processes and parameters that were used in the MA. **Learn more**

About the Millennium Assessment

The Millennium Ecosystem Assessment assessed the consequences of ecosystem change for human well-being. From 2001 to 2005, the MA involved the work of more than 1,360 experts worldwide. Their findings provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide, as well as the scientific basis for action to conserve and use them sustainably.
Read More

Useful Links

ISLANDPRESS
Order printed reports from Island Press

GreenFacts.org
GreenFacts: Popularized synthesis report

USGS nbii
MA Data Portal

Also on This Site

- **Directory of Authors**
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What are the main findings of MA?

- Over the past 50 years, humans have **changed ecosystems** more rapidly and extensively than in any period of time in human history, largely to meet *rapidly growing demands* for food, fresh water, timber, fiber and fuel. This has resulted in a **substantial and largely irreversible loss in the diversity** of life on Earth.
- The changes that have been made to ecosystems have contributed to substantial **net gains in human well-being** and economic development, but these gains have been achieved at growing costs in the form of the **degradation of many ecosystem services**, increased risks of **nonlinear changes,** and the exacerbation of **poverty** for some groups of people. These problems, unless addressed, will substantially diminish the benefits that *future generations* obtain from ecosystems.
- The degradation of ecosystem services could grow **significantly worse** during the first half of this century and is a barrier to achieving the Millennium Development Goals.
- The challenge of reversing the degradation of ecosystem while meeting increasing demands for services can be partially met under some scenarios considered by the MA, but will involve **significant changes in policies**, **institutions and practices** that are not currently under way. **Many options exist** to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.
- The bottom line of the MA findings is that **human actions are depleting Earth's natural capital**, putting such strain on the environment that the ability of the planet's ecosystems to sustain future generations can no longer **be taken for granted**. At the same time, the assessment shows that with appropriate actions it is **possible to reverse** the degradation of many ecosystem services over the next 50 years, but the changes in policy and practice required are substantial and not currently underway.

What’s new?

- The balance sheet.
  - 60% of a group of 24 ecosystem services are being degraded.
- Nonlinear changes (accelerating or abrupt).
  - Ecosystem changes are increasing the likelihood of nonlinear changes in ecosystems. Examples include disease emergence, abrupt alterations in water quality, the creation of “dead zones” in coastal waters, the collapse of fisheries, and shifts in regional climate.
- Drylands.
  - While major problems exist with tropical forests and coral reefs, from the standpoint of linkages between ecosystems and people, the most significant challenges involve dryland ecosystems. These ecosystems are particularly fragile, but they are also the places where human population is growing most rapidly, biological productivity is least, and poverty is highest.
- Nutrient loading.
  - Excessive nutrient loading of ecosystems is one of the major drivers today and will grow significantly worse in the coming decades unless action is taken. The issue of excessive nutrient loading, although well studied, is not yet receiving significant policy attention in many countries or internationally.

Critical Ecosystem Services

1. Climate and Biogeochemical Cycles
2. Regulation of Hydrologic Cycle
3. Soils and Erosion
4. Biodiversity and Ecosystem Functions
5. Mobile Links
6. Balance of Diseases Transmission

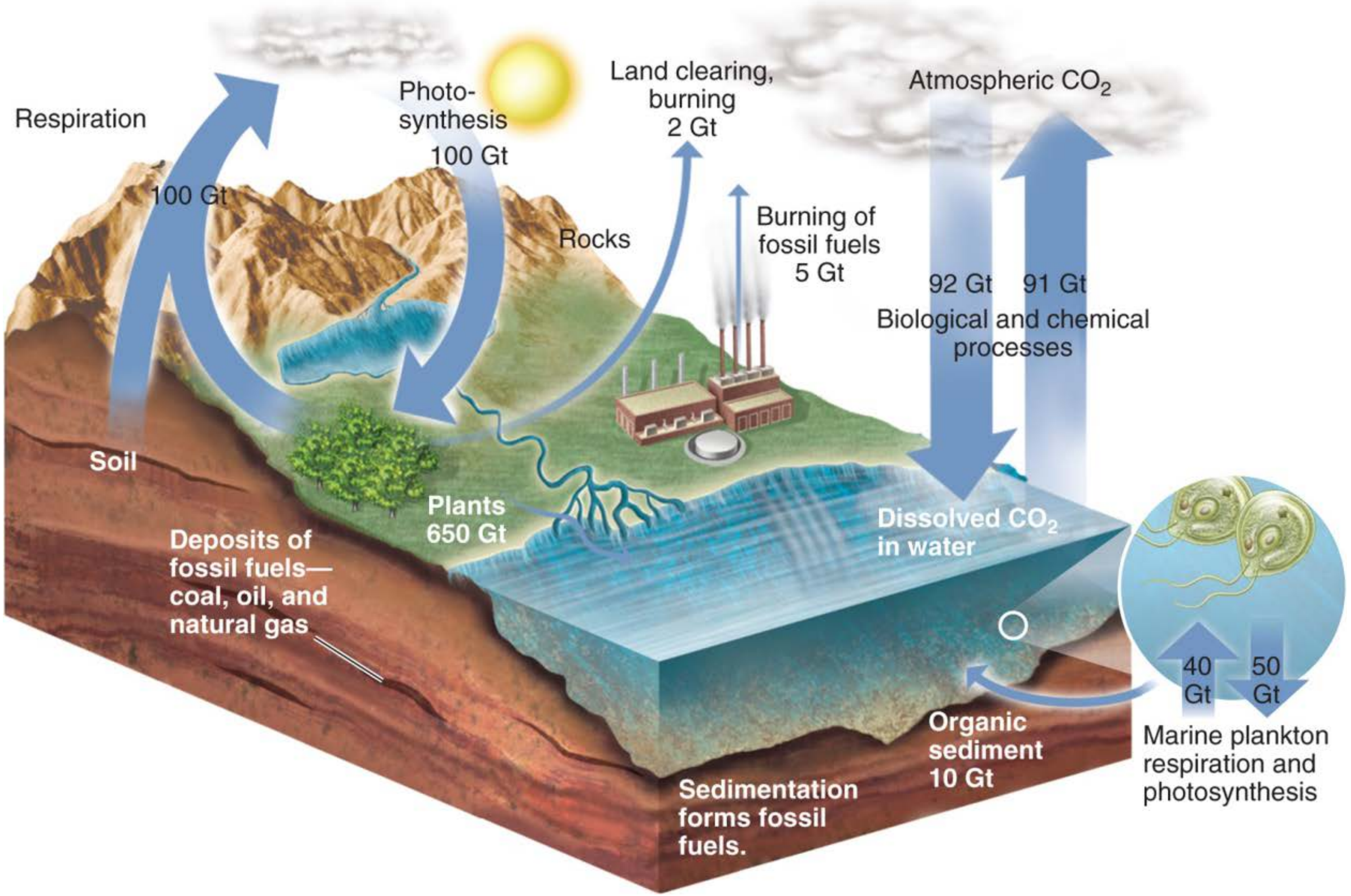
Critical Ecosystem Services

- Biogeochemical Cycles = "the transport and transformation of substances in the environment through life, air, sea, land, and ice" (Alexander et al. 1997)
- Carbon cycle
- Nitrogen cycle
- Phosphorus cycle

Carbon Cycle

Begins with intake of CO_2 during **photosynthesis** → incorporated into sugar → released by **cellular respiration** either in plant or in organisms that consumed it.

Sometimes the carbon is **not** recycled for a long time. Coal and oil are the remains of organisms that lived millions of years ago. The carbon in these is released when we burn them. Some carbon is also locked in calcium carbonate (fossil shell deposits of limestone).

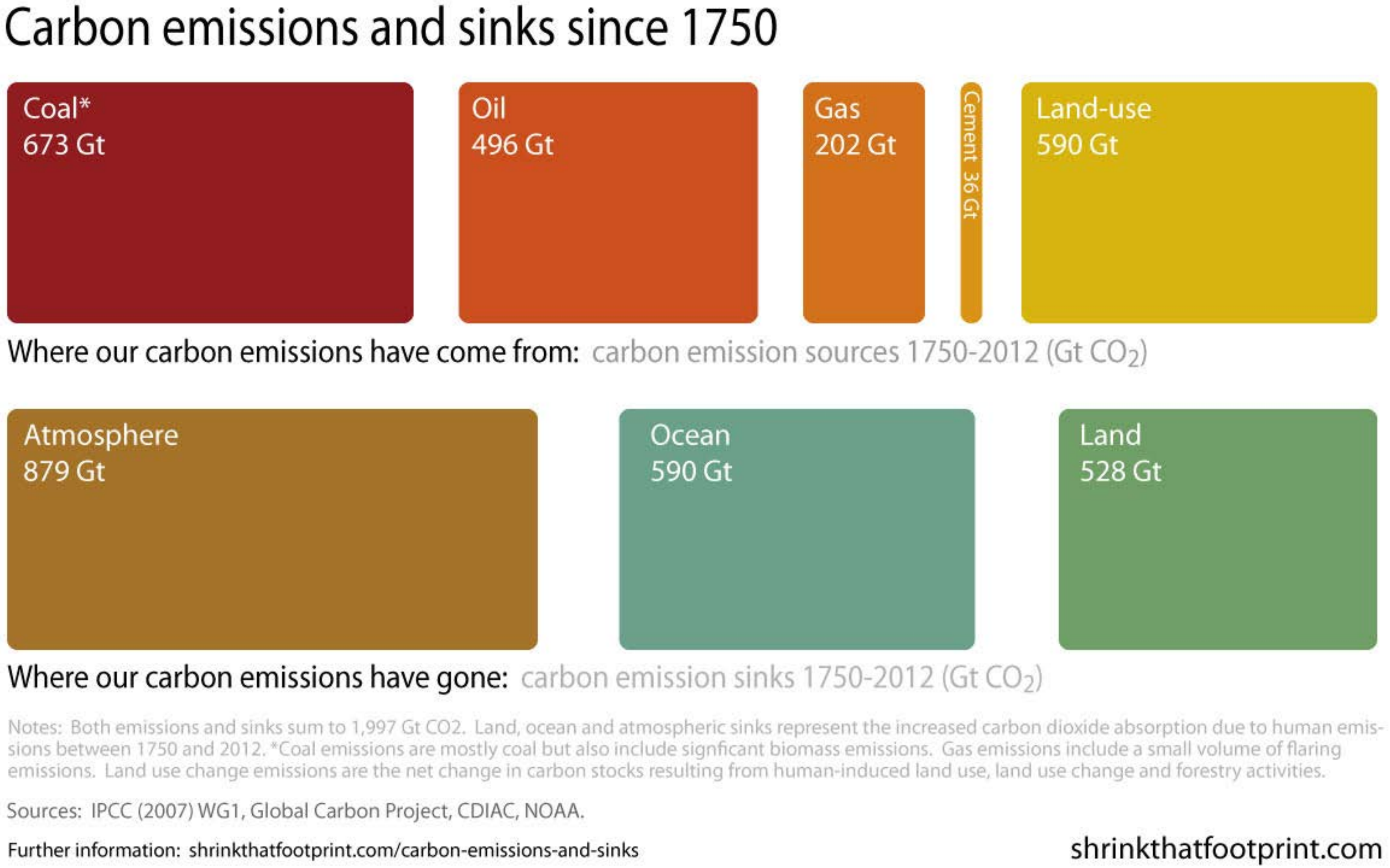


Carbon Cycle

The global carbon cycle has been disturbed by about 13% compared to the pre-industrial era -- as opposed to 100% or more for nitrogen, phosphorous, and sulfur cycles (Falkowski et al. 2000). BUT it has been enough to lead to the global climate change!

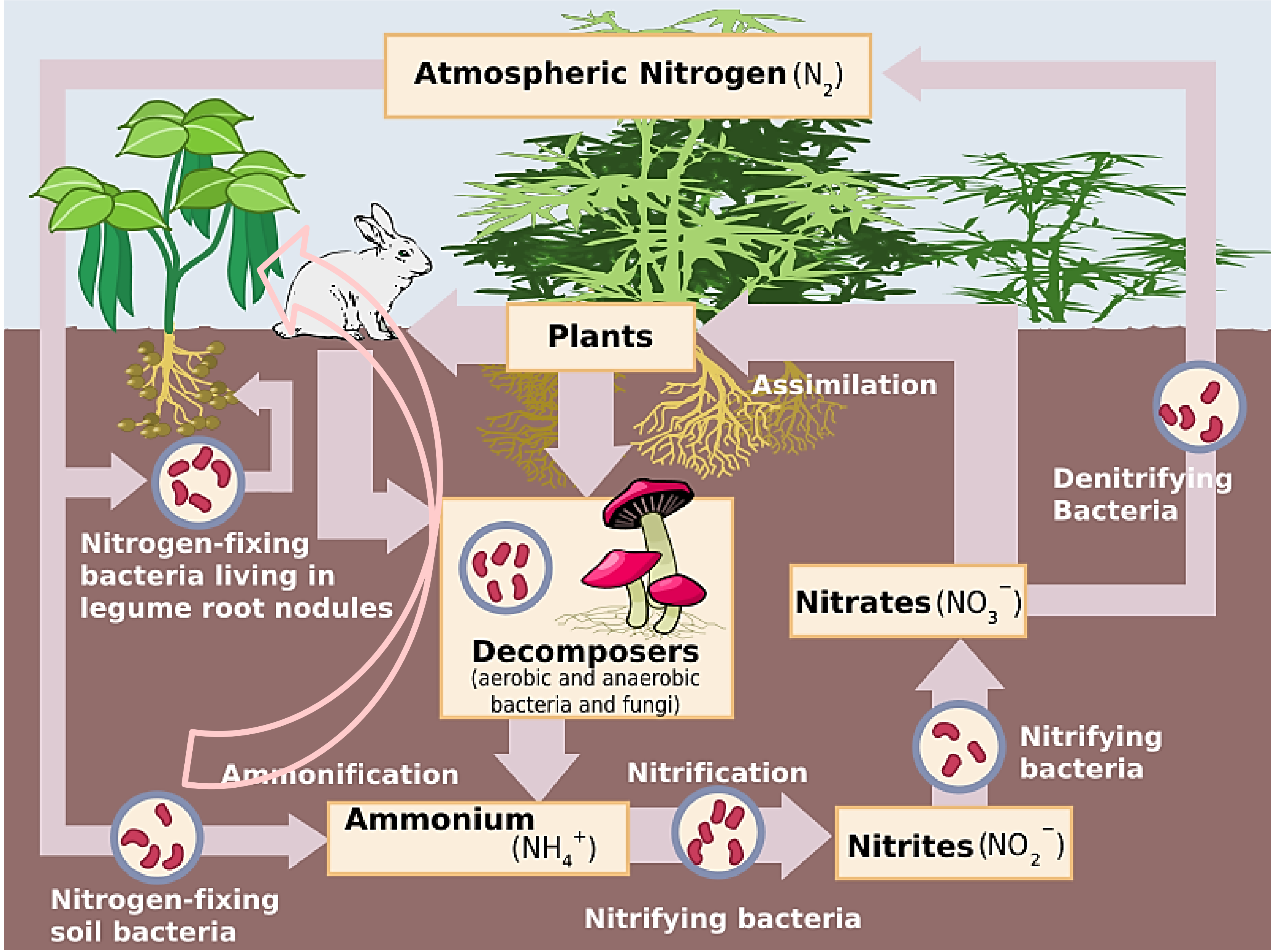
<u>Main Carbon Sinks</u>:

- Forest
- Ocean
- Soil



Nitrogen Cycle

- Plants take up inorganic nitrogen from the environment and build protein molecules which are later eaten by consumers.
- Nitrogen-fixing bacteria change nitrogen to a more useful form by combining it with hydrogen to make ammonia. Other bacteria convert ammonia to nitrites and nitrates, which can be taken up by plants to make proteins.



Nitrogen Cycle

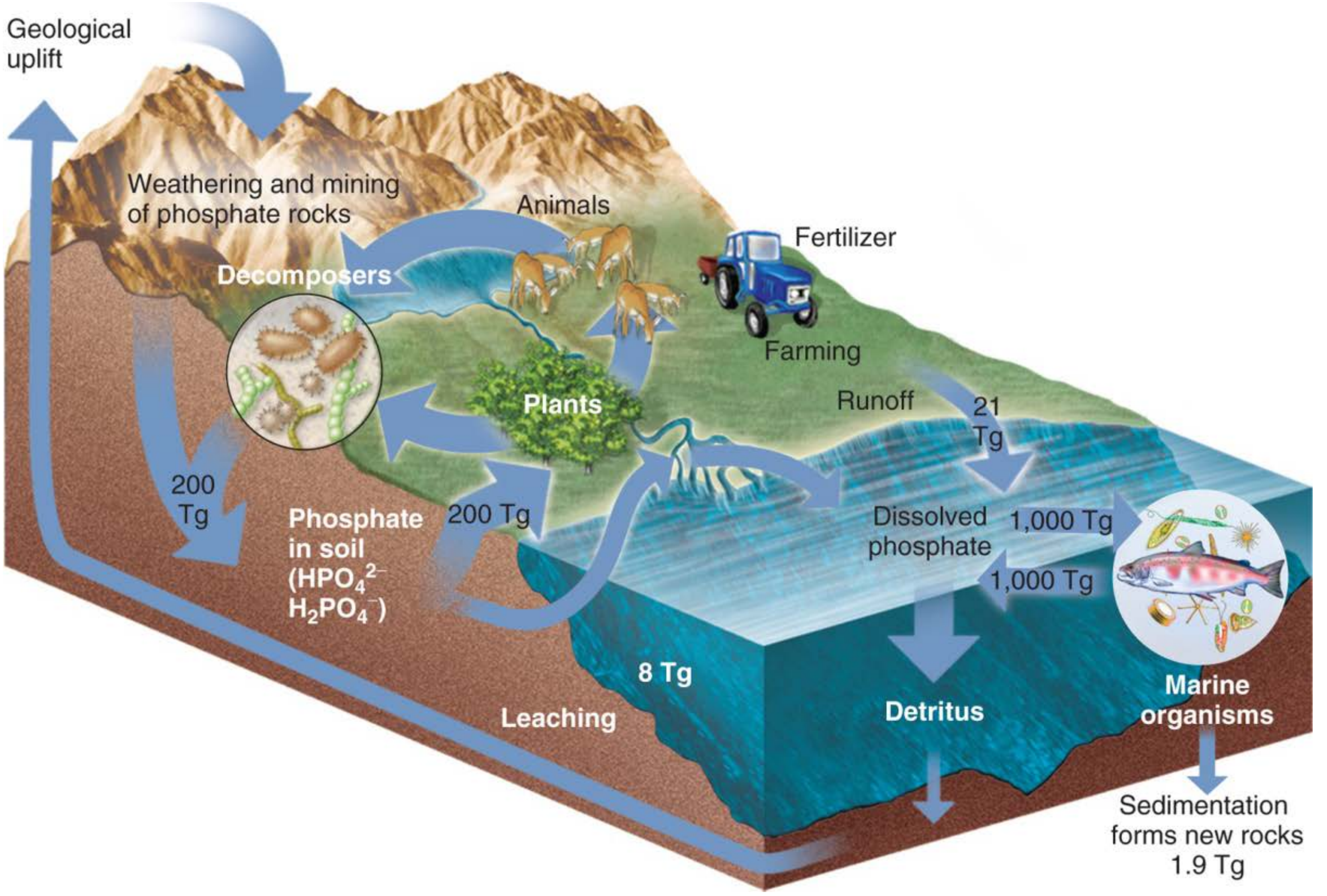
- N_2 makes up 78% of the atmosphere, → *only* made available to organisms through nitrogen fixation by cyanobacteria, nitrogen-fixing bacteria and algae
- Since 1945, industrial agriculture, industry and automobile emission have more than **doubled** N in circulation
- **80 million tons** of nitrogen every year are fixed artificially by industry to be used as fertilizer → nutrient overload, **eutrophication**, and elimination of oxygen in water bodies (**hypoxia**).
- Nitrogen oxides (N_2O) regularly produced as a result of fossil fuel combustion → potent greenhouse gases that increase global warming and also lead to smog, breakdown of the ozone layer, and acid rain

Phosphorus Cycle

P is *least* naturally available of major nutrients

P is leached from rocks and minerals → transported in aqueous form →taken in and incorporated by producers → consumers → returned to environment by decomposition

Cycle takes a long time as deep ocean sediments are significant sinks

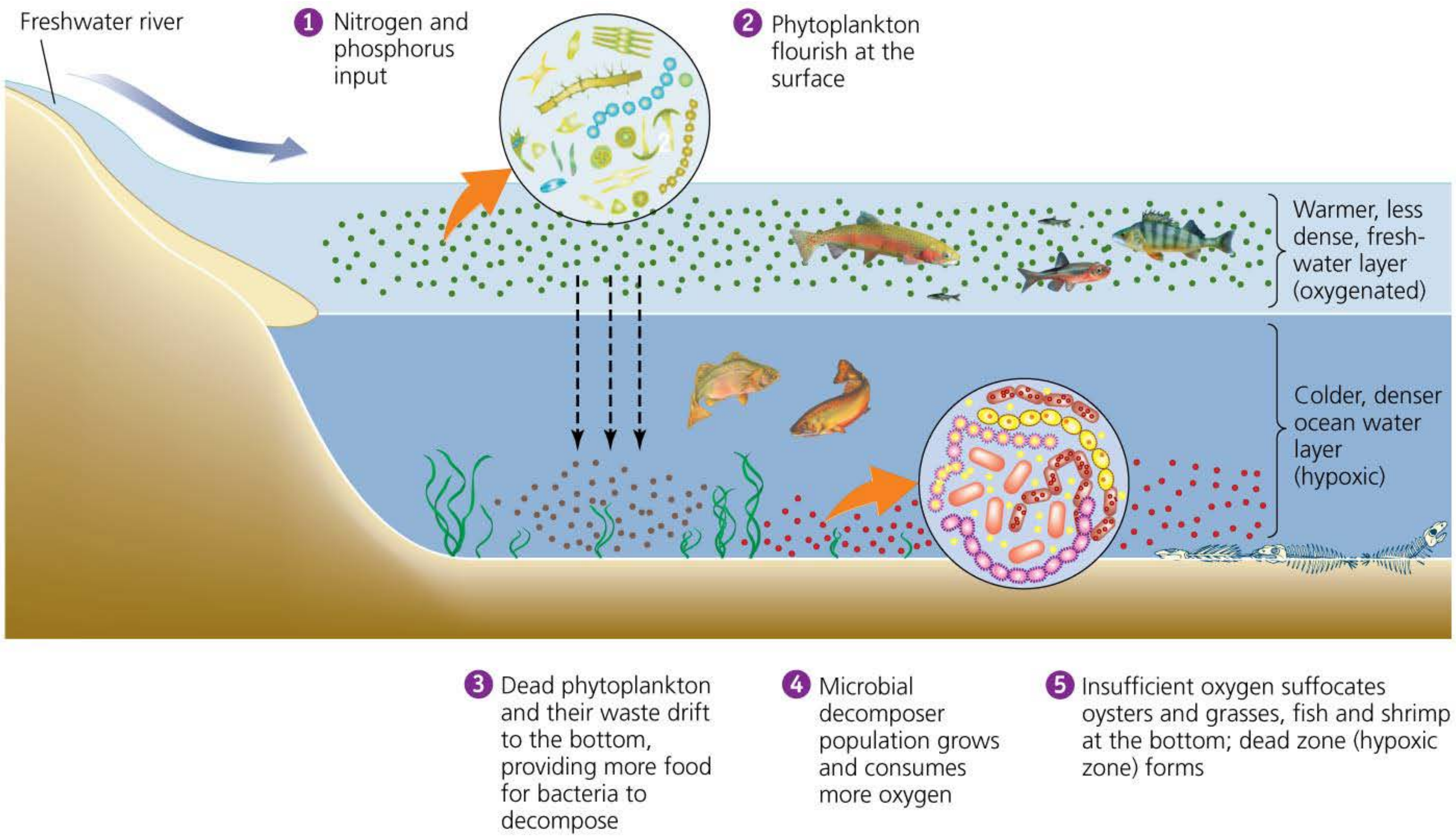


Phosphorus Cycle

- Use of phosphorous in artificial fertilizers, detergents and runoffs from animal husbandry often also leads to eutrophication in aquatic systems
- The mining of phosphate deposits and their addition to terrestrial ecosystems as fertilizers represents a **x6 increase** over the natural rate of mobilization of P by the weathering of phosphate rock and by plant activity

Environmental systems interact

- Addition of excess nutrients (N and P) to a water body
  leads to: Blooms of algae → Increased production of organic matter that dies and sinks → Decomposition and loss of dissolved oxygen → **eutrophication** & **hypoxia**



Environmental systems interact

- Over 500 **hypoxic dead zones** occur globally
  - Most are off the coasts of Europe and the U.S.
  - Mostly due to farm, city, and industrial pollution
  - Some are seasonal; others are permanent
- Fisheries and ecosystems are devastated
  - Causes over $2 billion/year in lost harvests