Unit 6
Ocean Preservation and Geoengineering

Learning Goals

1. Apply knowledge of the carbon cycle and food web dynamics to explain the conceptual approach that geoengineering strategies (i.e. ocean fertilization) are built on.

2. Analyze the pros and cons of implementing geoengineering solutions to address changes to the global climate system.

Geoengineering

= the deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming (*The Royal Society*).

Part One — Review

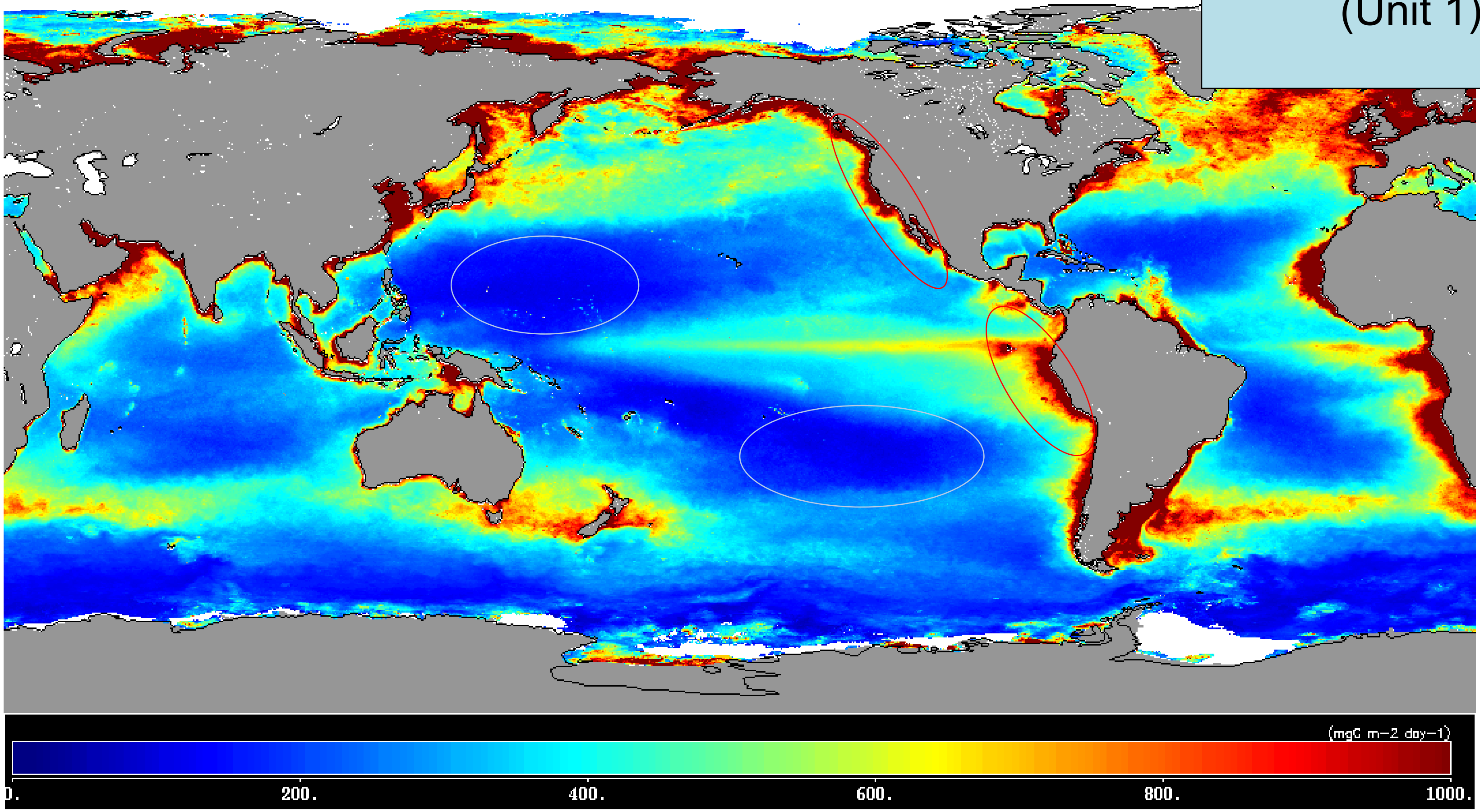
- Ocean Circulation Patterns & Biological Productivity (Unit 1)
- Ocean Carbon Cycle (Unit 2)
- Food Webs (Unit 3)

Part Two – Processes and feedbacks

- The Biological Pump
- Ocean Fertilization & Lessons Learned (?)
- What is Next: Other Geoengineering Strategies

Currents and Surface Primary Productivity

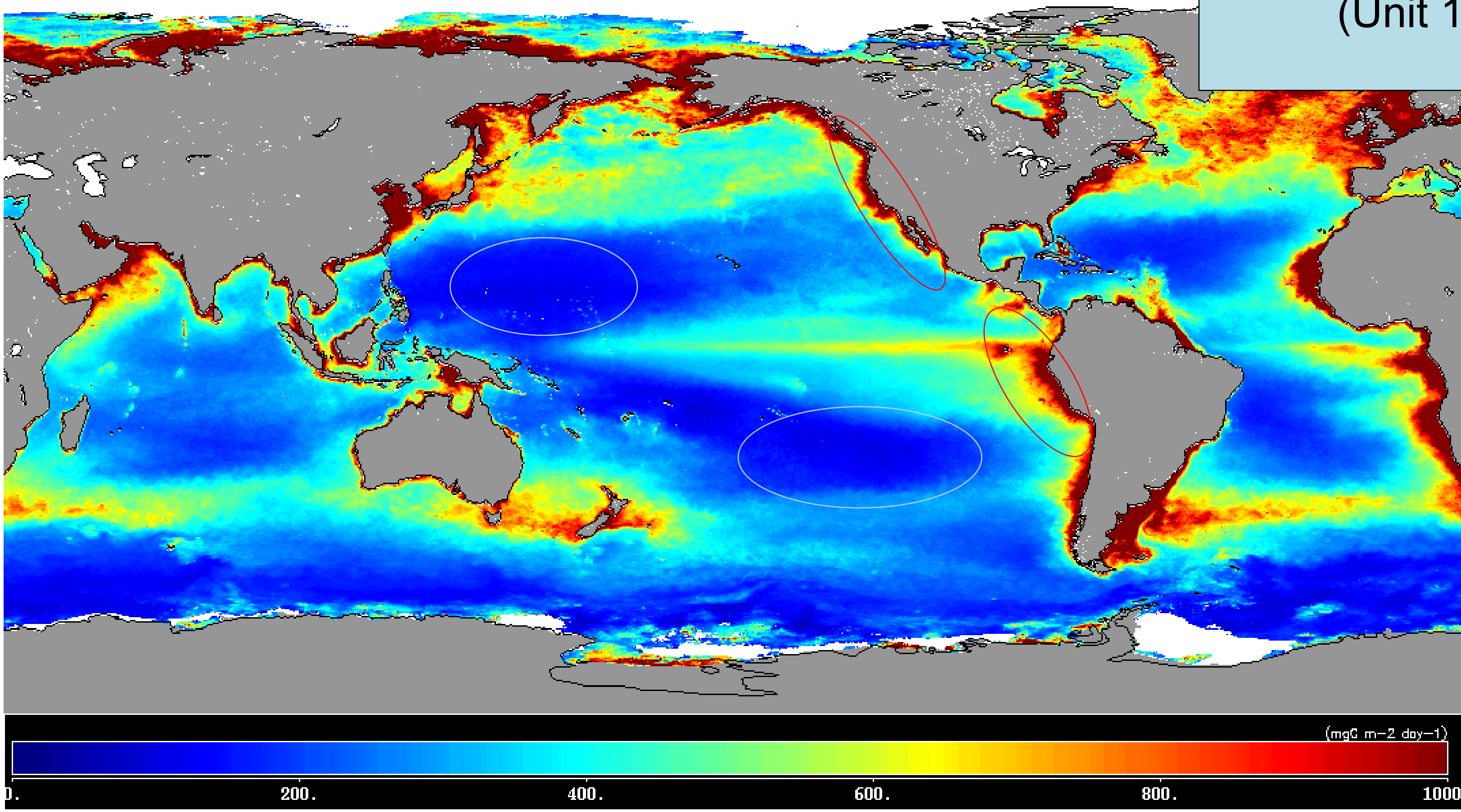
Ocean Circulation/
Temperature
(Unit 1)



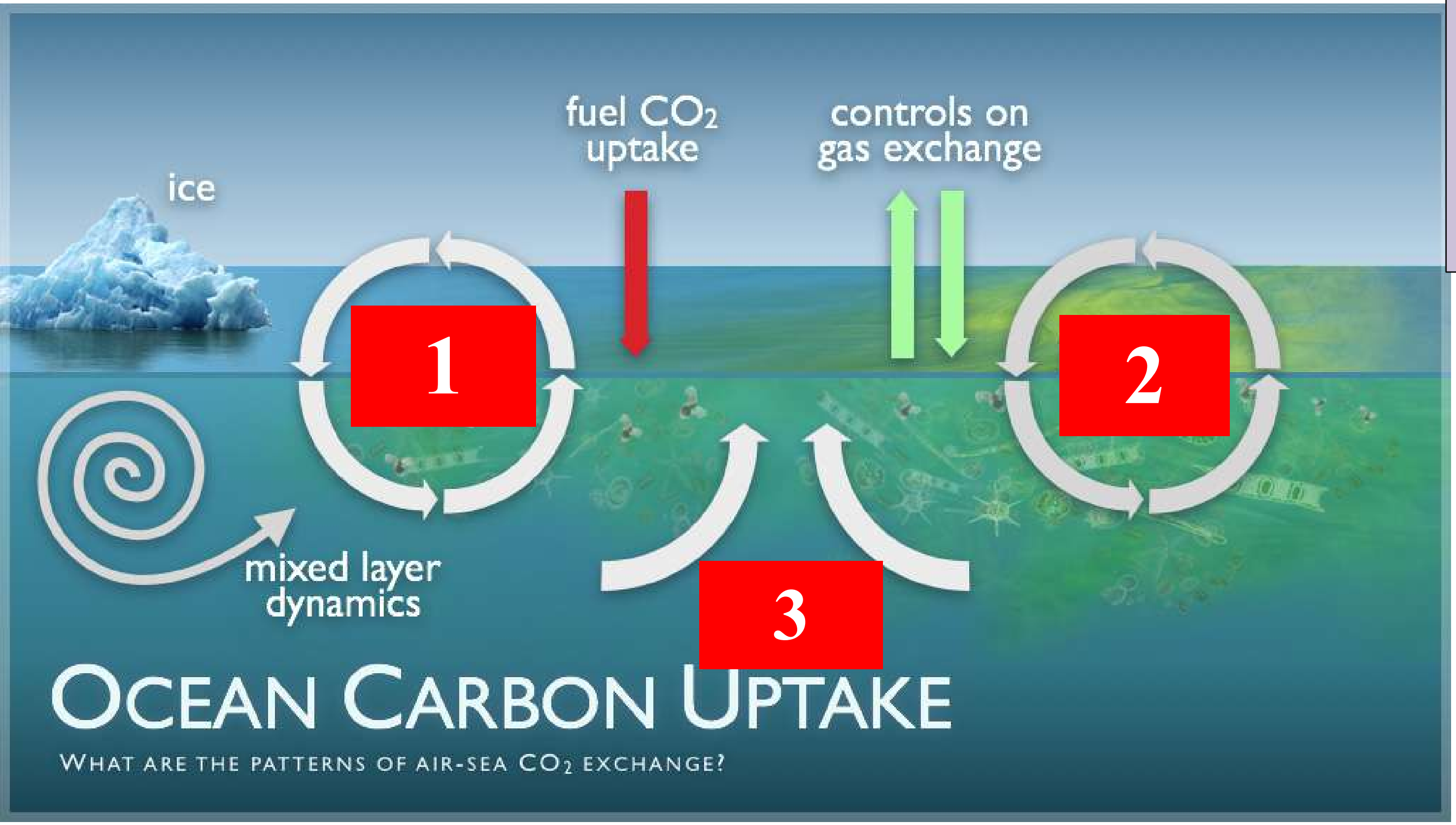
	direction of water	**nutrient availability**
red circles indicate	?	?
blue circles indicate	?	?

Currents and Surface Primary Productivity

Ocean Circulation/ Temperature
(Unit 1)



	direction of water	**nutrient availability**
red circles indicate	upward / coastal upwelling	nutrient-rich
blue circles indicate	circular gyres	nutrient-poor

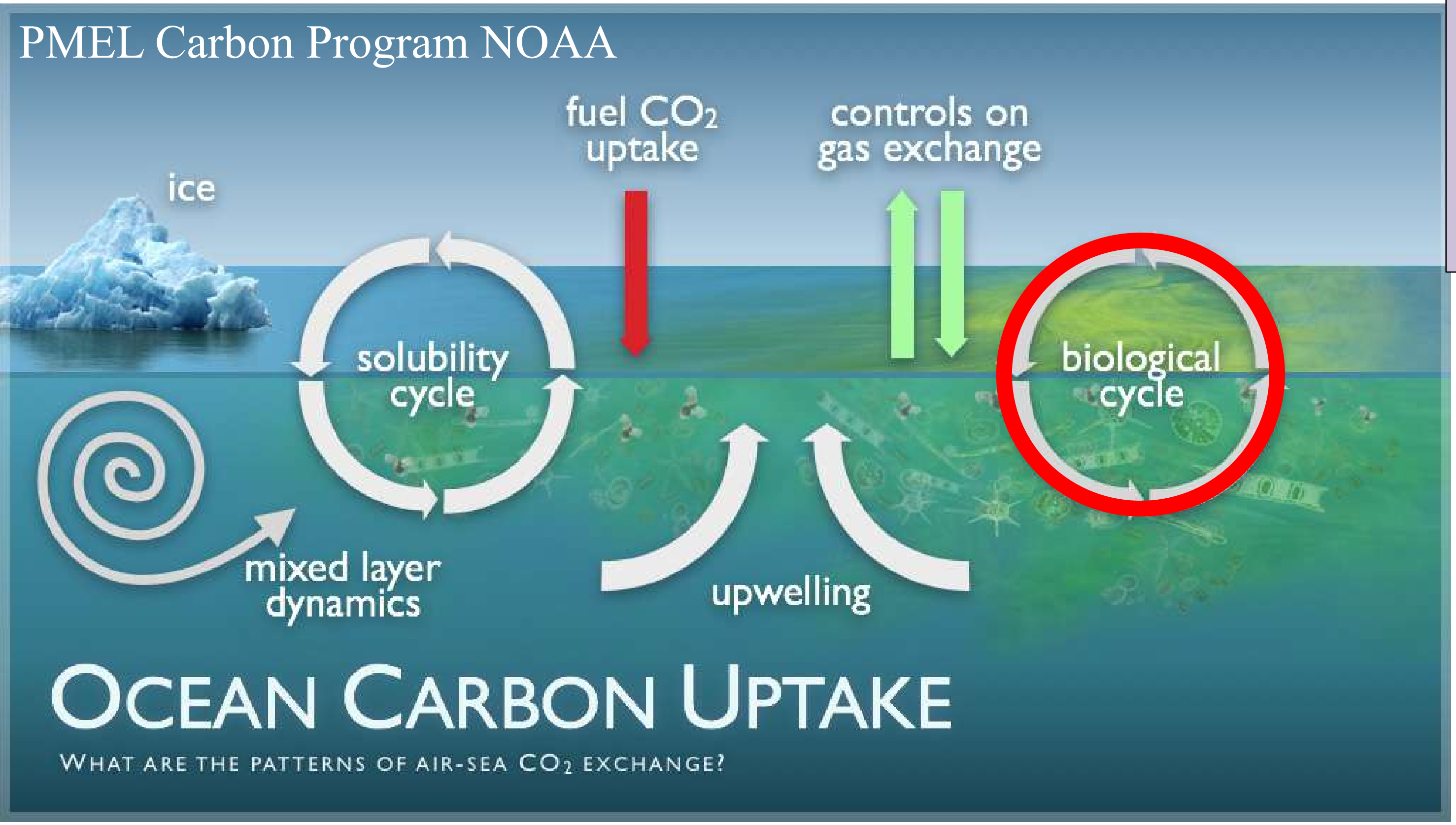


Ocean Chemistry
(Unit 2)

1 What is the cycle called that results in the transport of dissolved carbon (DC) based on physiochemical gradients?

2 What is the cycle called where organisms drive carbon transformation (fate of Particulate Carbon = PC) ?

3 What is the process called that transports colder, nutrient-rich deep water to the surface?



Ocean Chemistry
(Unit 2)

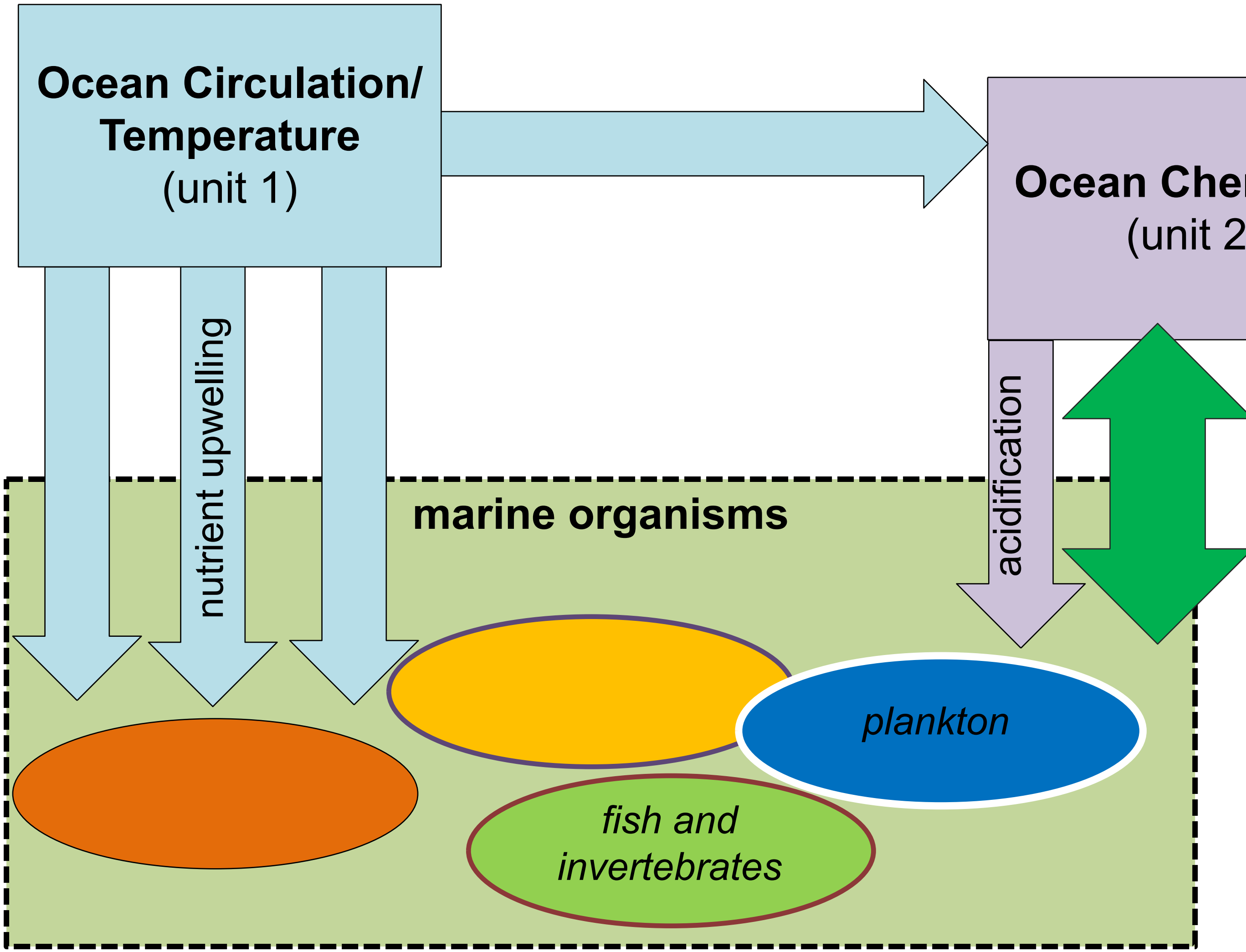
1 **solubility cycle**

2 **biological cycle**

3 **upwelling**

Review of examples on how temperature and carbon concentration may interact and affect organisms

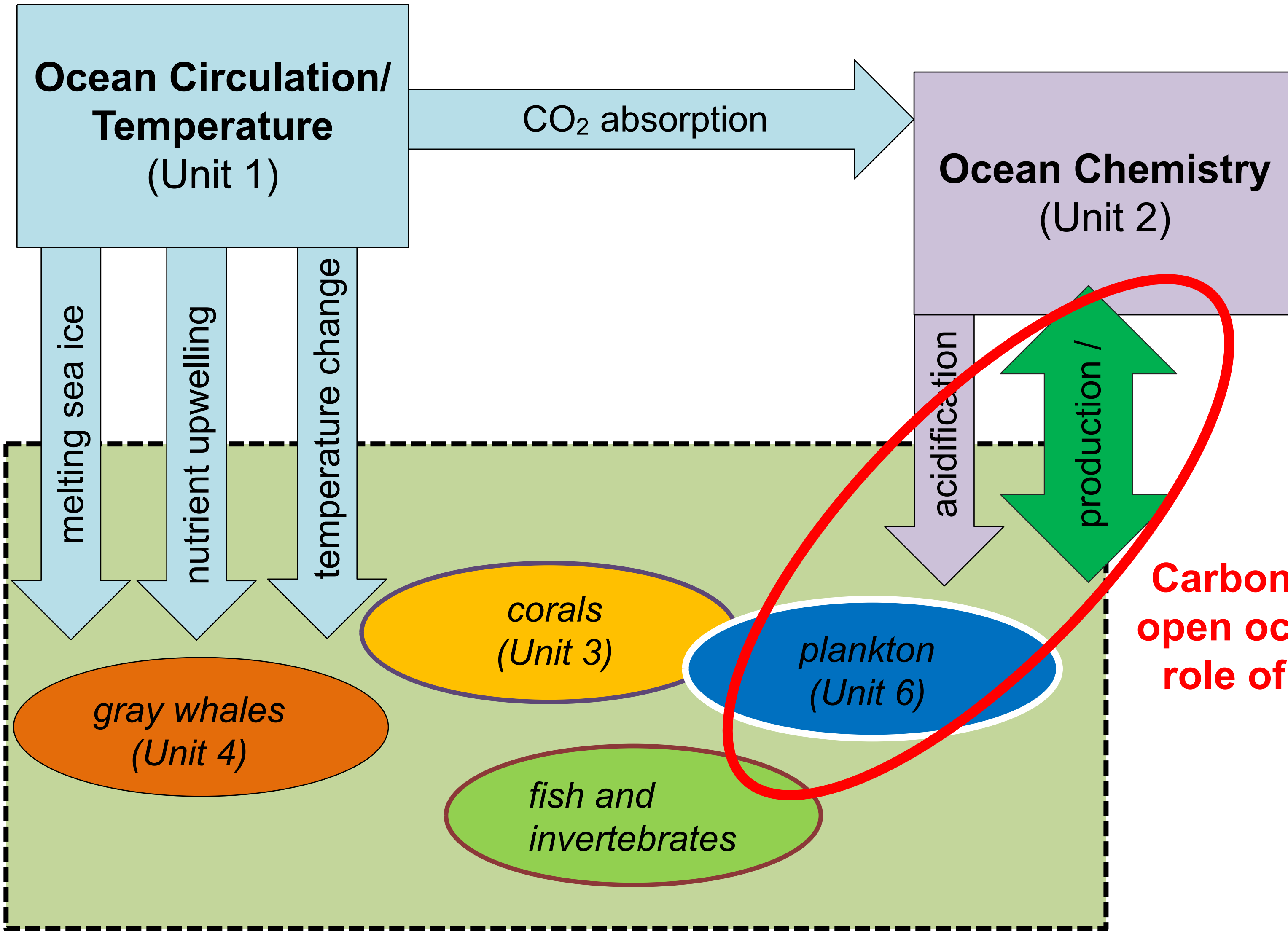
Activity 1 — 8 minutes, add missing terms in empty arrows (i.e., processes) and circles (organisms). When you have completed this figure, then pair up with another student in class and discuss your answers.



Terms

- gray whales
- melting of sea ice
- CO_2 absorption
- production/ respiration
- corals
- upwelling/mixing

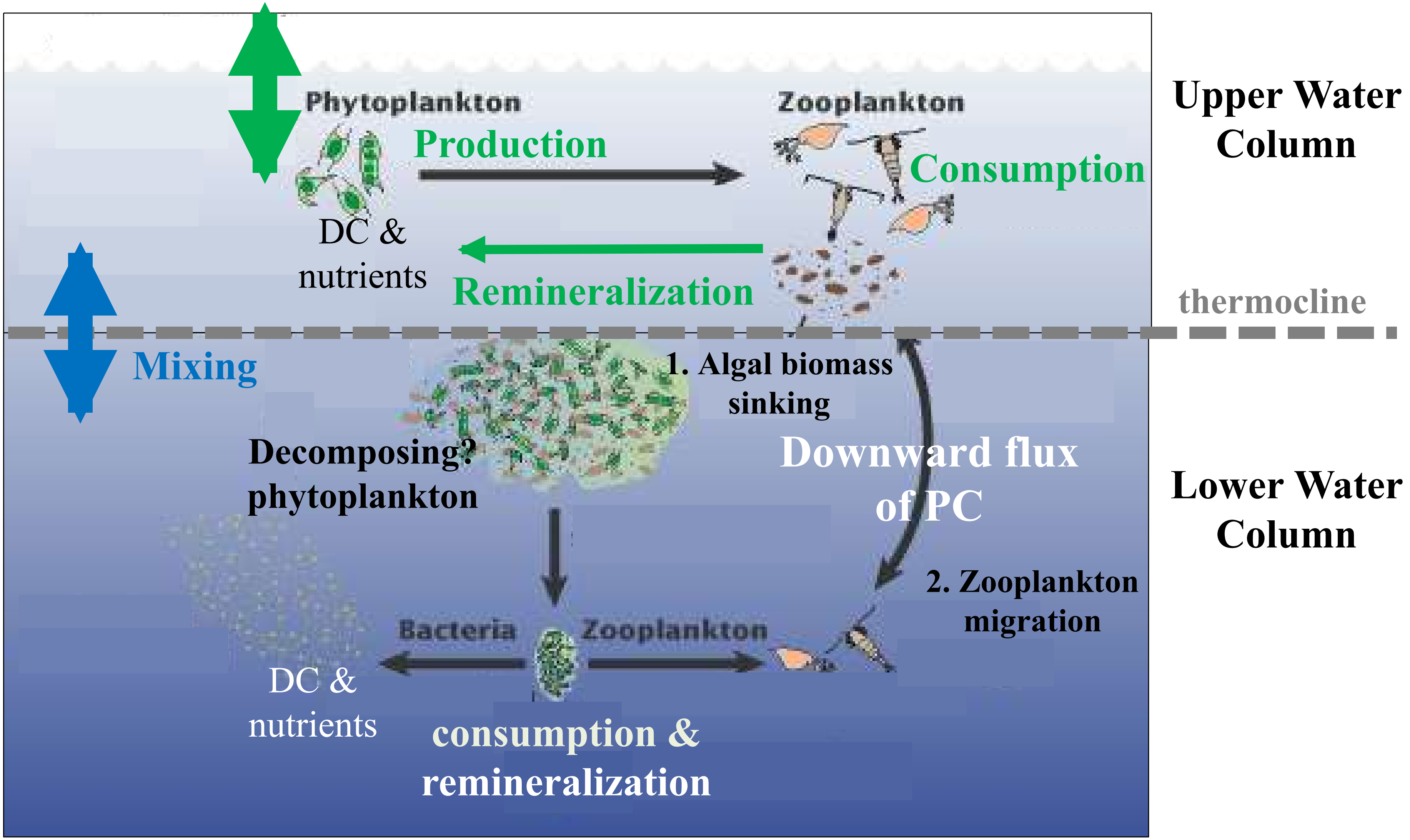
Review of examples on how temperature and carbon concentration may interact and affect organisms



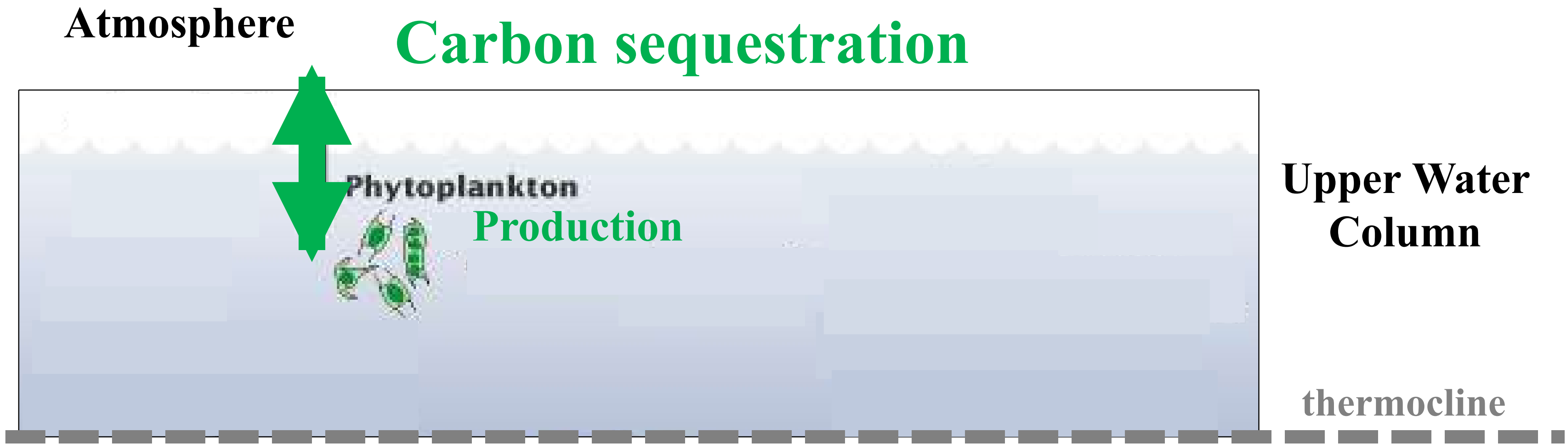
Carbon balance in open ocean and the role of plankton?

The Biological Cycle or the Biological Carbon Pump

Process of **surface carbon reaching the deep ocean**, mediated by biology (e.g., sinking algal cells)

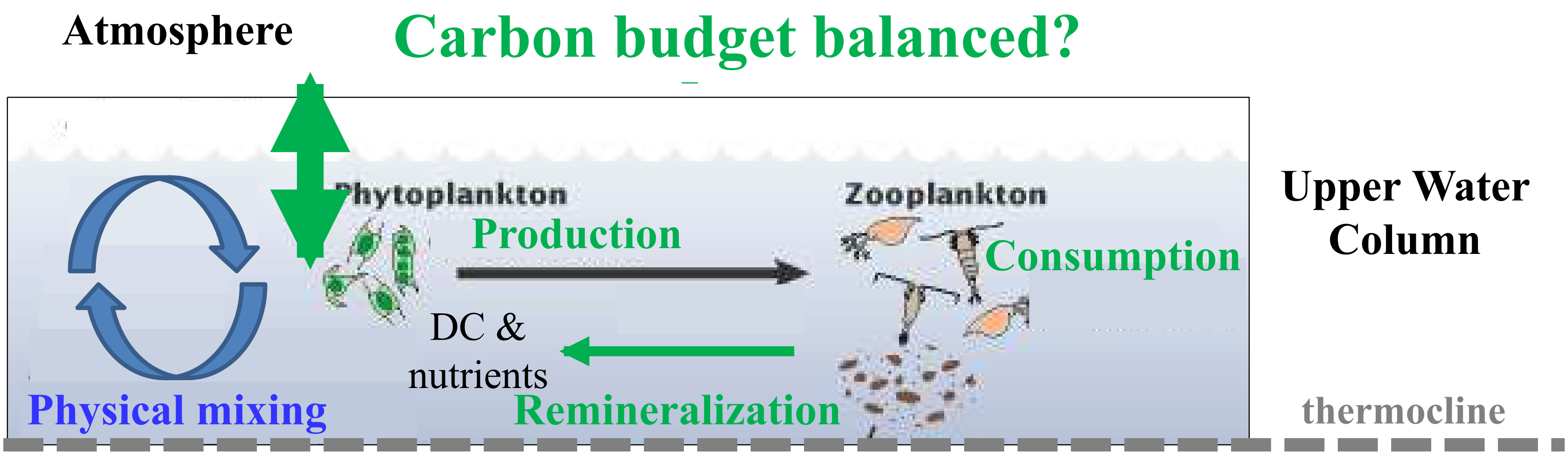


The Biological Carbon Pump — Food Webs



What happens to carbon within the upper (mixed) water column, above the thermocline?

The Biological Carbon Pump — Food Webs



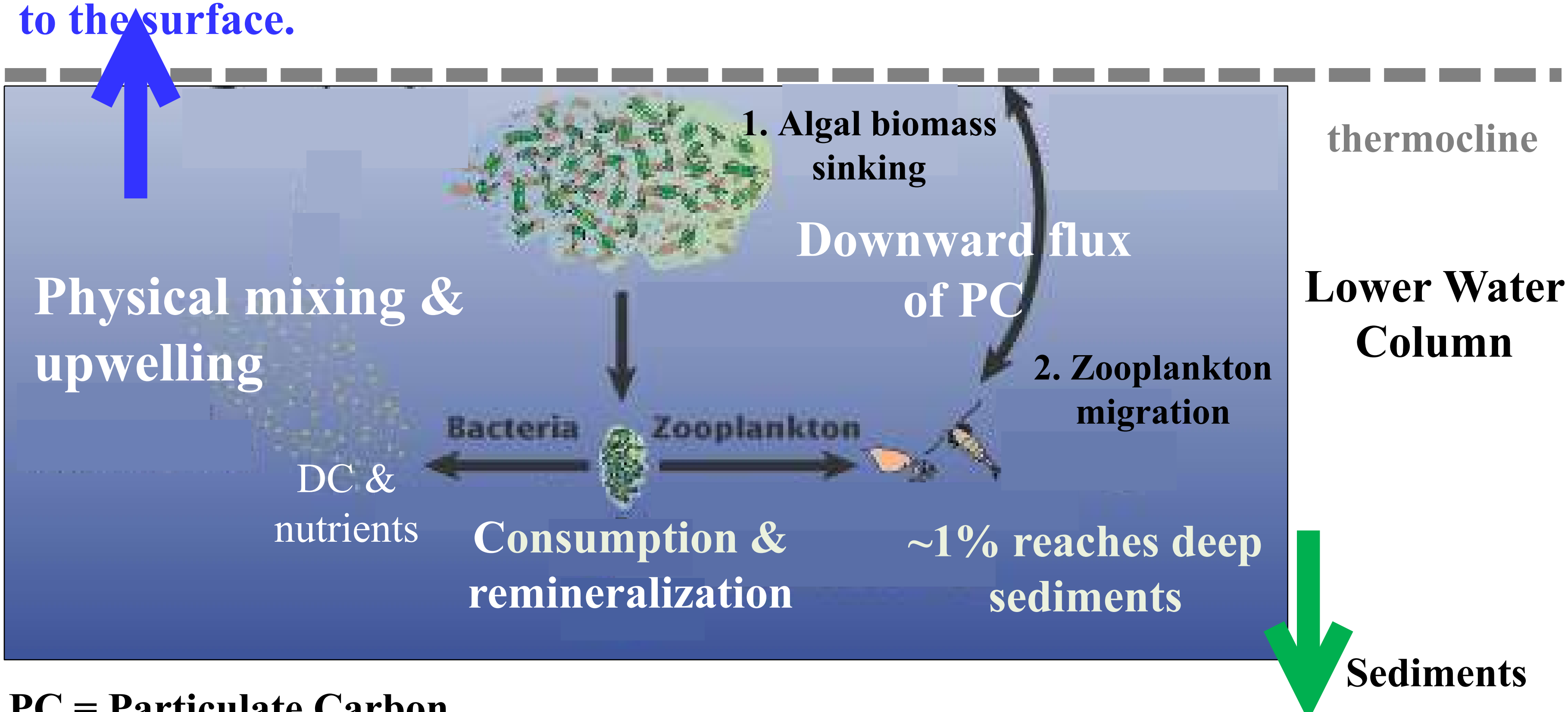
What happens to carbon within the upper (mixed) water column, above the thermocline?

DC = Dissolved Carbon (solubility pump)

The Biological Carbon Pump

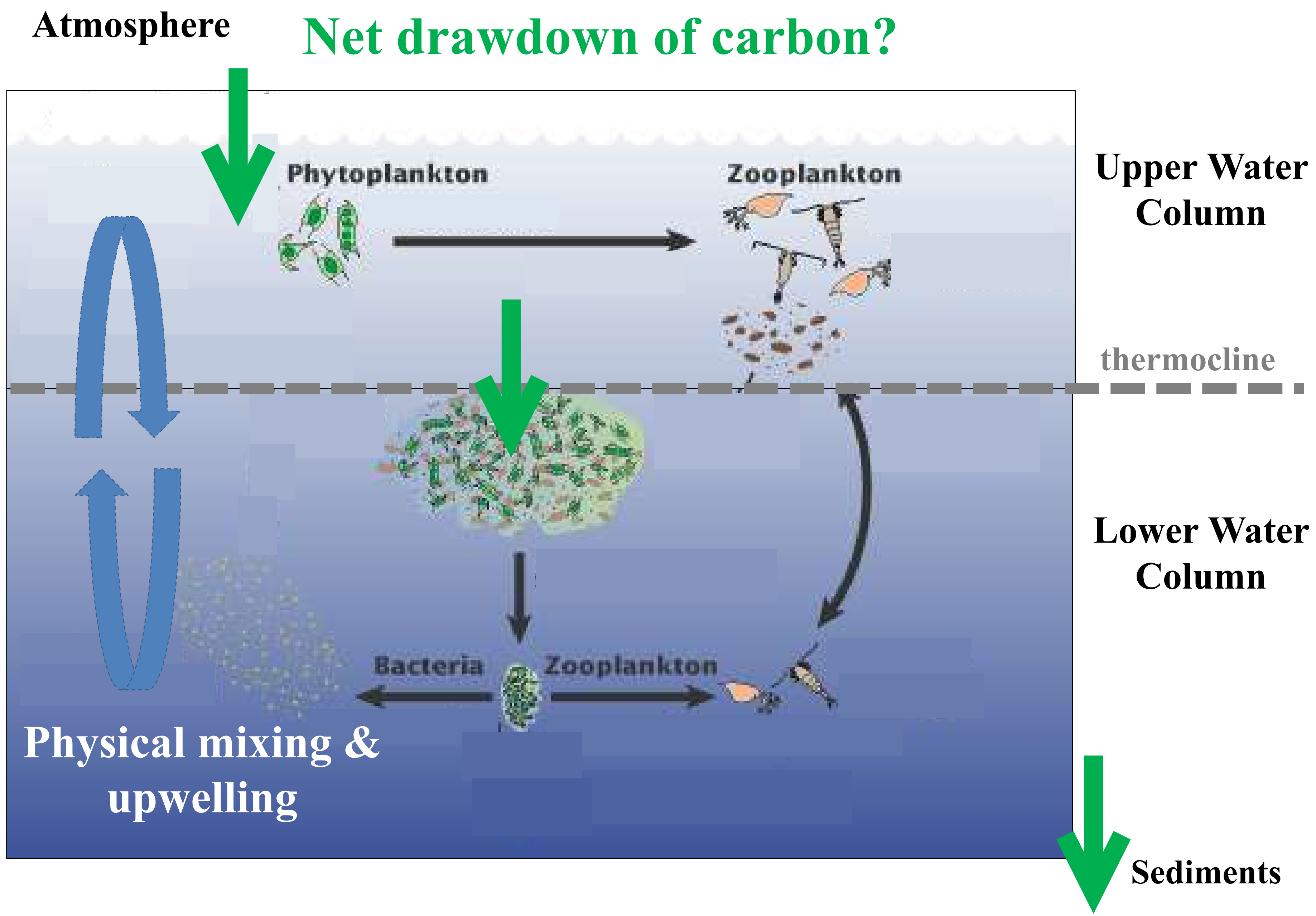
What happens to carbon biomass (PC) that leaves the surface layers?

Most carbon remineralized at depth is eventually (~100s of years) brought back to the surface.

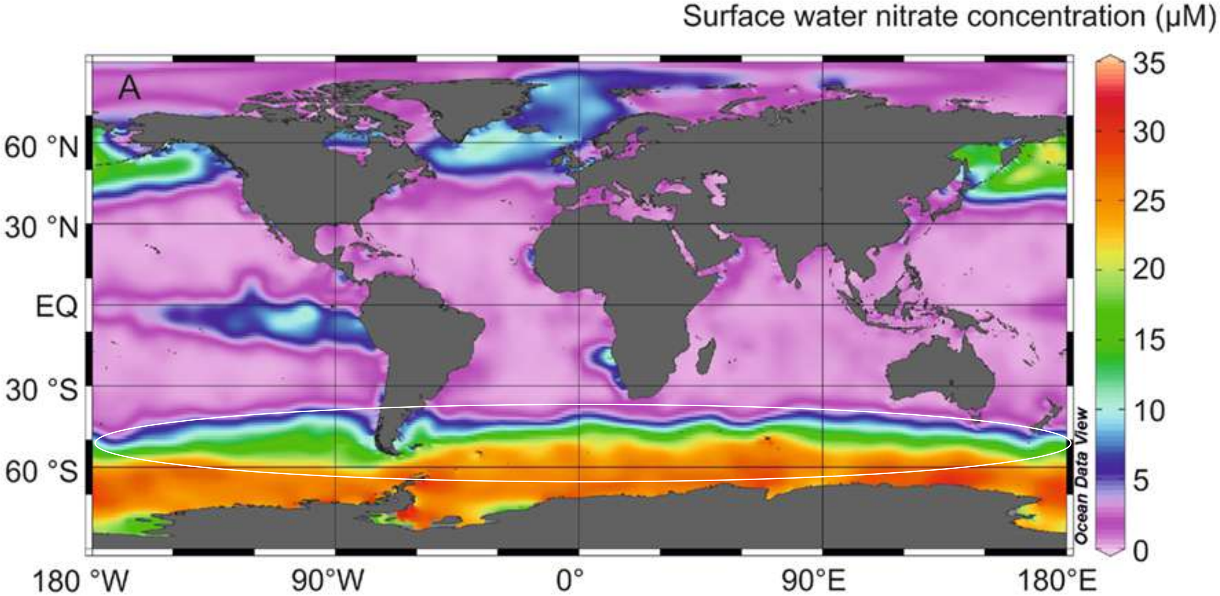


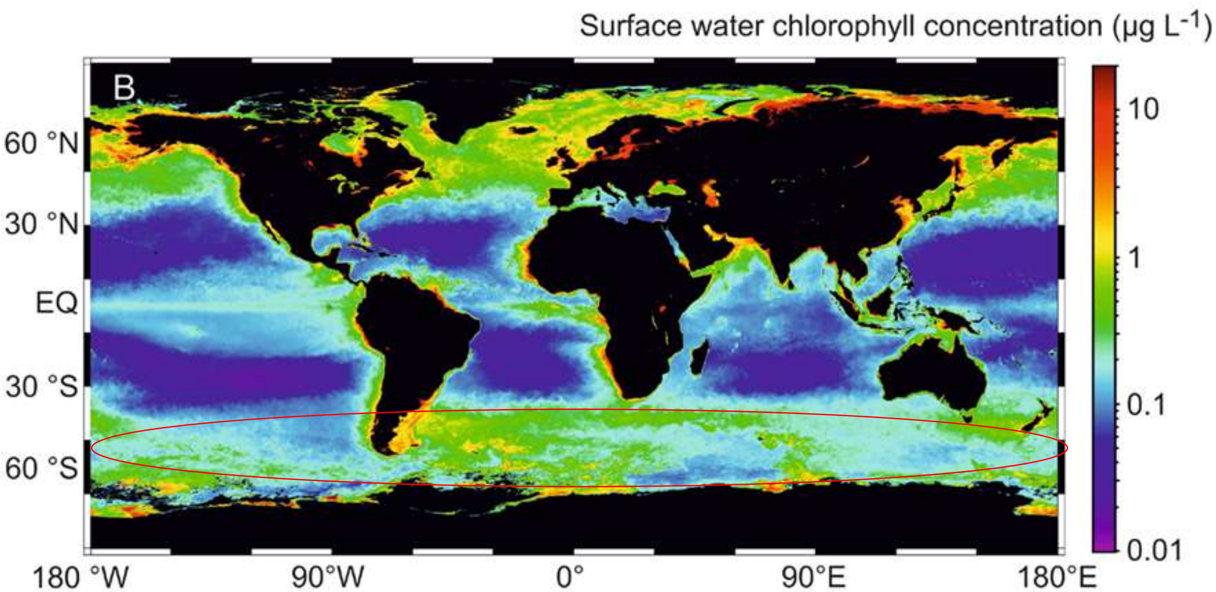
PC = Particulate Carbon

The Biological Carbon Pump



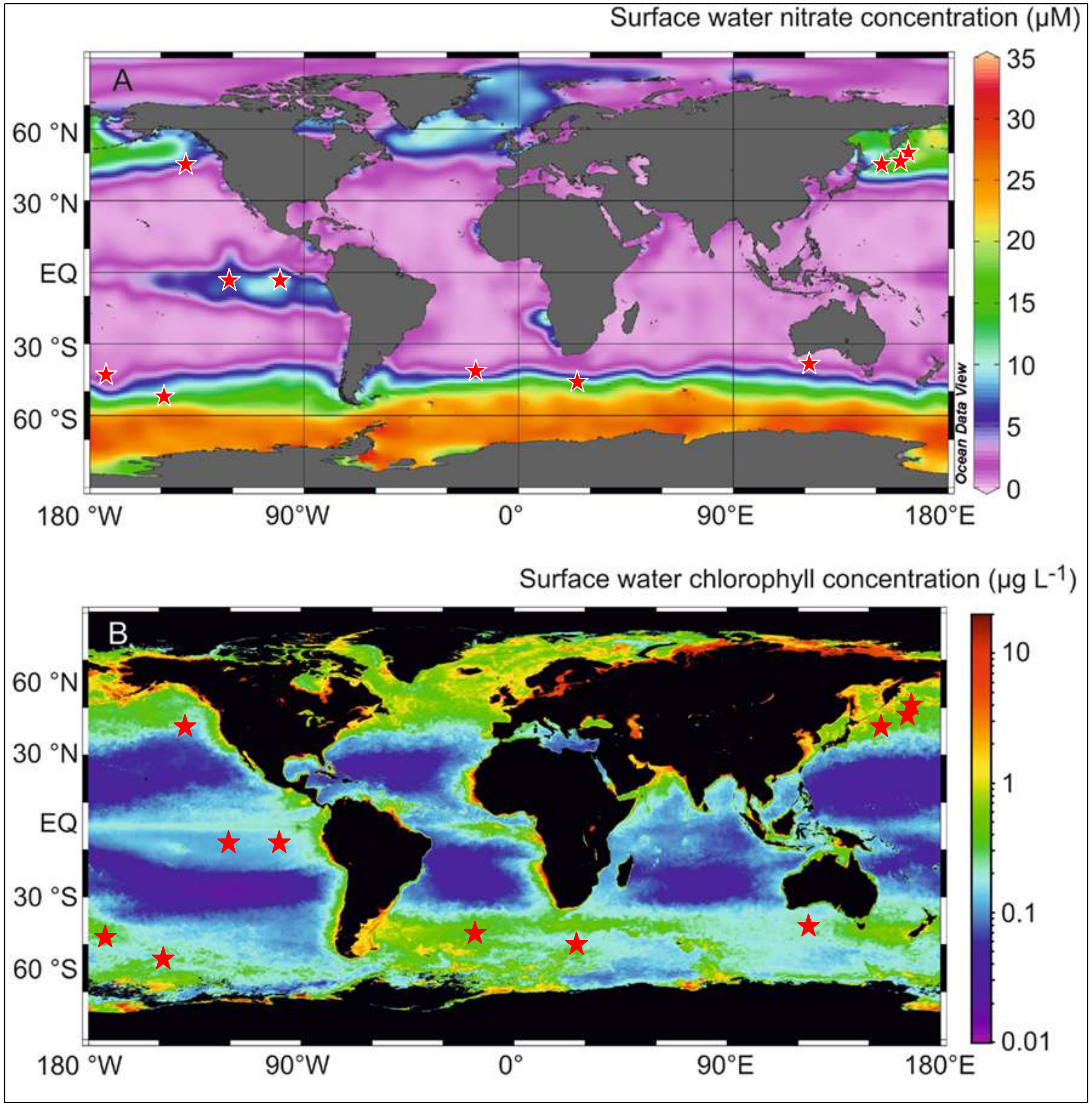
High Nutrients Low Productivity areas (HNLP)?





Available nutrients (i.e. nitrate) not utilized by algae?

What limits growth?

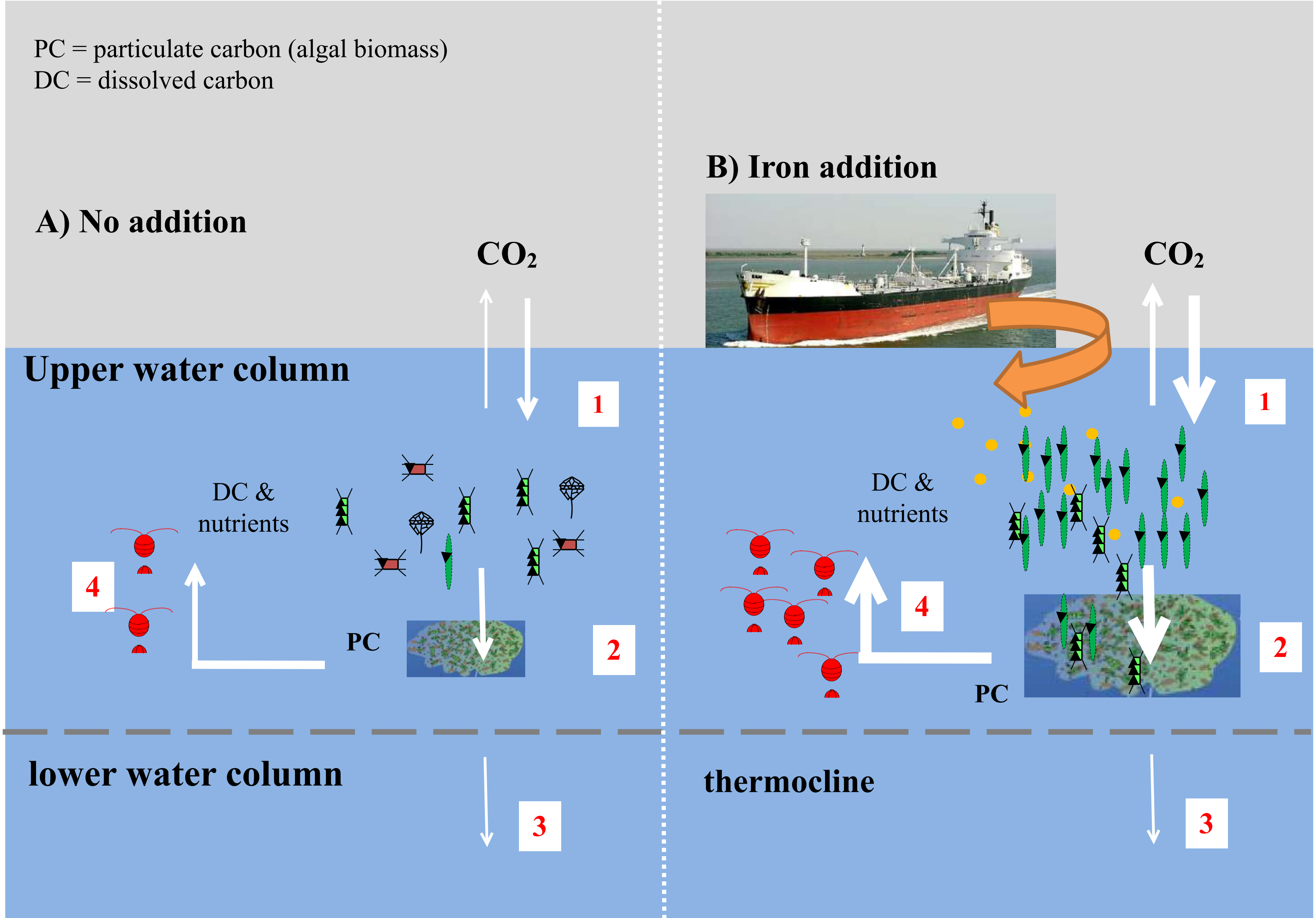


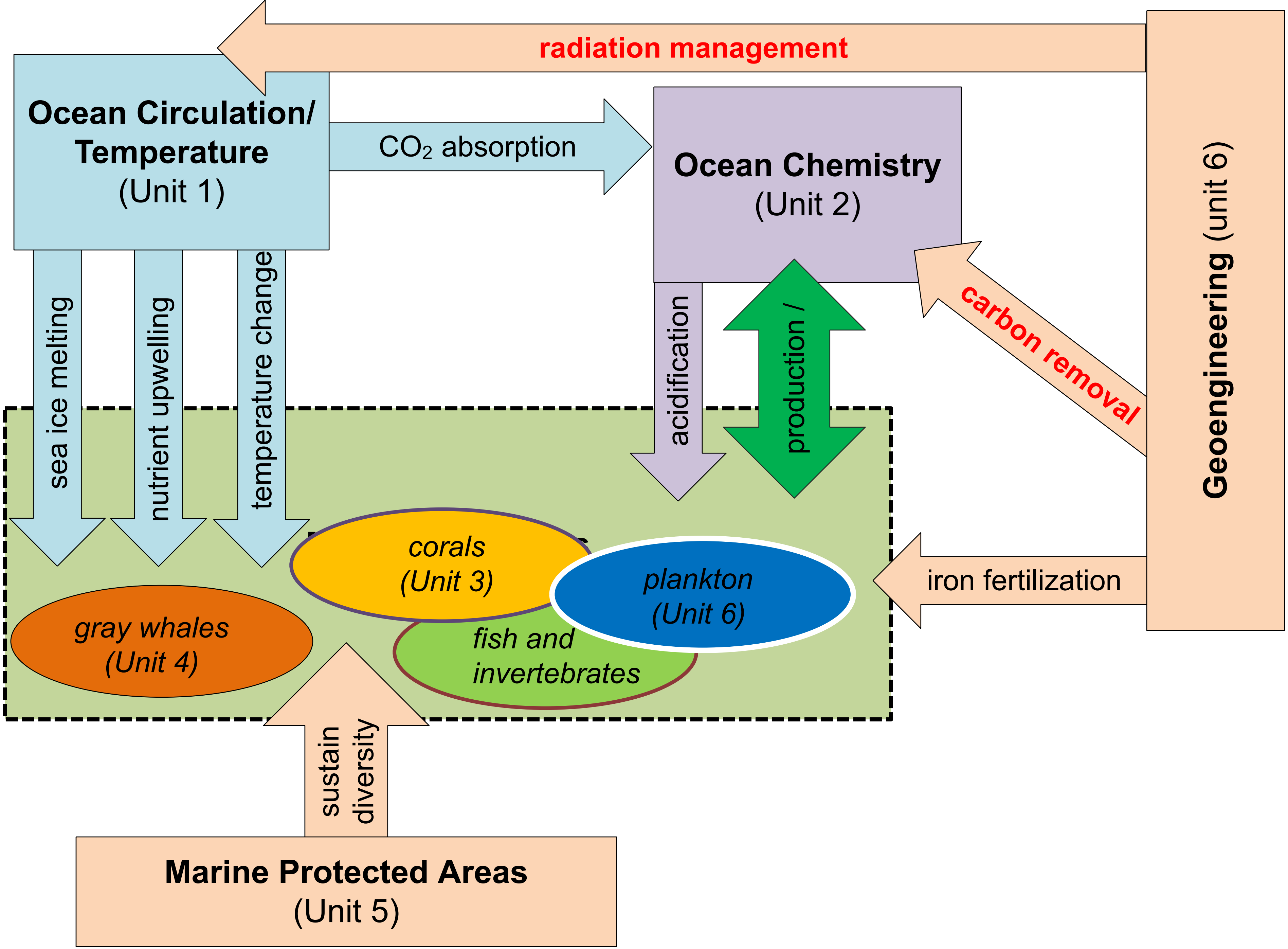
Locations of 12 **iron fertilization** experiments (1993 to 2005): 1–3 metric tons of iron (liquid iron sulfate) dispensed from tankers dispersed in 100-km^2 patches

Iron Fertilization Experiments

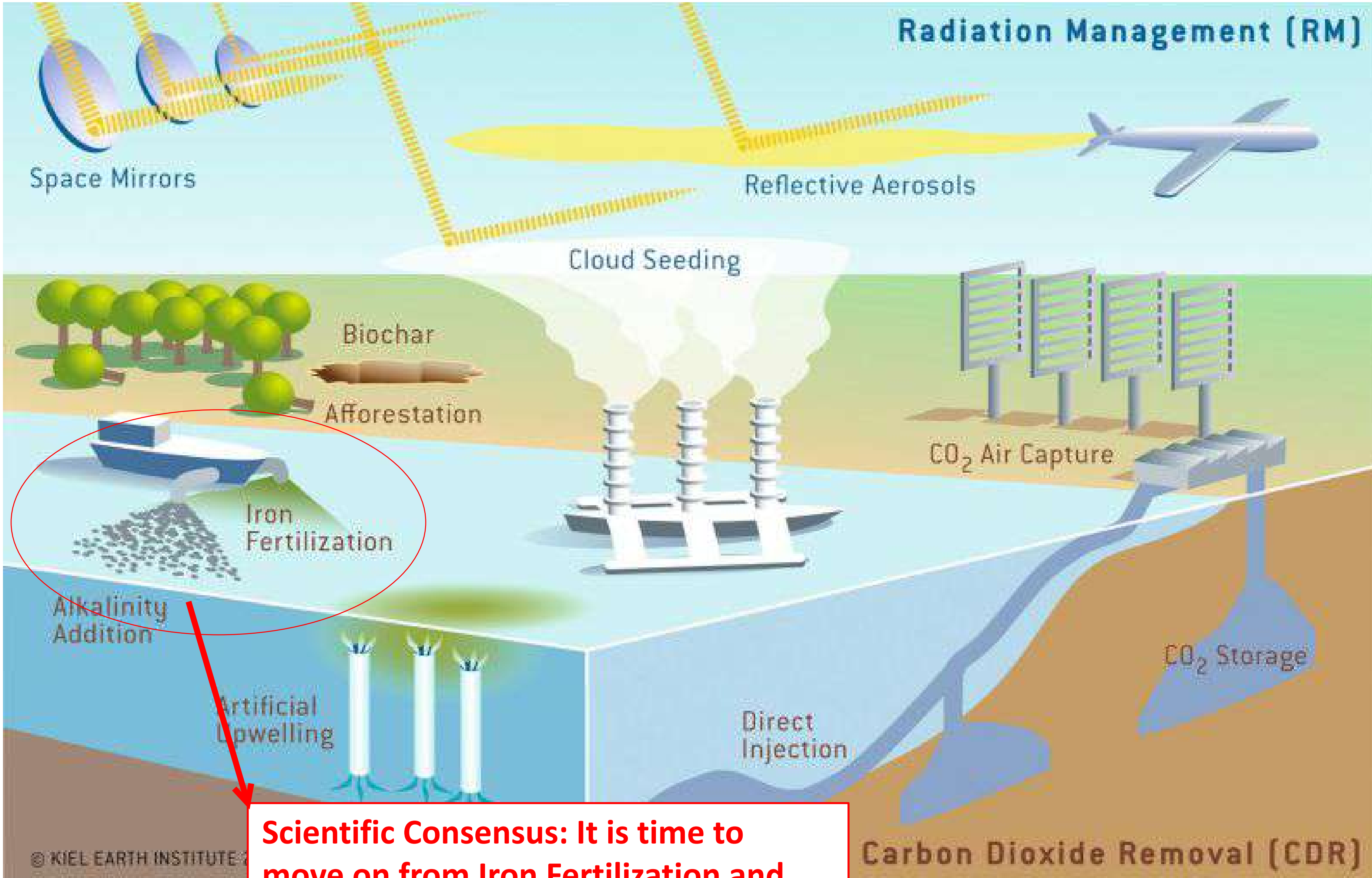
Based on the biological pump stimulated higher surface productivity results in ____________ carbon export to depth?

Activity 2 — 10 minutes, individual activity




radiation management
Ocean Circulation/ Temperature
(Unit 1)
CO2 absorption
Ocean Chemistry
(Unit 2)
Geoengineering (unit 6)
carbon removal
sea ice melting
nutrient upwelling
temperature change
acidification
production /
corals
(Unit 3)
plankton
(Unit 6)
iron fertilization
gray whales
(Unit 4)
fish and invertebrates
sustain diversity
Marine Protected Areas
(Unit 5)

What is next? Other geoengineering strategies



Scientific Consensus: It is time to move on from Iron Fertilization and explore other, more effective options!

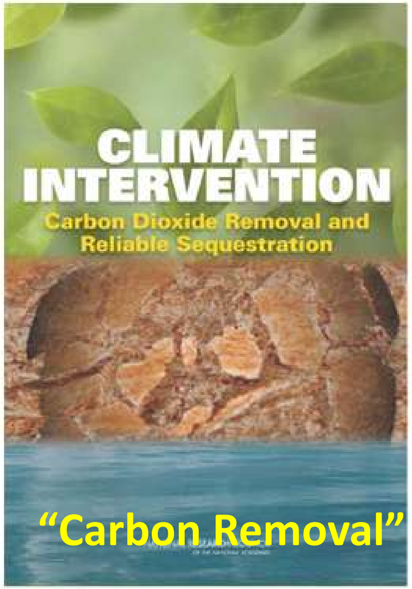
Where from here….. future recommendations?

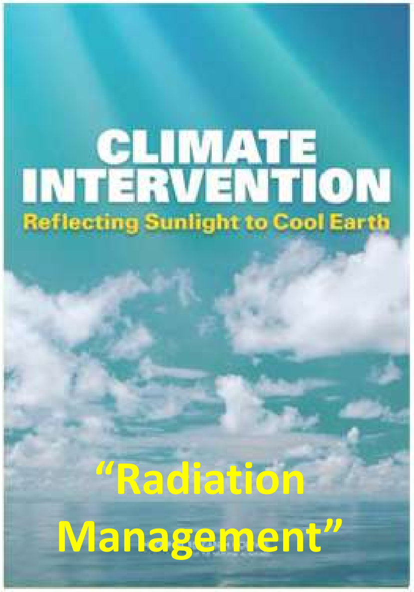
Policy studies are conducted through the National Research Council (NRC). Access information about current and recently completed studies, including more than 5,000 publications available free online.

"Geoengineering and its consequences are the price we may have to pay for failure to act on climate change."

"Used irresponsibly or without regard for possible side effects, geoengineering could have catastrophic consequences similar to those of climate change itself."

John Shepherd, University of Southampton, UK





Additional Slide

Brief History of Ocean Fertilization:

- 1930s: scientists suggest iron deficiency limits algal growth in Antarctic Ocean
- **John H. Martin** (Moss Landing Marine Laboratories, CA):

  "***Give me half a tanker of iron, and I'll give you an ice age***"
- *1972 London convention*:
  - ✓ global agreement to protect the marine environment from human activities
  - ✓ regulate ocean dumping
  - ✓ guard against detrimental commercial use of the ocean
- *U.S. National Research Council (NRC):*
  - cost effective removal of CO_2?
  - => ocean scientists conduct ~ dozen small-scale field experiments by 2005
- *London protocol 2006:*
  - ✓ additional restrictions on dumping
  - ✓ amendment to the protocol allows storage of CO_2 under the seabed (= alternate geoengineering strategy)
  - ✓ permits and impact assessments required enforced by **Environmental Protection Agency**
- **Carbon Cap and Trade** business very lucrative ***if*** Ocean Fertilization works; plans by several companies (e.g. Planktos or Climos) for additional experiments to proof concept