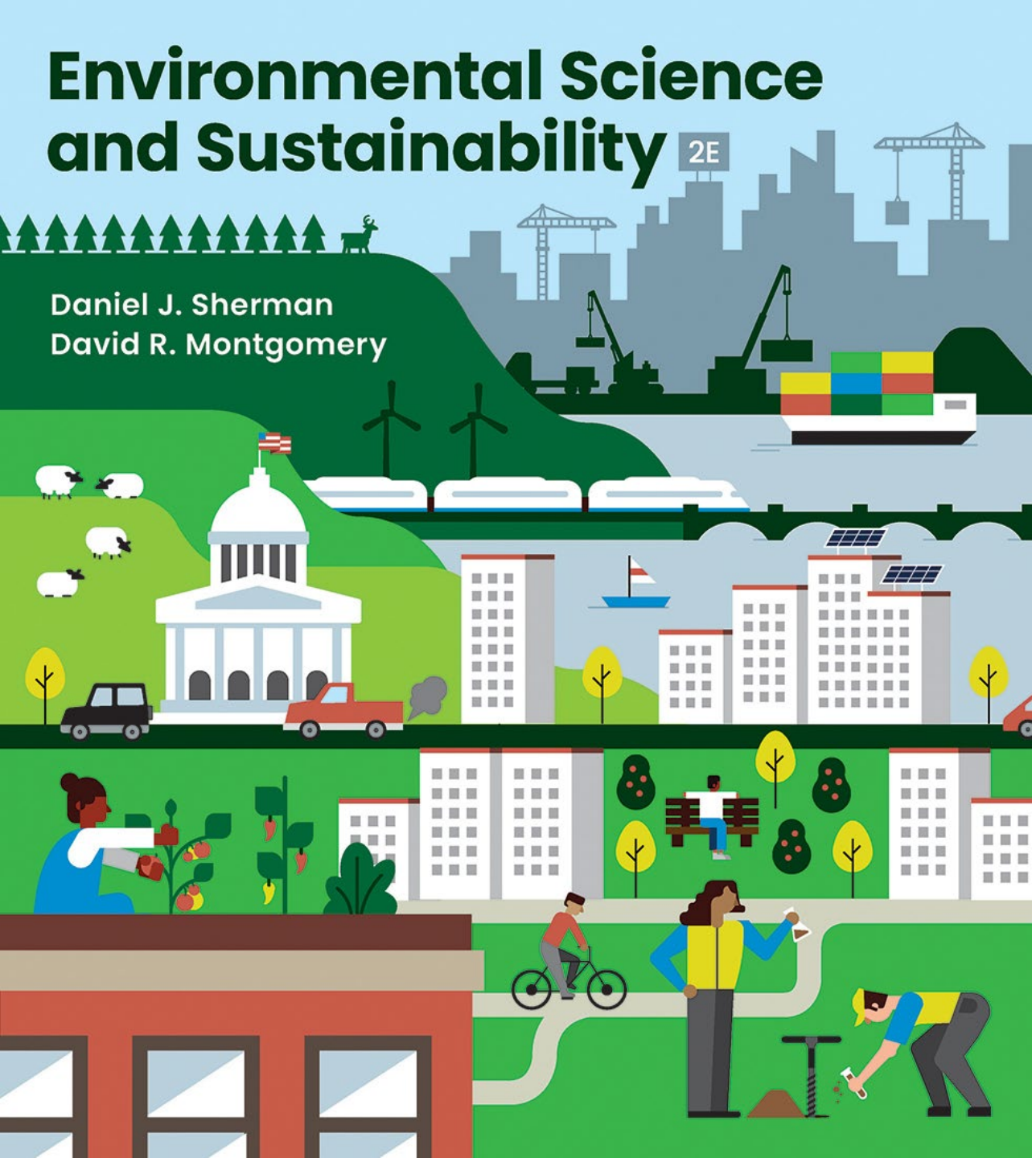
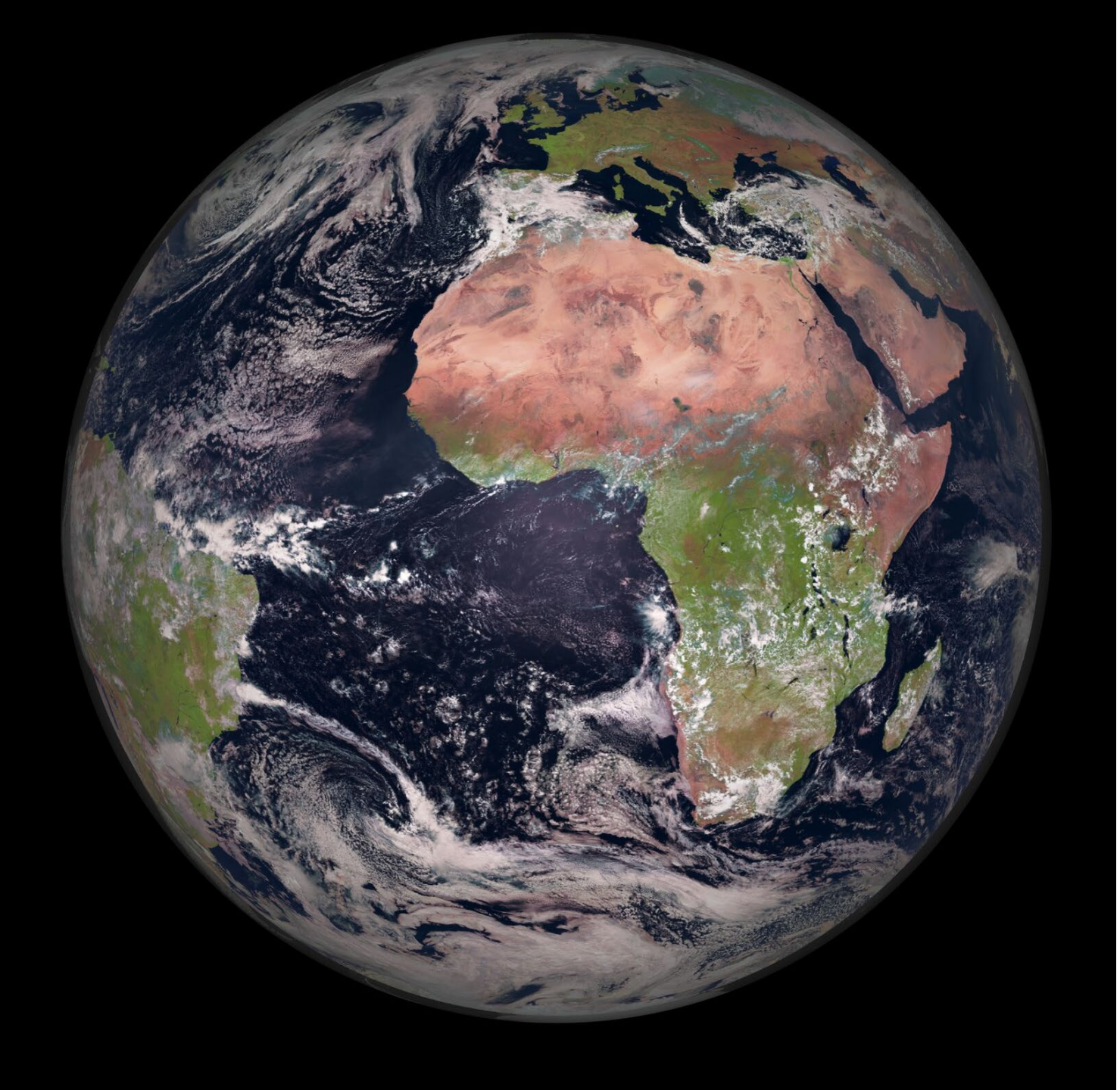


CHAPTER 10

Systems and Cycles



Key terms

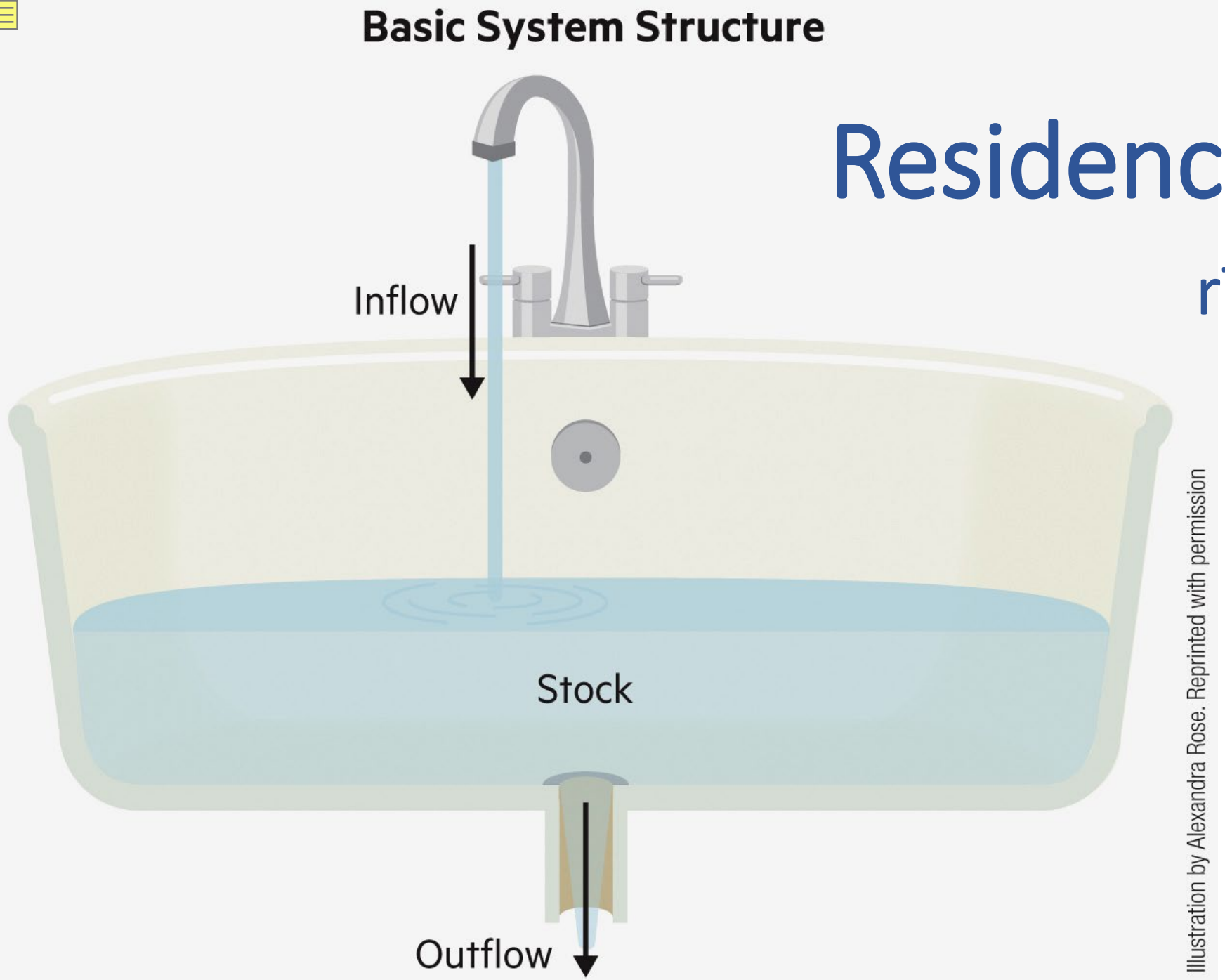
- Open vs Closed systems
- Biogeochemical cycles
- Feedbacks
  - Positive vs Negative
- Nitrification
- Greenhouse Gases (GHG)
- Photosynthesis
- Ocean acidification
- Box models
  - Sink, stock, inflow, outflow

Room temp vs. On ice

System Types

- Open – A system that exchanges material and energy with its surroundings.
- Sun's energy
  - Some is absorbed/received
  - Some is reflected

- Closed – Most of the Earth's material is continuously recycled.
- Mass/material is neither gained or lost just changed.
- Rock and Water cycles



Residence Time = ?

$rT = S/F$

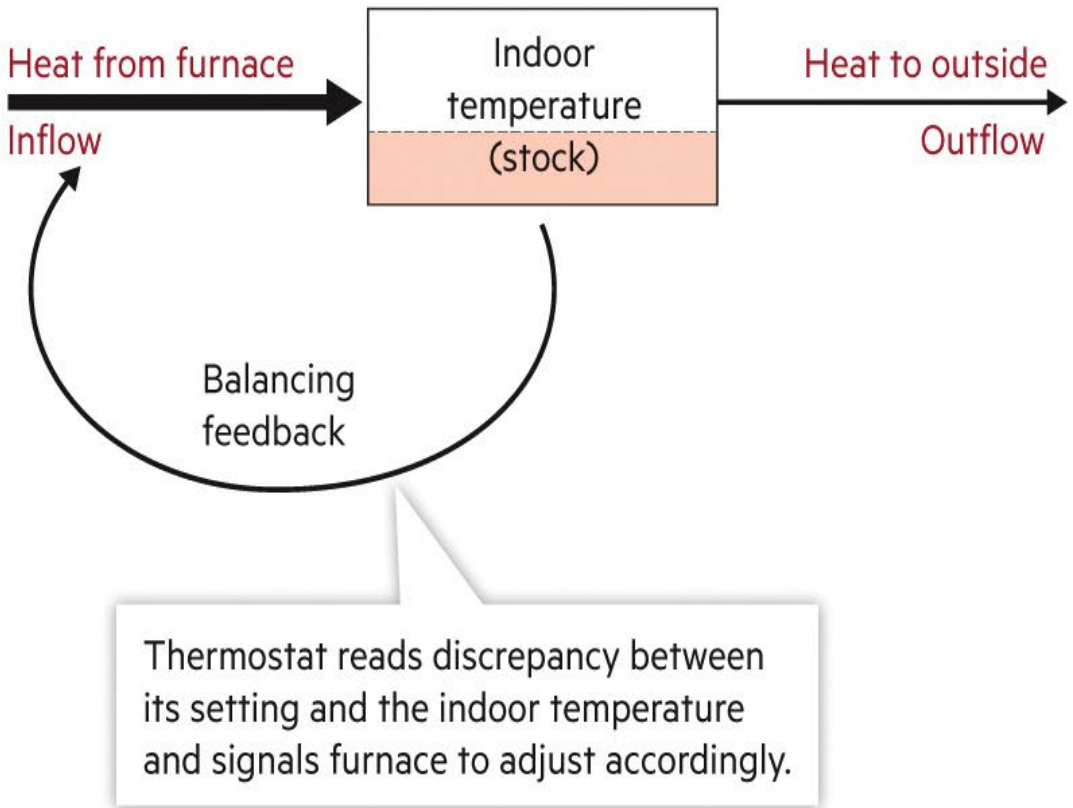
S = size of stock

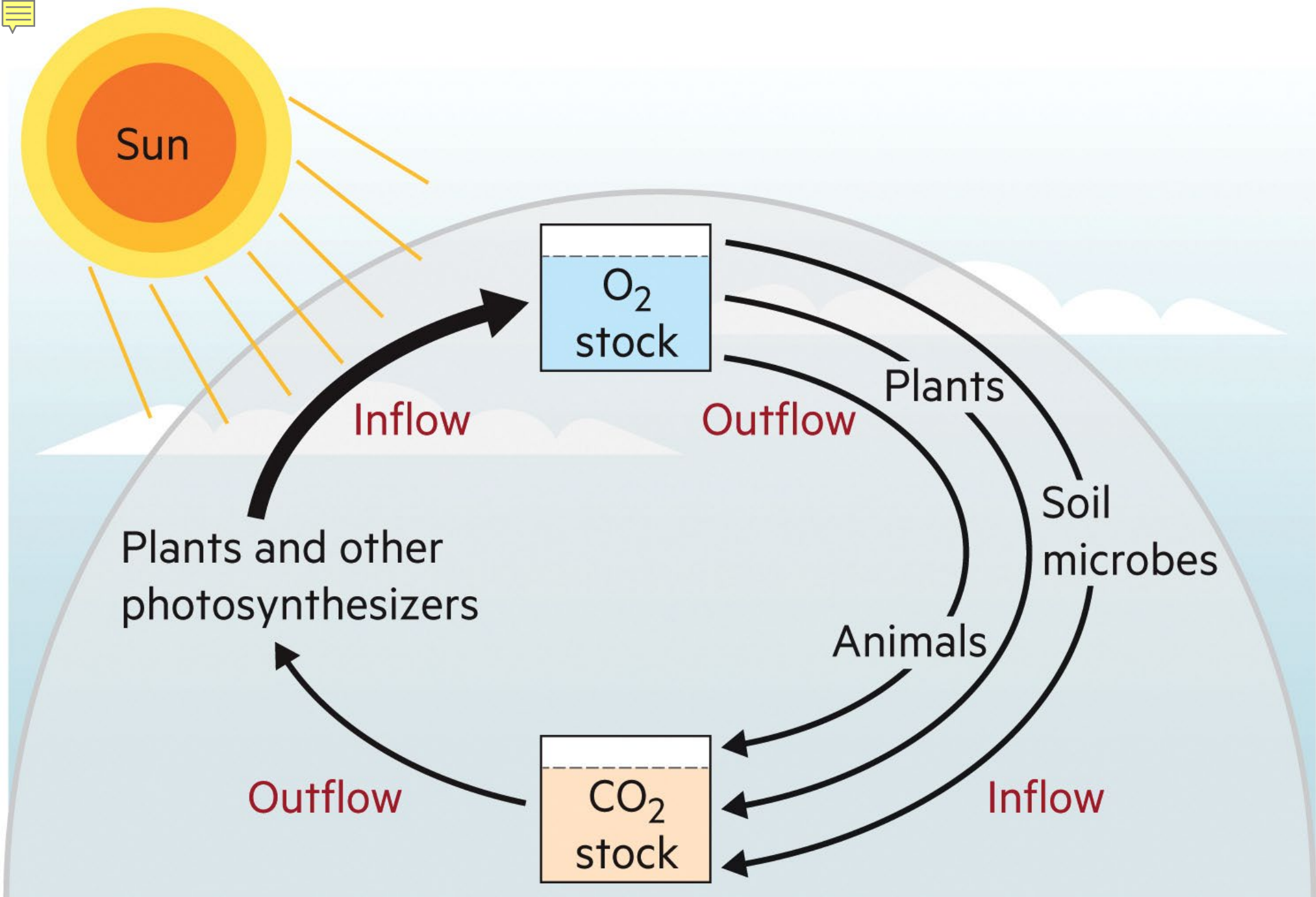
F = rate of transfer

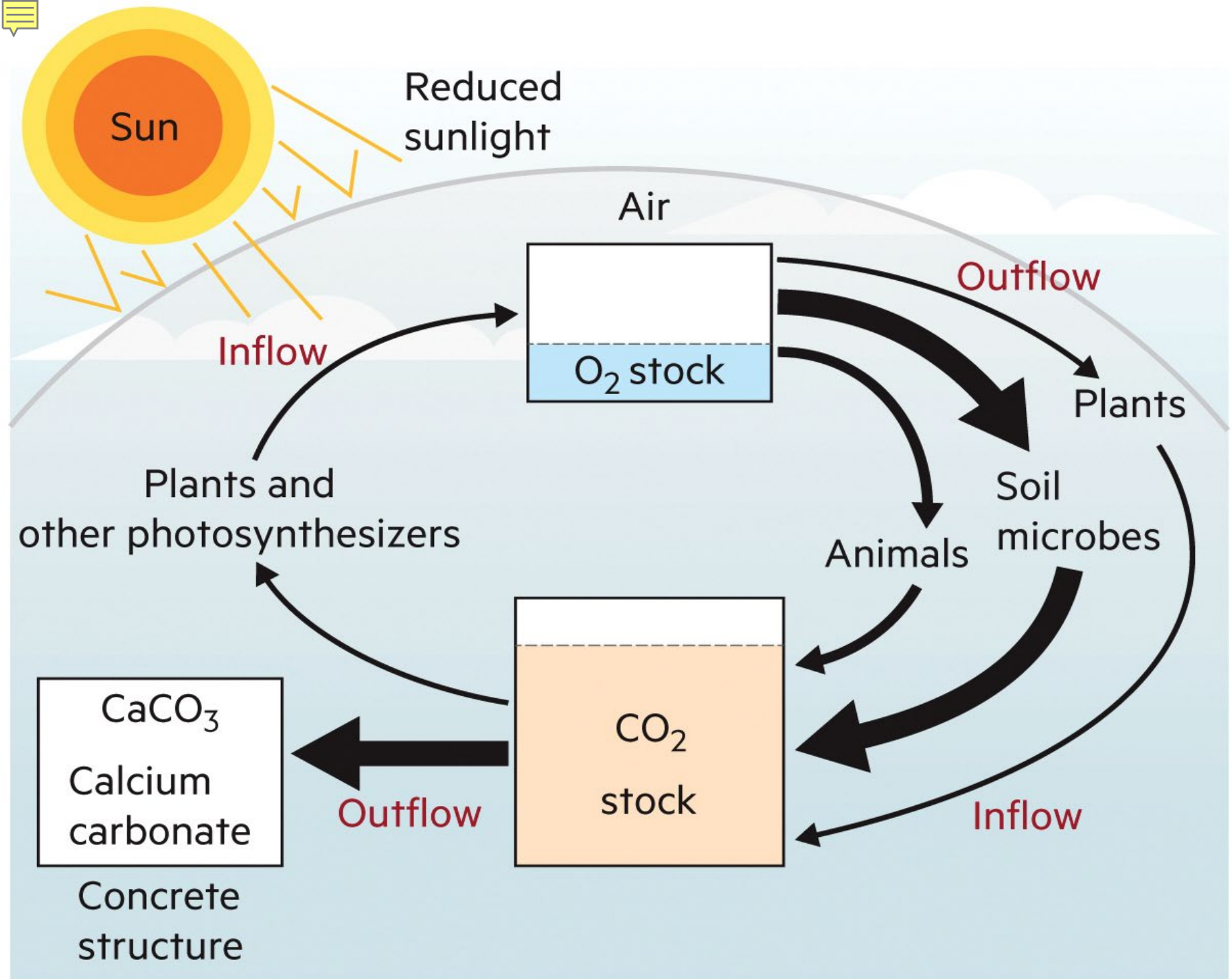
Illustration by Alexandra Rose. Reprinted with permission

Heating or Cooling a room

Steve Cukrov/Shutterstock




Sun
O_2 stock
Inflow
Outflow
Plants
Soil microbes
Animals
Plants and other photosynthesizers
Outflow
CO_2 stock
Inflow


Sun
Reduced sunlight
Air
Outflow
Inflow
O_2 stock
Plants
Plants and other photosynthesizers
Soil microbes
Animals
$CaCO_3$
Calcium carbonate
Concrete structure
CO_2 stock
Outflow
Inflow

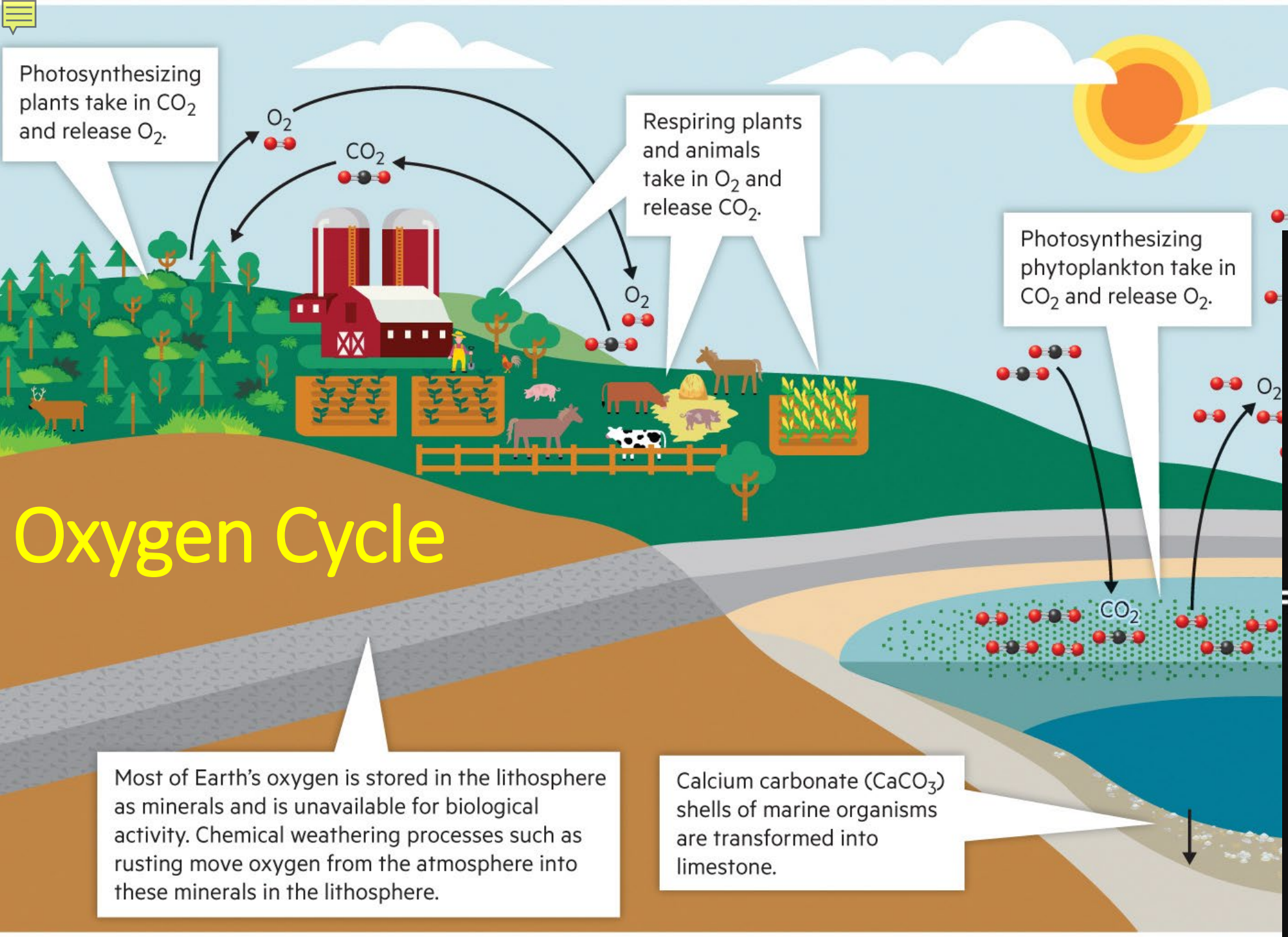
System Interactions

Solar Radiation - Exothermic

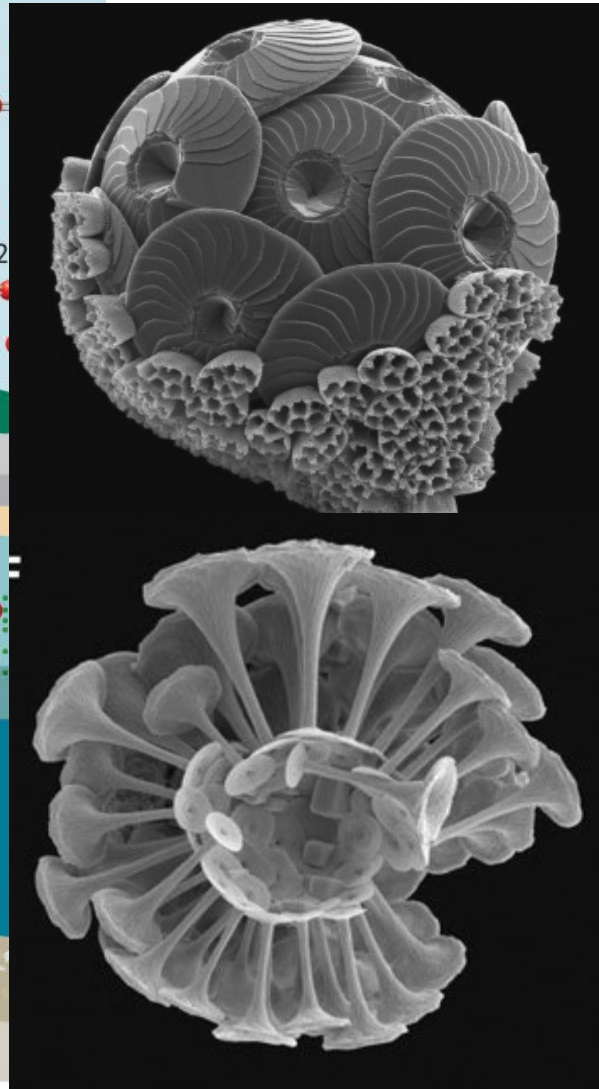
Atmosphere
Hydrosphere
Biosphere
Lithosphere

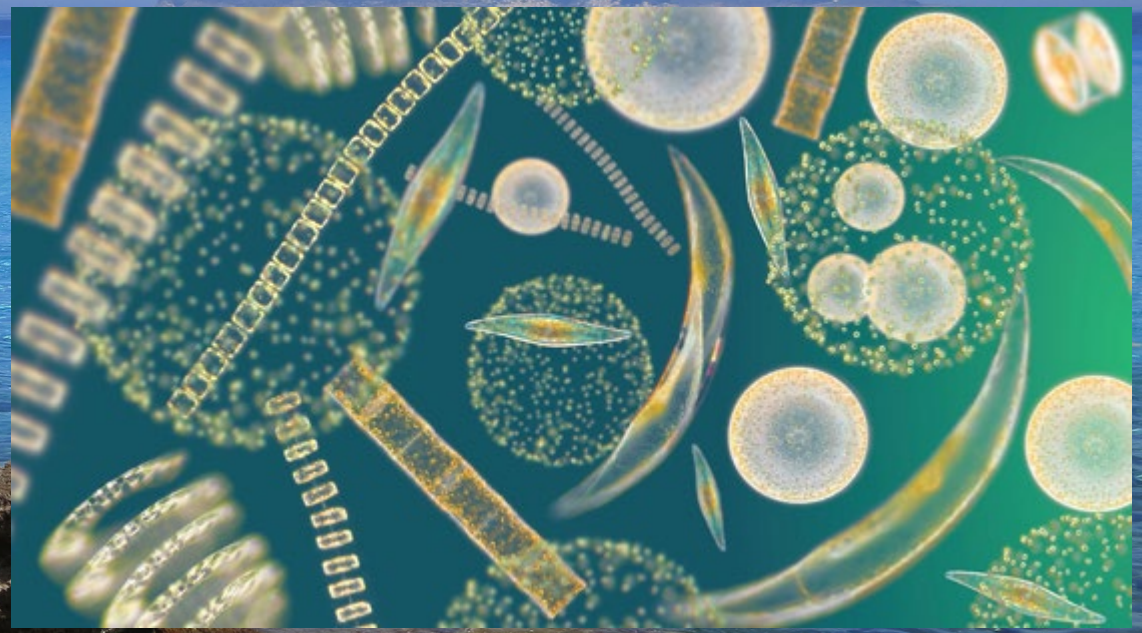
Earth's Hot Core – Endothermic

Use – Organic respiration



Oxygen Cycle



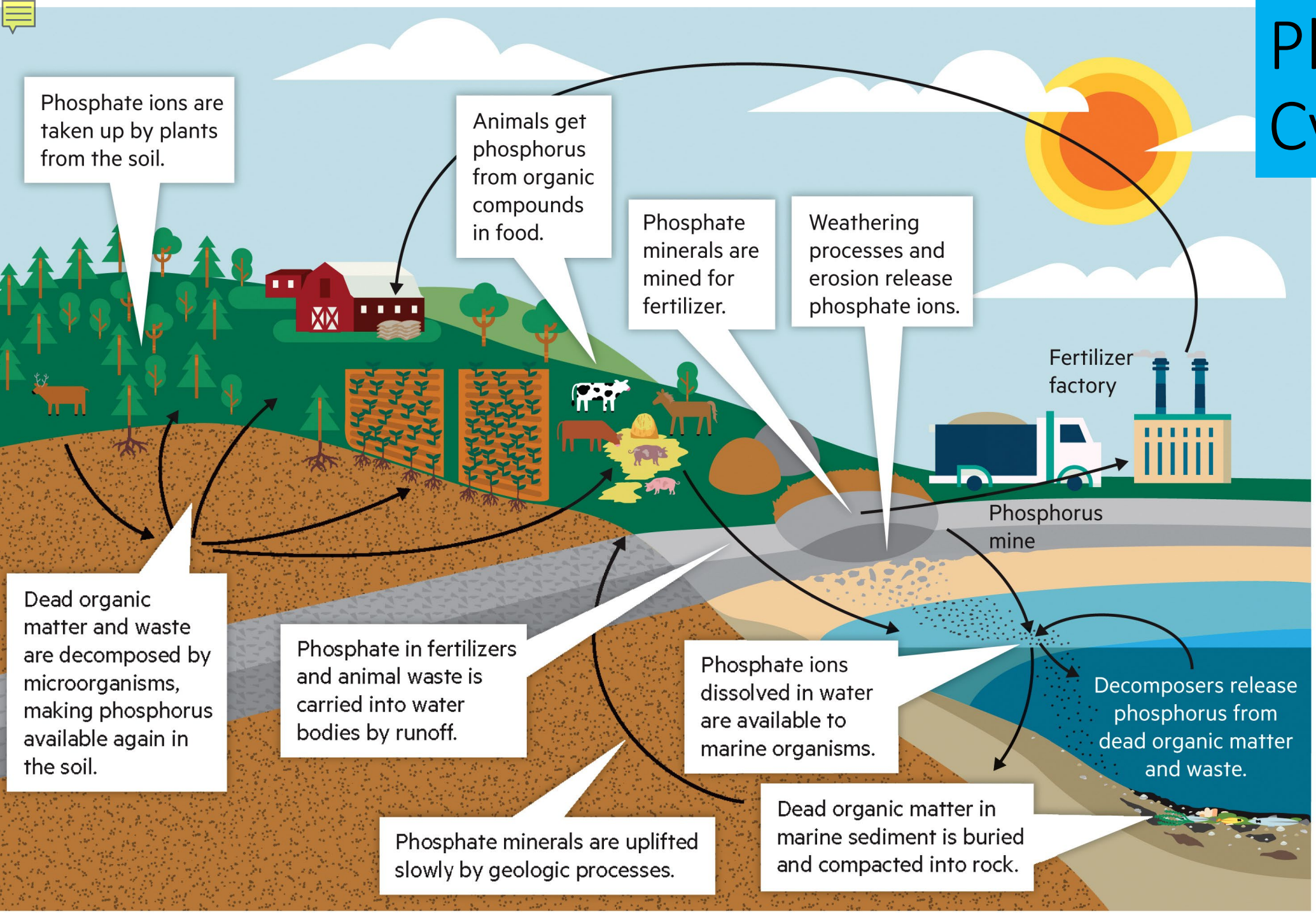


Calcite
$CaCO_3$

Limestone made of $CaCO_3$


I HATE NO
Shell
CONTR

Phosphorus Cycle



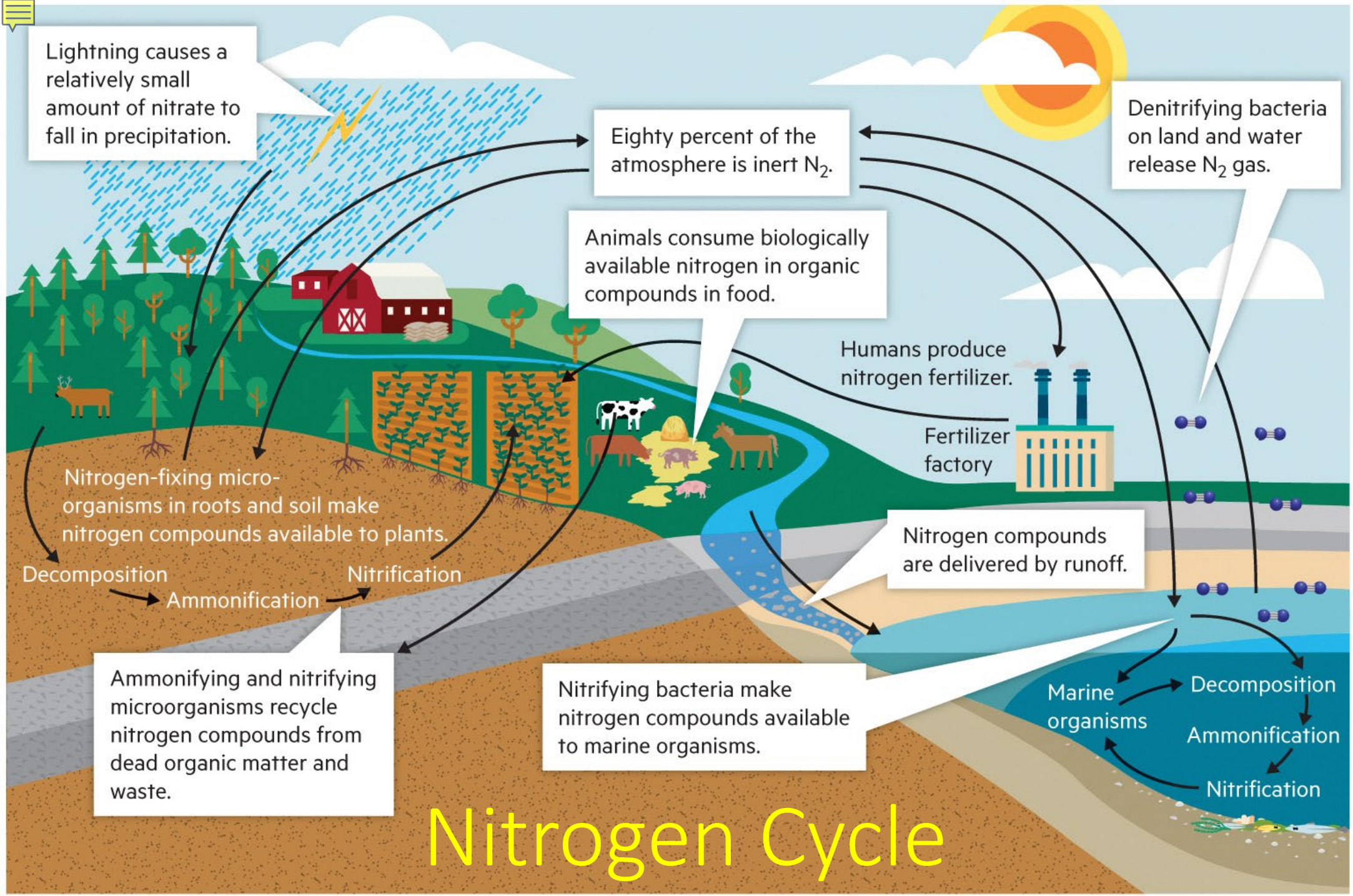
Use: Fertilizer

“If you cannot grow it, You have to mine it”

Oticki/Shutterstock

Criniger Kolio/Shutterstock

Use – Fertilizer



Nitrogen Cycle

Nitrogen Conversion Processes

(a)

Dark Moon Pictures/Shutterstock

(b)

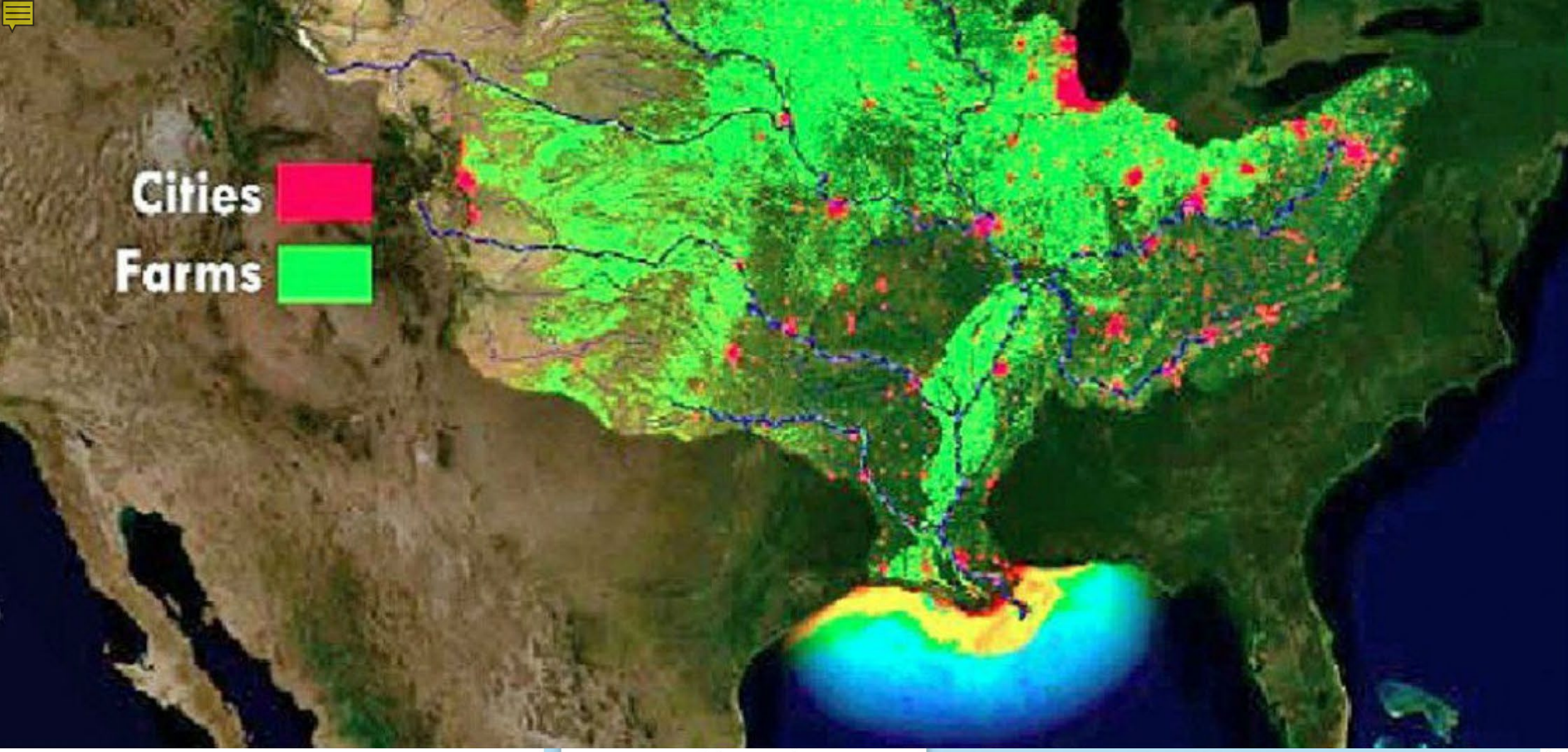
Dr Jeremy Burgess/Science Source

(c)

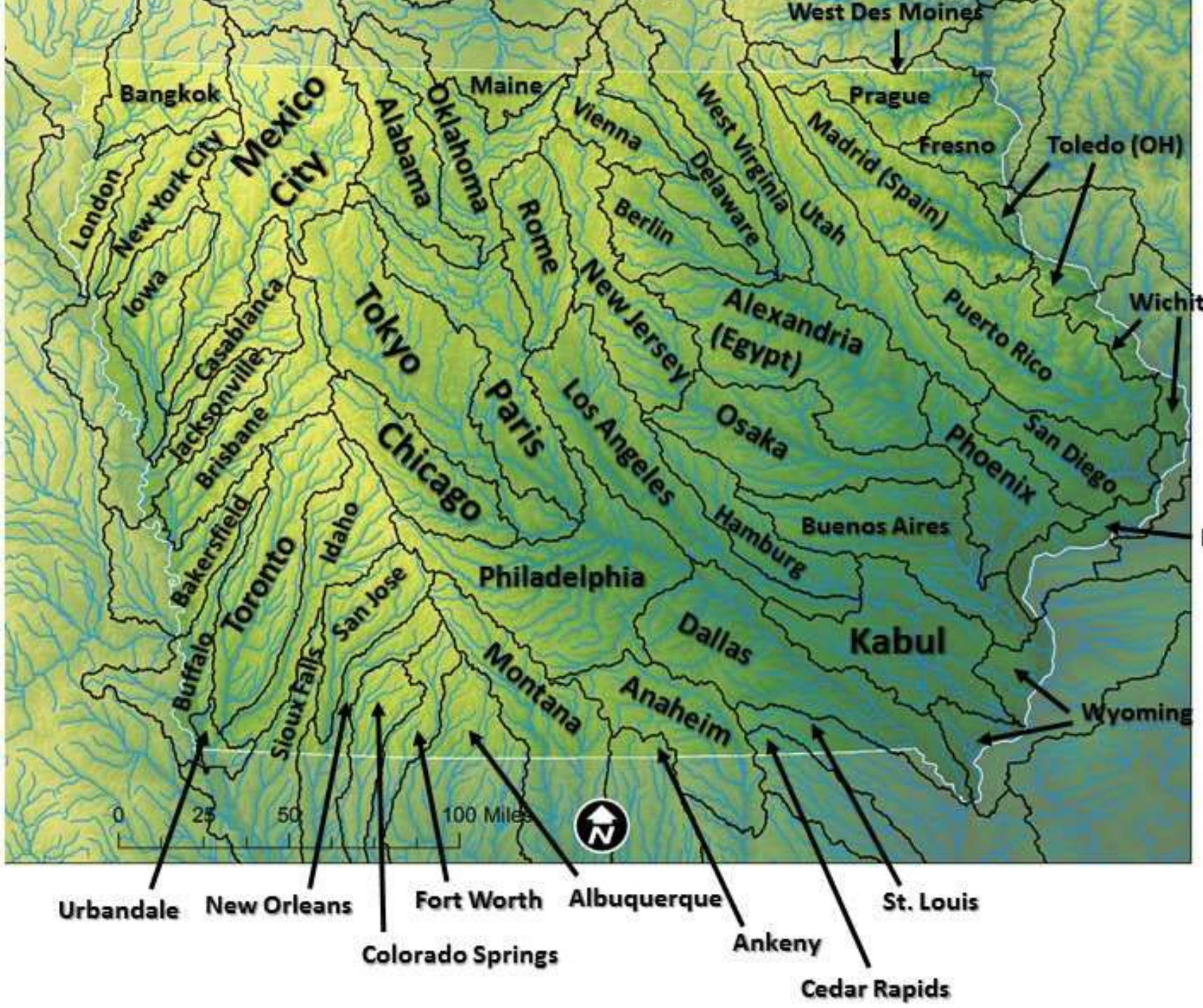
Mycelium/Shutterstock

(d)

Kevin Britland/Alamy Stock Photo



Externalities



Population, from
294,122
to with animals
3,289,237

Statewide
24 million pigs
3 million people
8:1

Chris Jones
U Of Iowa
IIHR

Lynn Betts, USDA Natural Resources Conservation Service

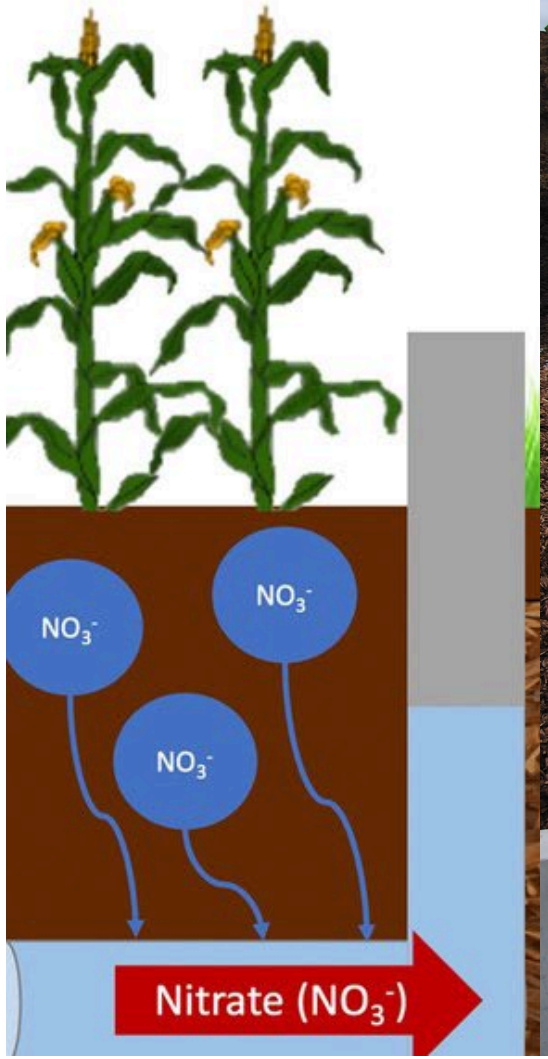
No-Till Farming

Lynn Betts, USDA Natural Resources Conservation Service

Vegetation Buffers

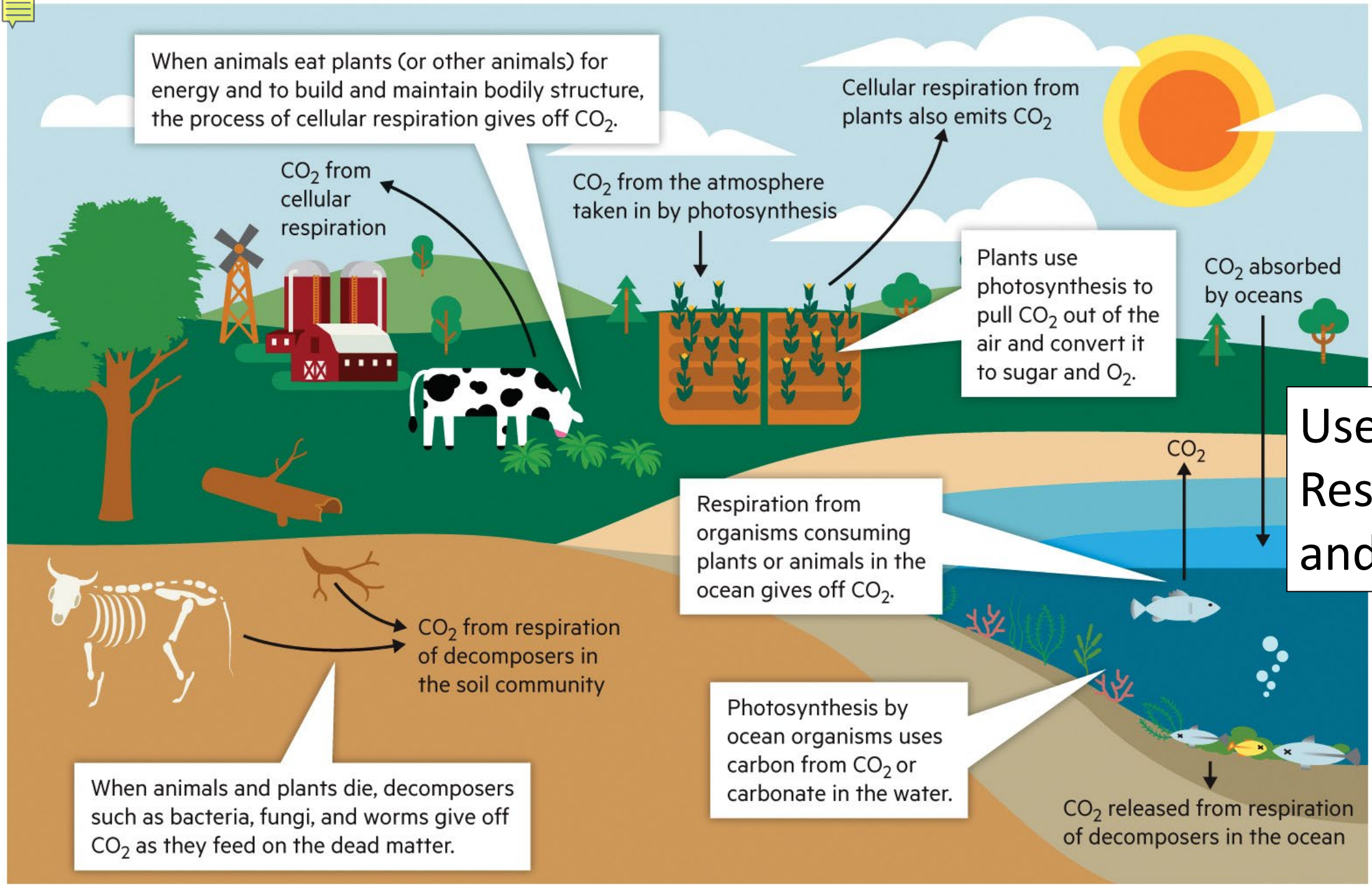
Bioreactors

What is a “Typical” Woodchip Bioreactor?

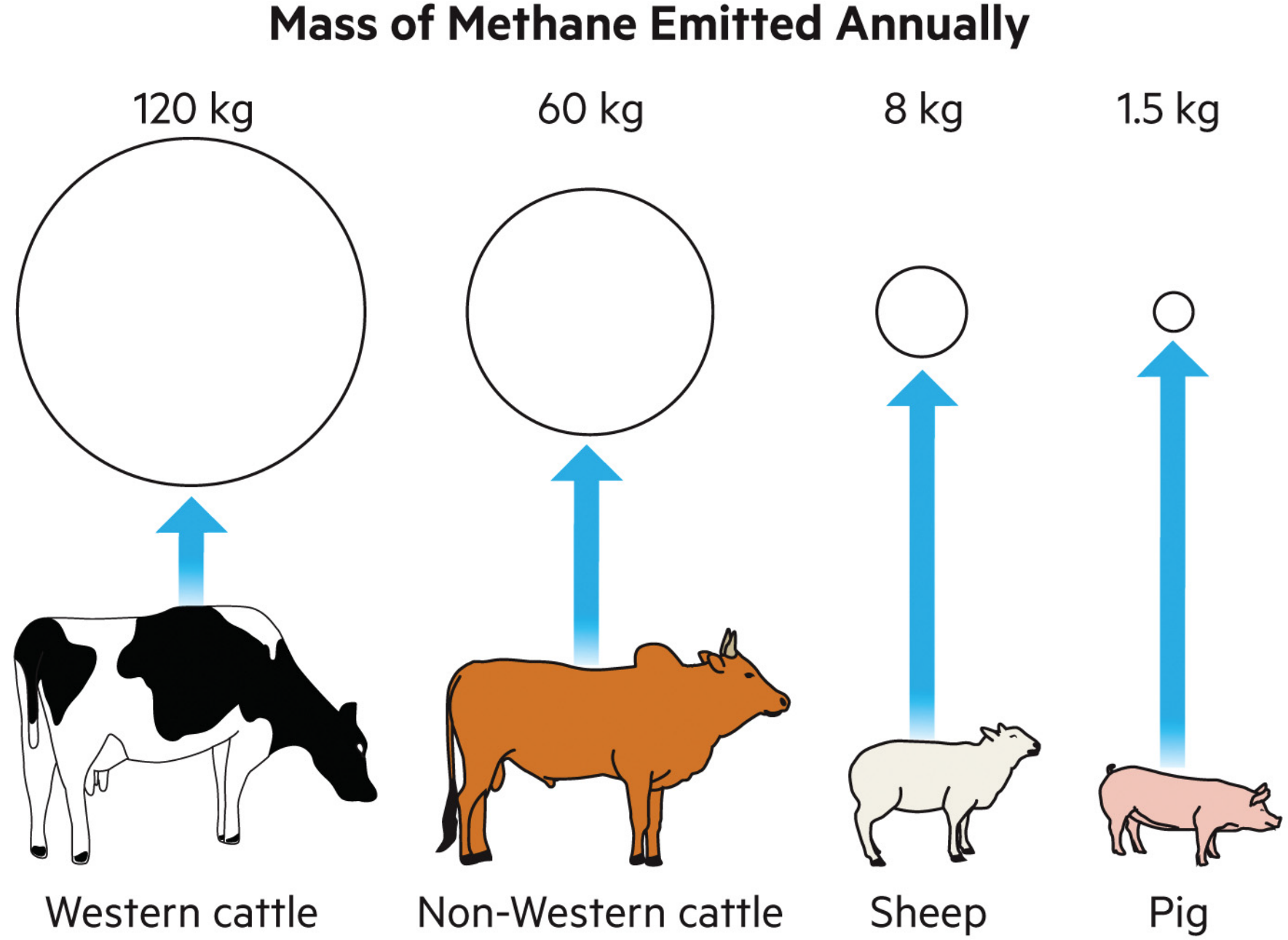


er Water

Carbon Cycle

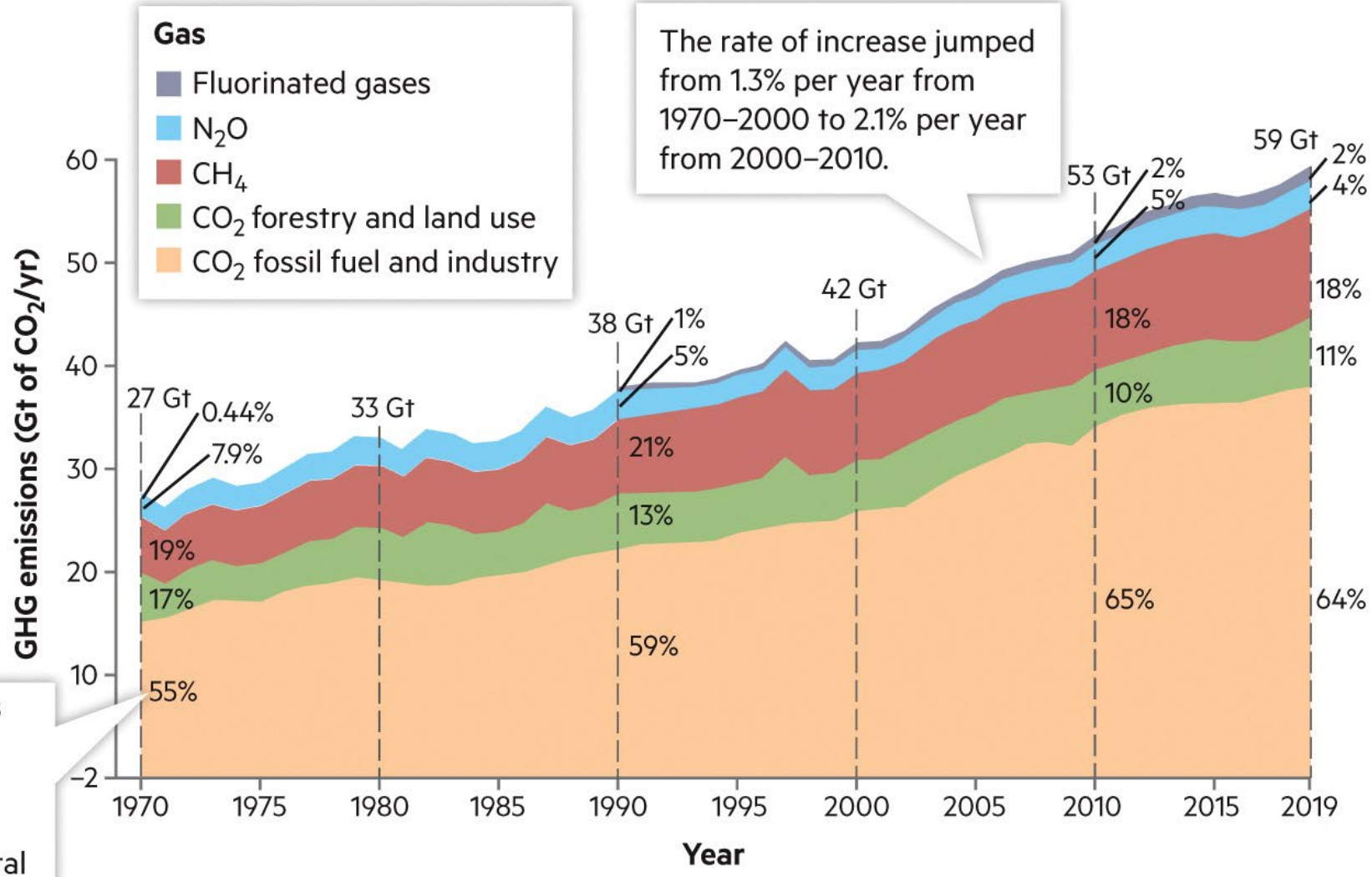


Use – Respiration and Energy



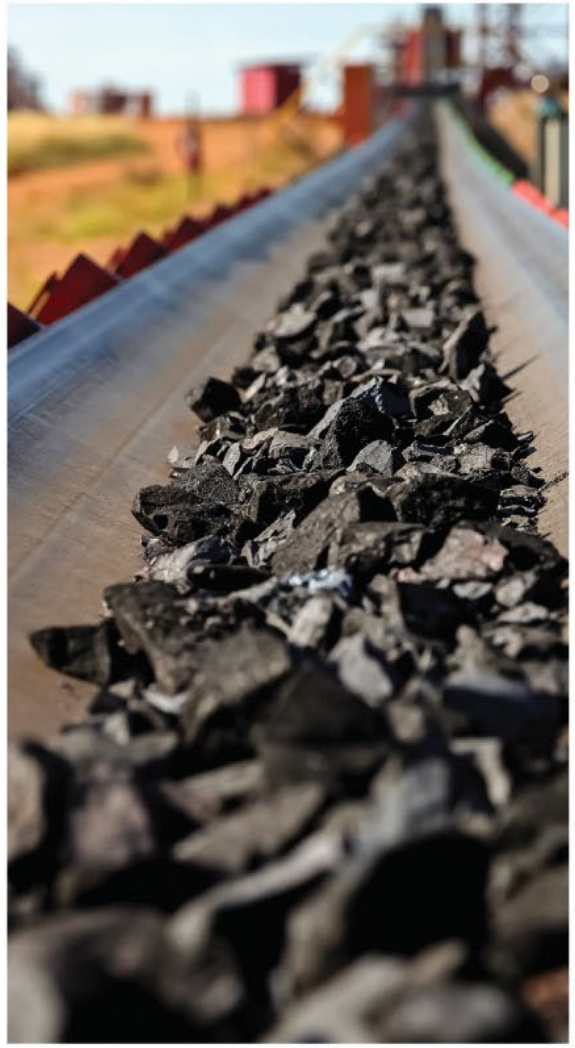
Moving Carbon from the Biosphere to atmosphere

Methanogens- Mirco-organisms that convert C to Methane (CH_4) in anoxic environments.



These numbers indicate the percentage that each gas makes up of total GHG emissions in 1970, 1990, 2010, and 2019.

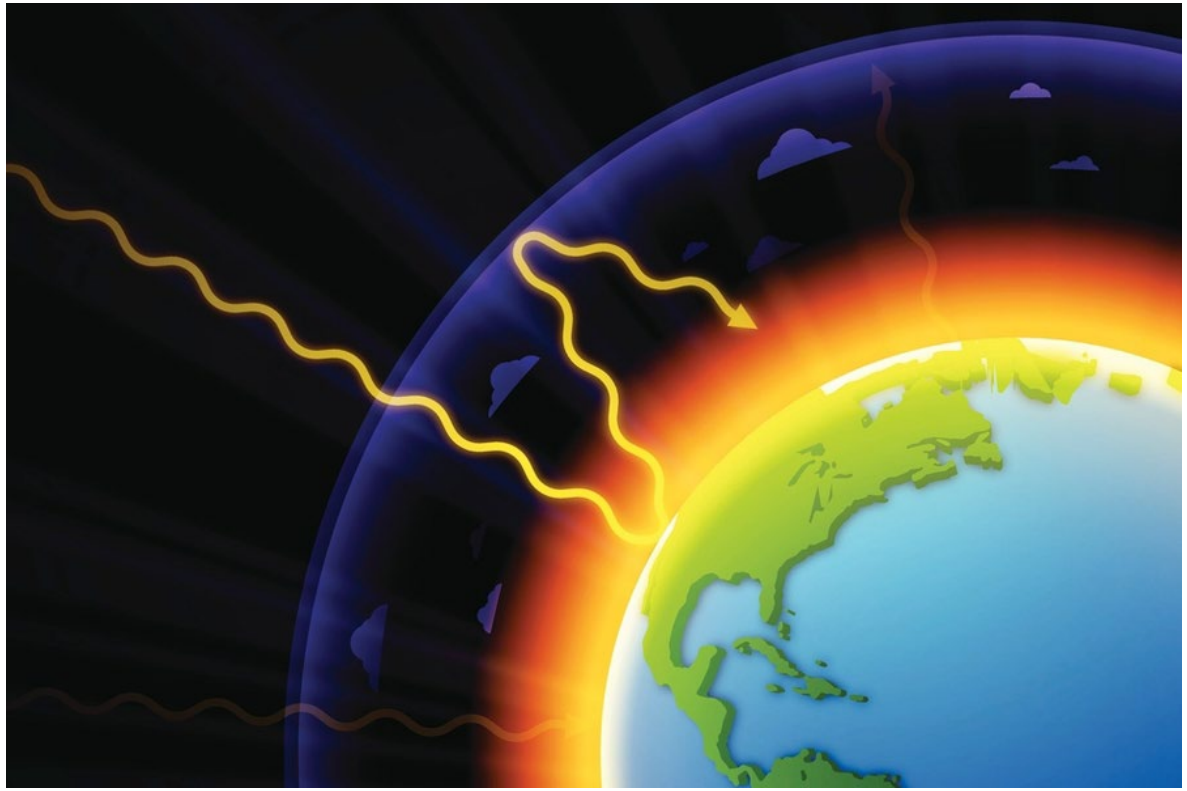
Figure SPM.1 IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.



Sunshine Seeds/Shutterstock

Greenhouse Gases (GHG)

- Carbon Dioxide CO_2
- Methane CH_4
- Nitrous oxide N_2O
- Water vapor $H2O_v$
- Fluorinated gas synthetic gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).



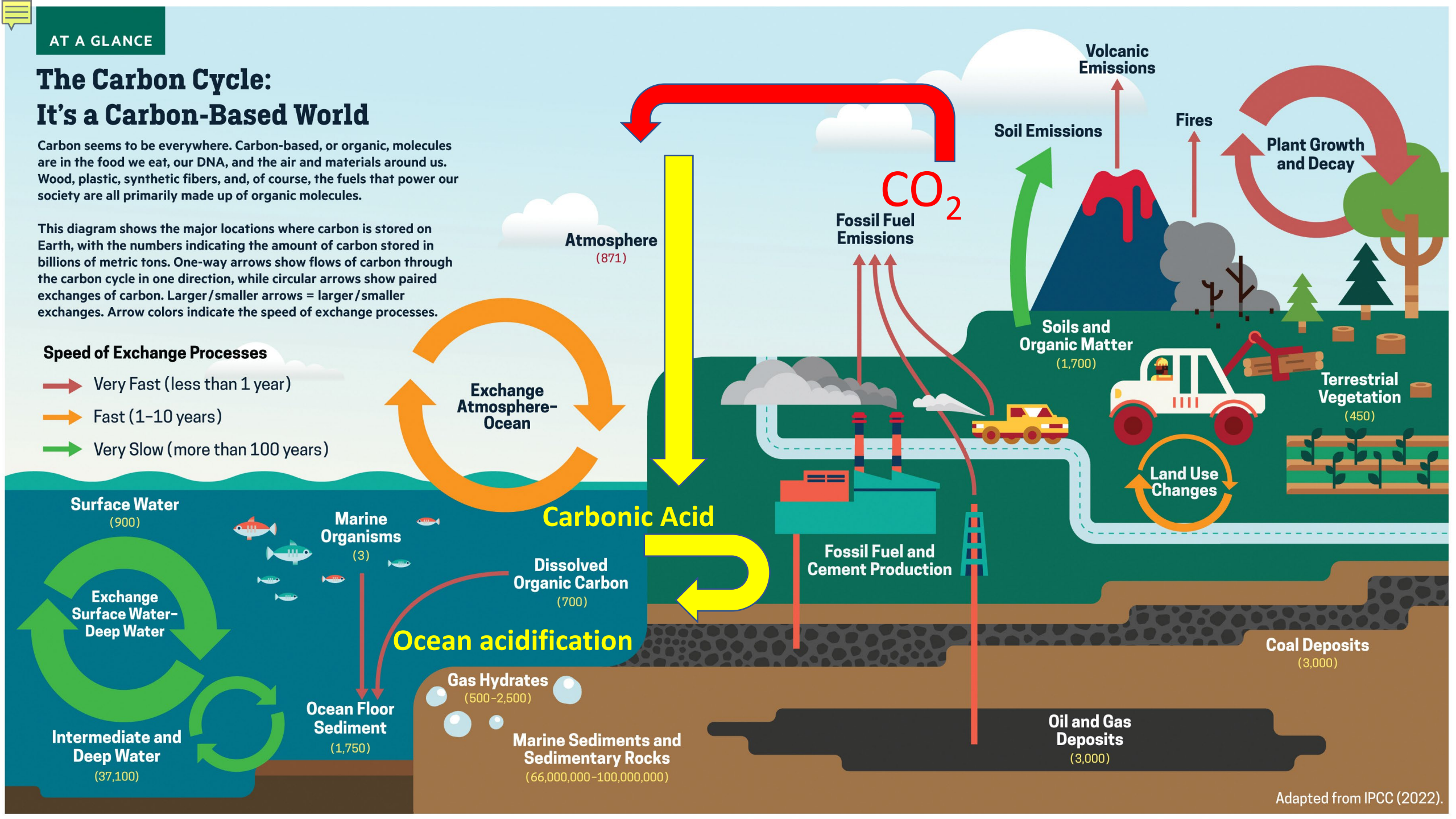
Positive Feedback

AT A GLANCE

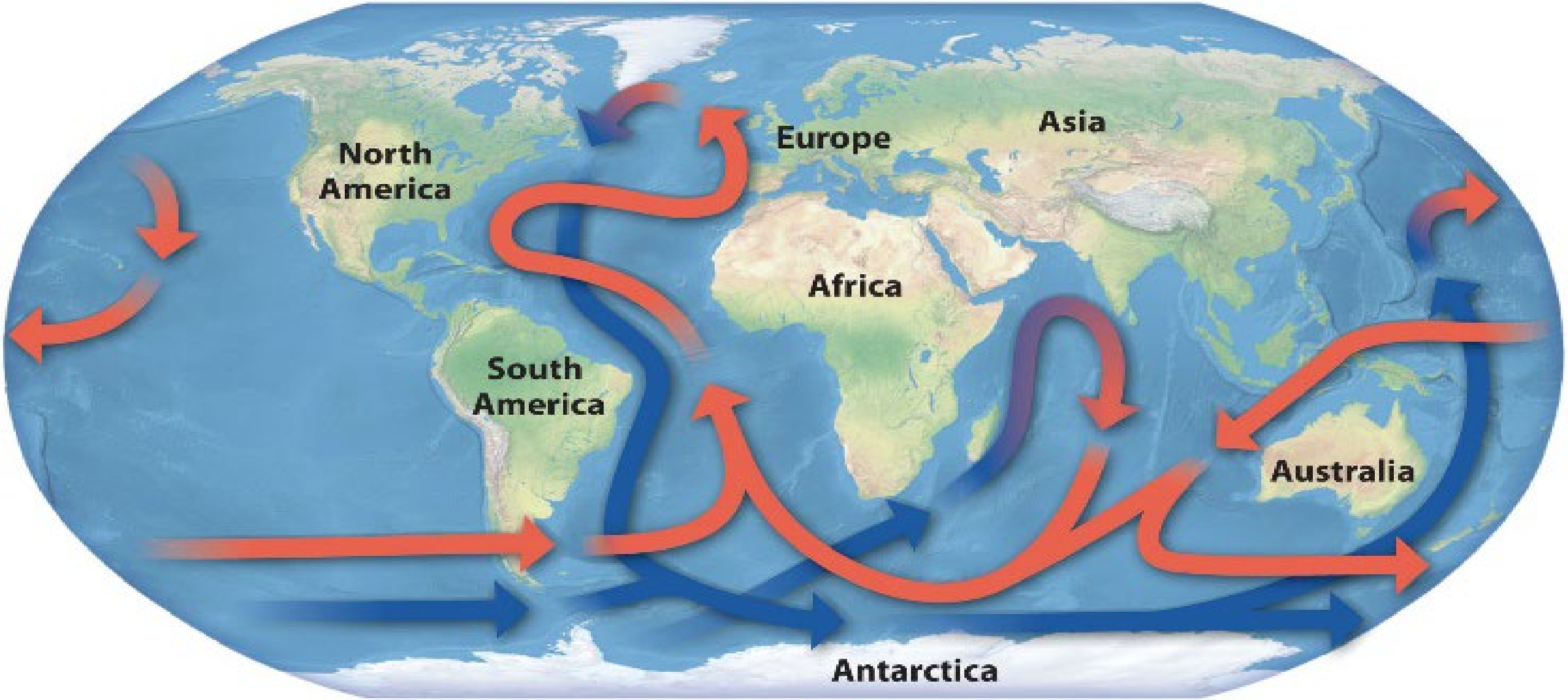
The Carbon Cycle: It's a Carbon-Based World

Carbon seems to be everywhere. Carbon-based, or organic, molecules are in the food we eat, our DNA, and the air and materials around us. Wood, plastic, synthetic fibers, and, of course, the fuels that power our society are all primarily made up of organic molecules.

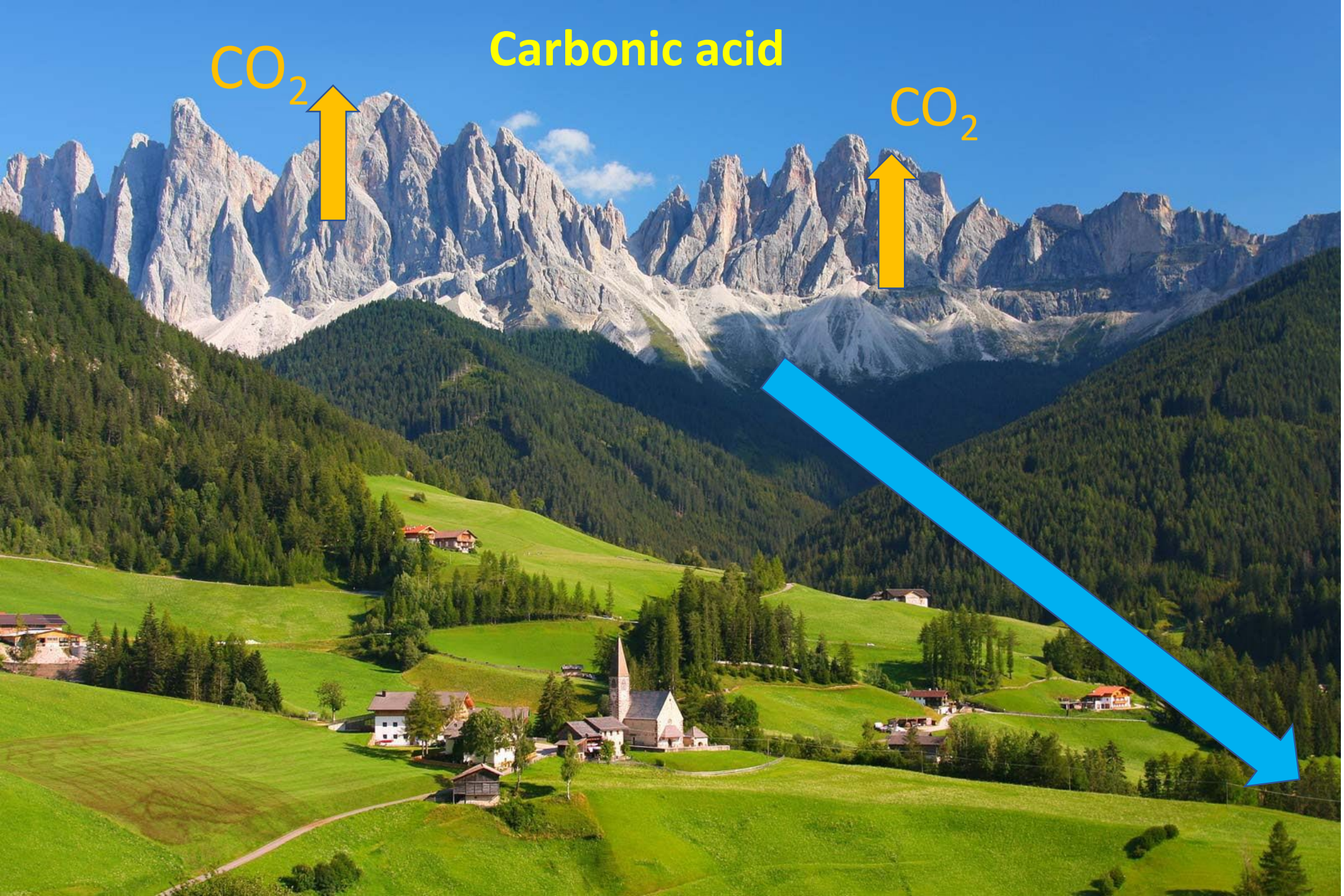
This diagram shows the major locations where carbon is stored on Earth, with the numbers indicating the amount of carbon stored in billions of metric tons. One-way arrows show flows of carbon through the carbon cycle in one direction, while circular arrows show paired exchanges of carbon. Larger/smaller arrows = larger/smaller exchanges. Arrow colors indicate the speed of exchange processes.

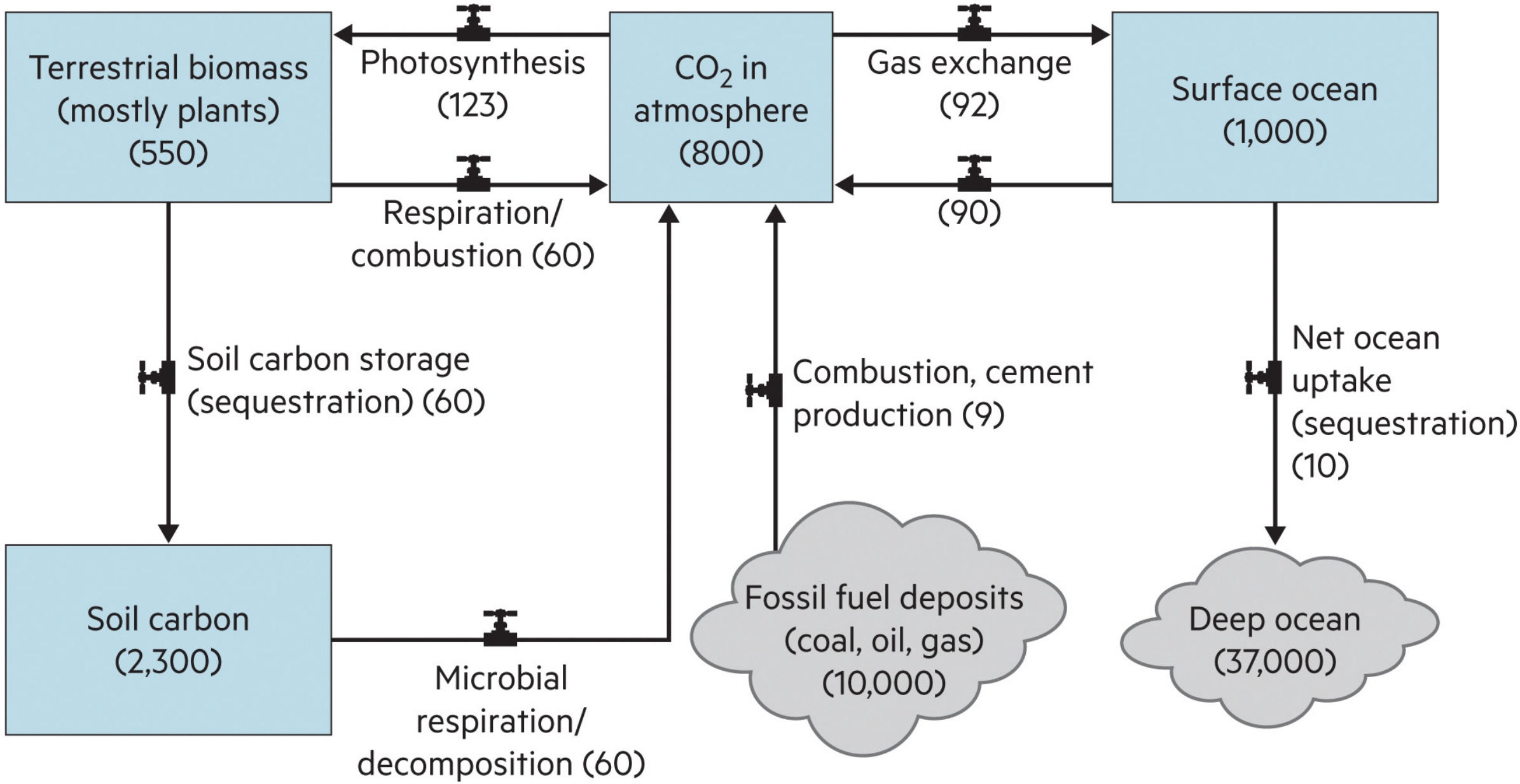


Adapted from IPCC (2022).

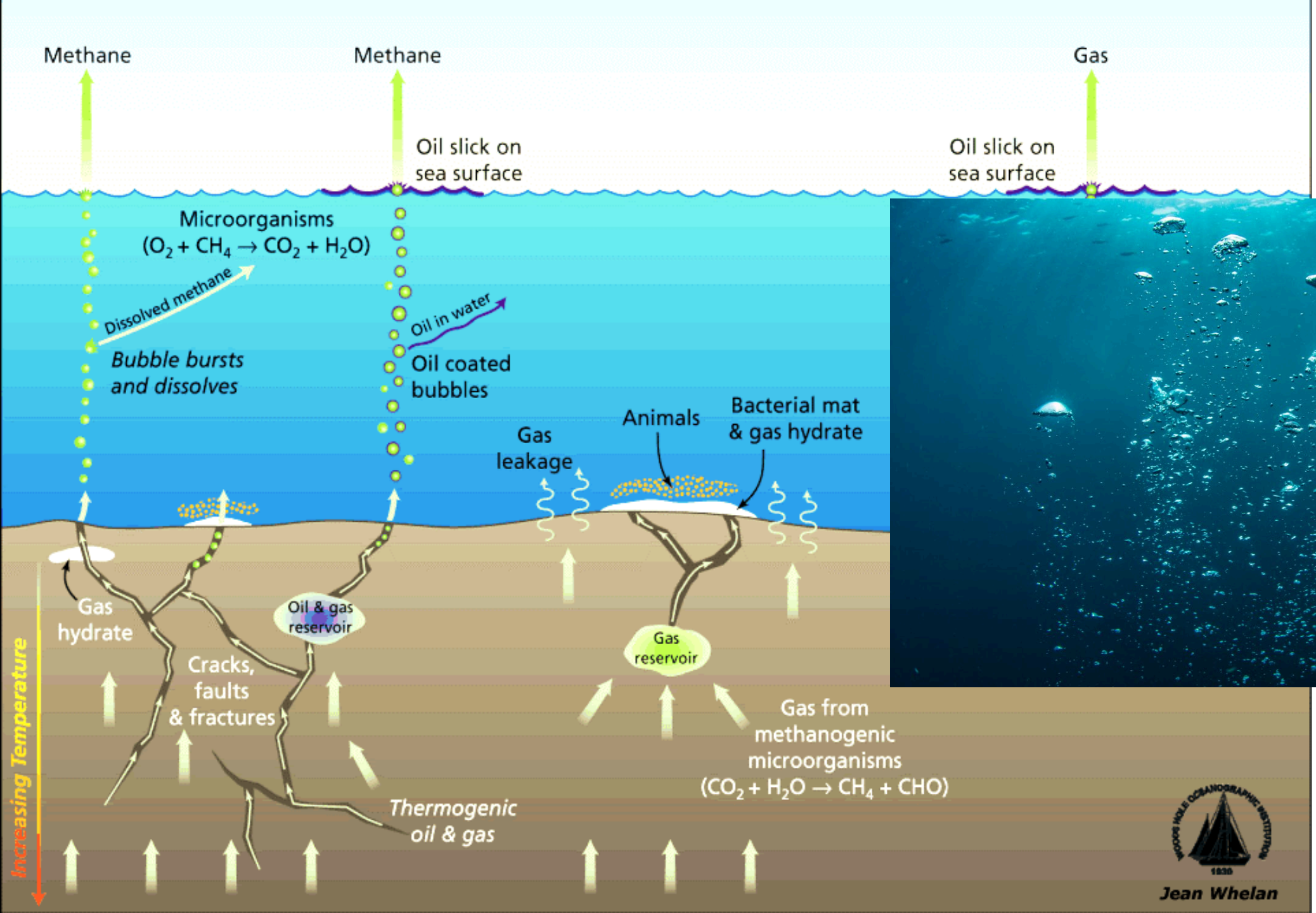


Ocean thermohaline circulation involves sinking of cold, salty water at the poles (shown in blue). This sinking water produces deep cold currents and shallow warm surface currents (shown in red).

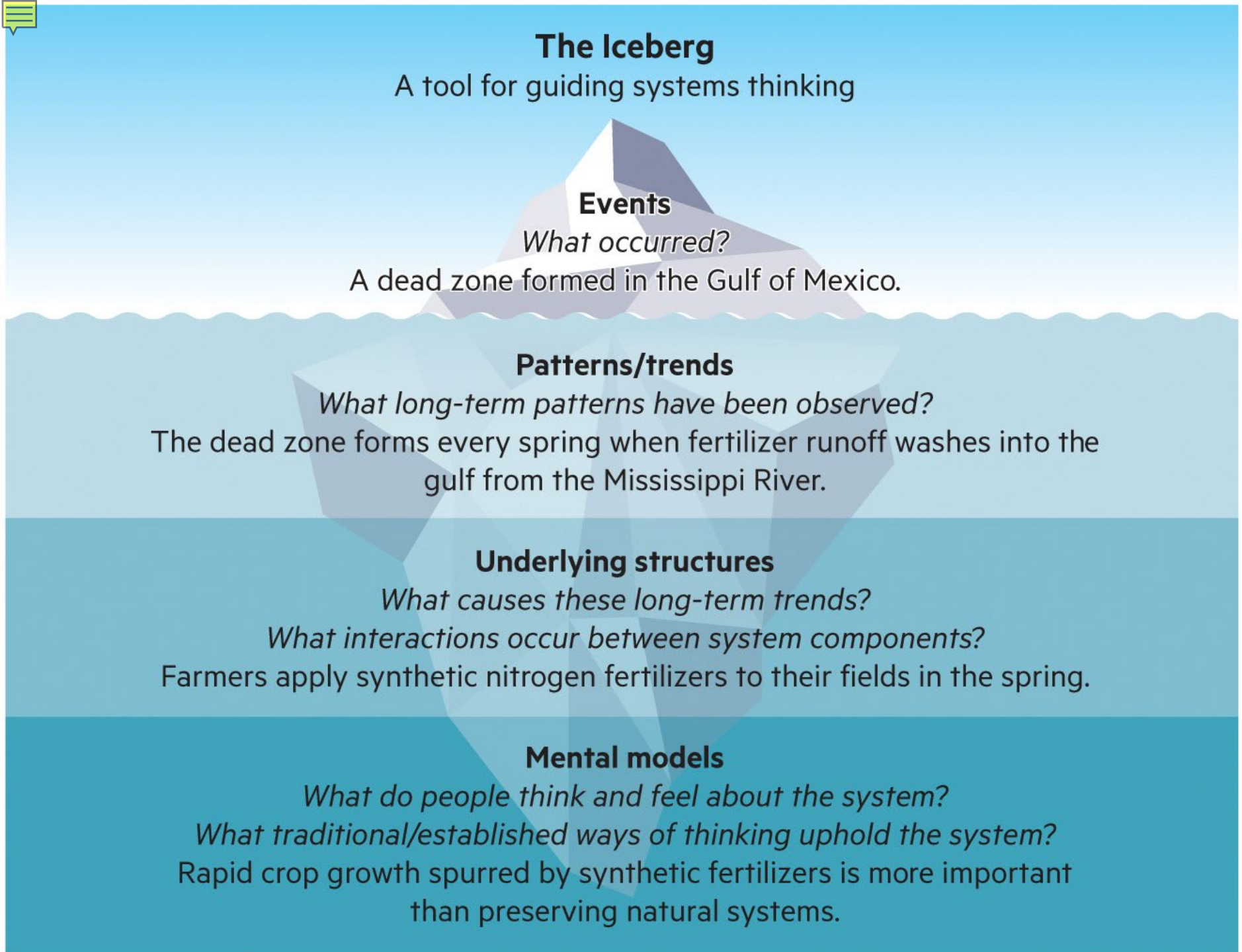

Carbonic acid
CO_2
CO_2


Terrestrial biomass (mostly plants) (550)
Photosynthesis (123)
CO_2 in atmosphere (800)
Gas exchange (92)
Surface ocean (1,000)
Respiration/ combustion (60)
(90)
Soil carbon storage (sequestration) (60)
Combustion, cement production (9)
Net ocean uptake (sequestration) (10)
Soil carbon (2,300)
Microbial respiration/ decomposition (60)
Fossil fuel deposits (coal, oil, gas) (10,000)
Deep ocean (37,000)

Room temp vs. On ice

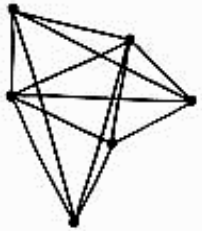

Methane
Methane
Gas
Oil slick on sea surface
Oil slick on sea surface
Microorganisms
$(O_2 + CH_4 \rightarrow CO_2 + H_2O)$
Dissolved methane
Oil in water
Bubble bursts and dissolves
Oil coated bubbles
Gas leakage
Animals
Bacterial mat & gas hydrate
Gas hydrate
Oil & gas reservoir
Gas reservoir
Cracks, faults & fractures
Thermogenic oil & gas
Gas from methanogenic microorganisms
$(CO_2 + H_2O \rightarrow CH_4 + CHO)$
Increasing Temperature
Jean Whelan

Systems Thinking



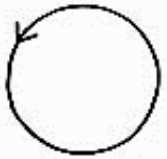
TOOLS OF A SYSTEM THINKER

DISCONNECTION

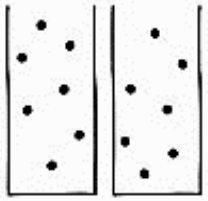


INTERCONNECTEDNESS

LINEAR



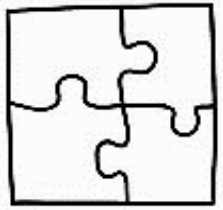
CIRCULAR



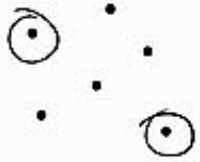
SILOS

EMERGENCE

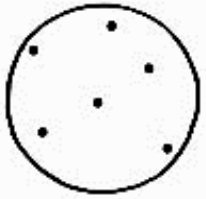
PARTS



WHOLES

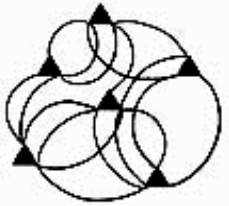


ANALYSIS



SYNTHESIS

ISOLATION



RELATIONSHIPS

DISRUPT DESIGN