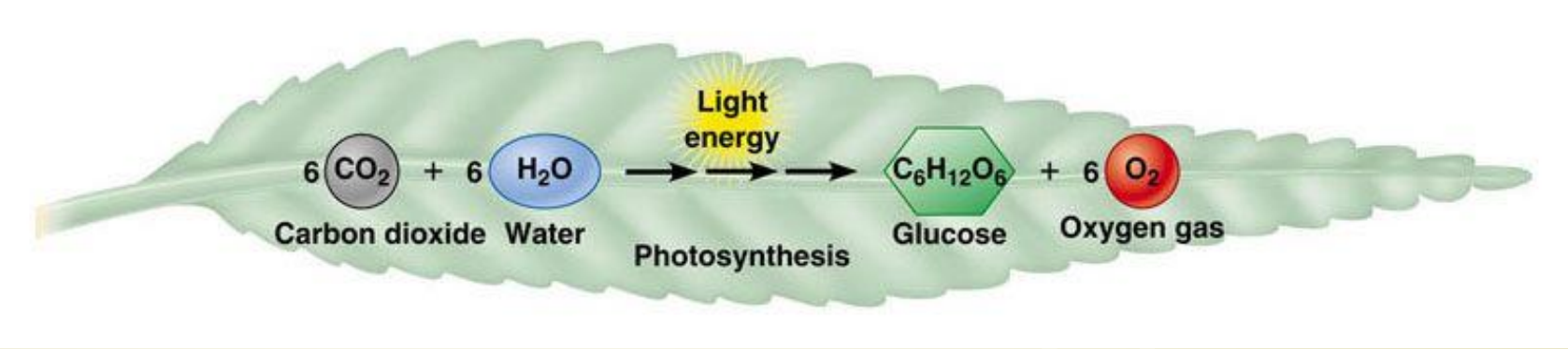
1.8 Primary Productivity

Enduring Understanding: Energy can be converted from one form to another.

Learning Objective: Explain how solar energy is acquired and transferred by living organisms

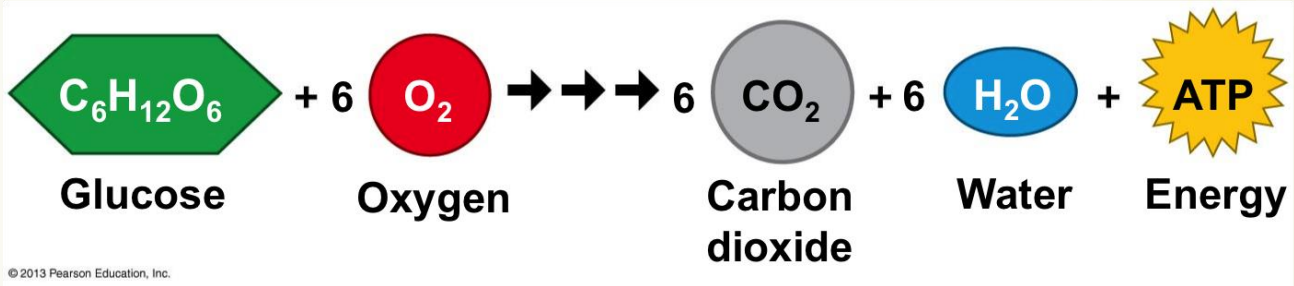
Primary Production Provides Energy and Biomass For Ecosystems

- ***Primary production***
  - Rate at which energy/biomass is accumulated by plants and other producers in an ecosystem (or measured area)
    - Conversion of solar energy to chemical energy in the bonds of sugars by producers during ***photosynthesis***
    - **Biosynthesis** uses these sugars (and other nutrients) as the building blocks to synthesize all of the producers organic compounds.
      - carbohydrates, lipids, proteins, nucleic acids
    - Therefore, as the amount of energy accumulated increases, the biomass of producers increases proportionately



Gross Primary Productivity

- The rate at which sunlight energy is transformed into chemical energy which is stored in producer biomass (glucose) is the ***gross primary productivity (GPP)*** of an ecosystem (or a measured area).
- Plants use the energy/biomass of organic compounds produced during photosynthesis to produce ATP during ***cellular respiration***.

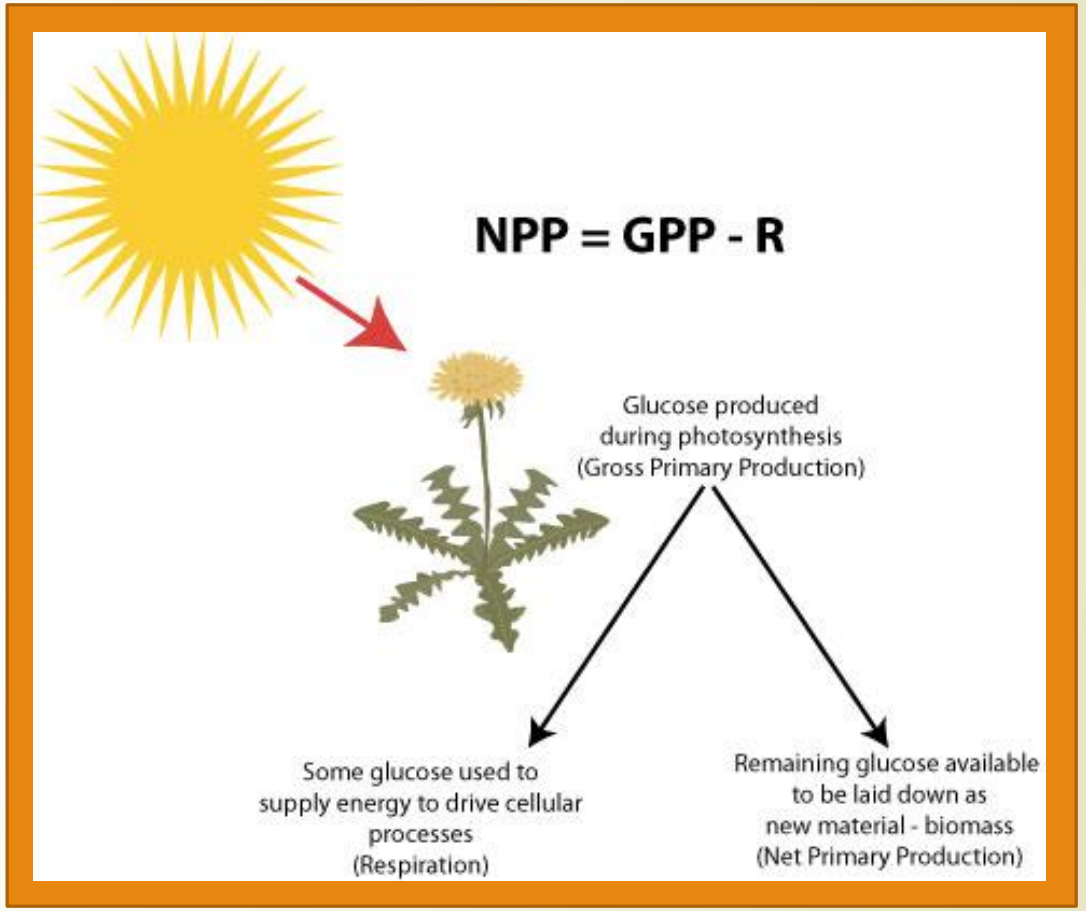


  - Cellular respiration consumes glucose to fuel cellular work thereby reducing a producers potential biomass.
  - Cellular respiration and cellular work releases large amounts of energy as heat to the atmosphere, thereby reducing a producers potential store of energy.
  - Thus the energy/ biomass stored in producers is less than what is measured by GPP.

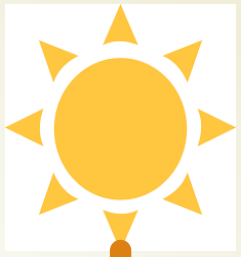
Net Primary Productivity

- ***Subtracting cellular respiration losses of biomass/energy from gross primary productivity gives the Net Primary Productivity (NPP)***
  - This is the biomass/energy stored in the producers tissues.
  - NPP is the amount of energy available for consumption by consumers in an ecosystem
  - Productivity (NPP or GPP) is a RATE, usually expressed as $g/m^2/year$ or $kcal/m^2/year$

NPP = GPP - respiration



NPP,GPP, and Respiration



Reflected Light
Energy not absorbed so not utilized by producers

Respiration
Energy lost as heat as a result of cellular metabolism

Producers use sunlight energy to make their food from CO_2 and H_2O. The amount of energy captured and stored as biomass per unit if area per unit if time is
Gross Primary Productivity (GPP)

Net Primary Productivity (NPP)
The energy/biomass available to primary consumers

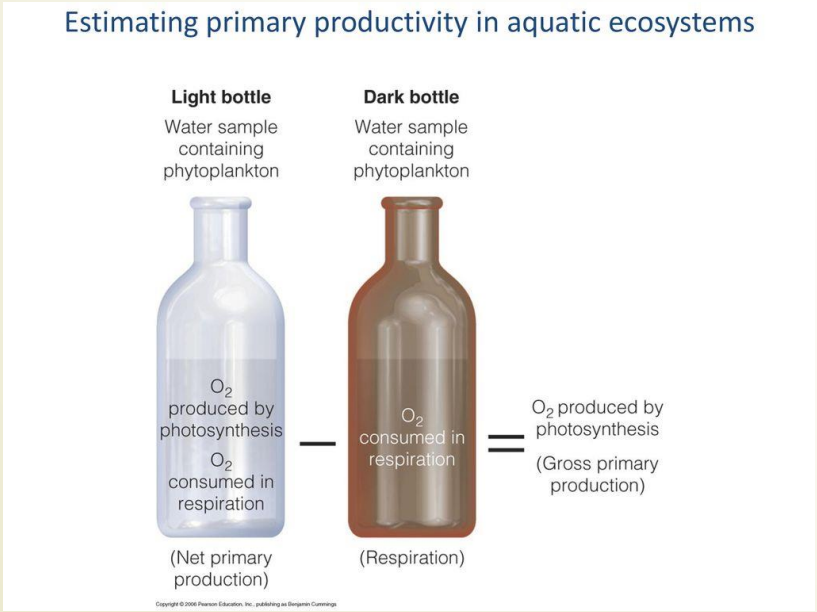
Dead Organic Material
Available to detritivores and decomposers

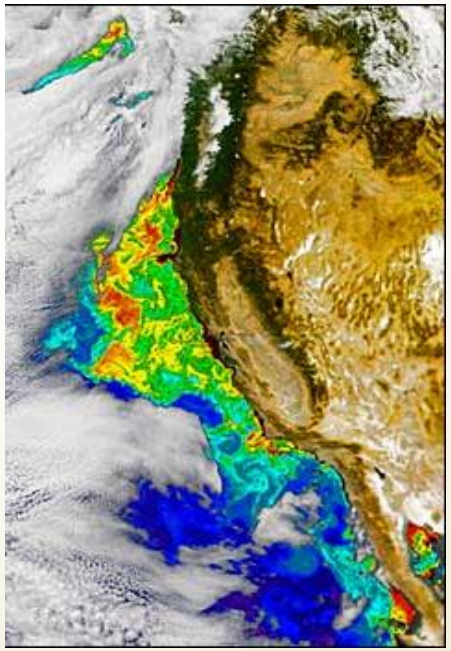
Measuring Primary Productivity

Estimating productivity of ecosystems can be difficult since measuring rates of photosynthesis and respiration is technically difficult.

- In terrestrial ecosystems, changes in plant biomass (dry weight) is a good indicator of NPP
- In aquatic ecosystems, NPP can be estimated by measuring changes in dissolved oxygen in the water.

- Measuring GPP is more difficult as ongoing respiration uses up some of the organic compounds (glucose) produced initially by producers.





Tracking Ocean Productivity

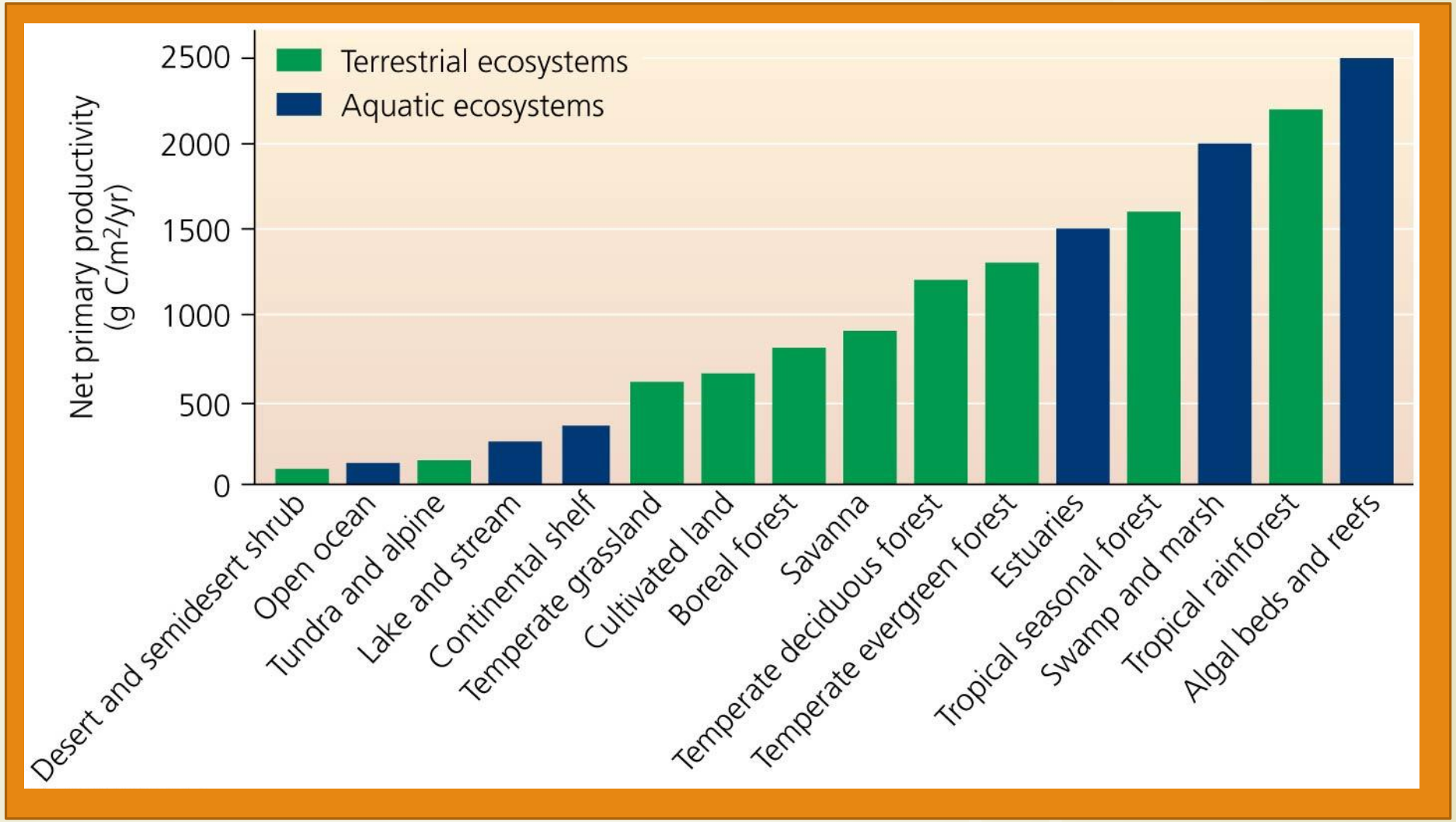
Phytoplankton floating in the uppermost layers of the ocean are responsible for almost all of the primary productivity in the oceans.

Remote sensing with satellites allows scientists to track ocean productivity by looking at differences in the color of the water.

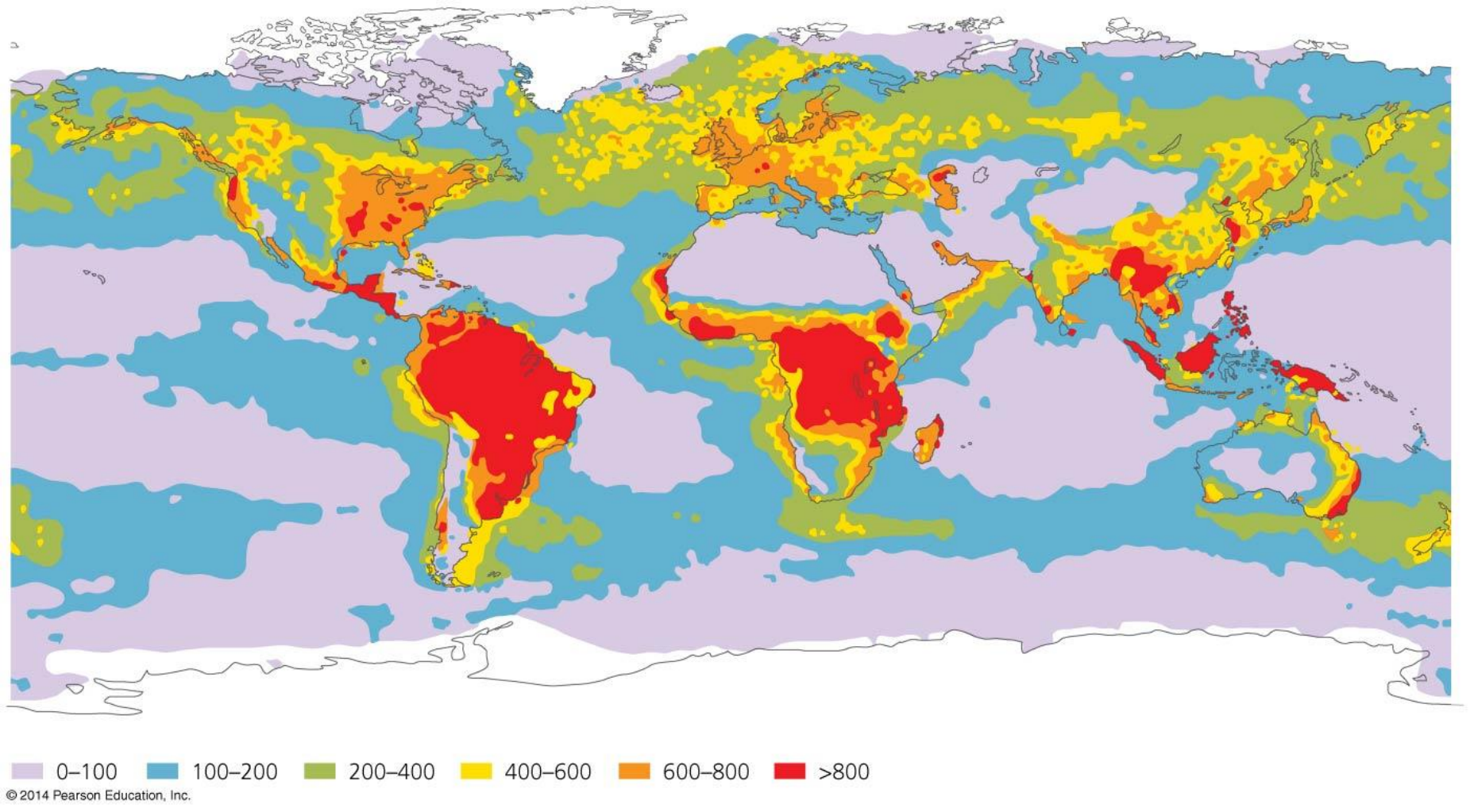
Sensors detect chlorophyll absorption. As the concentration of chlorophyll increases, satellite images show the ocean surface changing from blue to shades of green. To more clearly illustrate the differences most ocean color imagery uses a color palette ranging from purple to green to red as chlorophyll concentrations increase.

Ecosystems differ in net primary productivity

- What causes these differences in NPP between ecosystems?

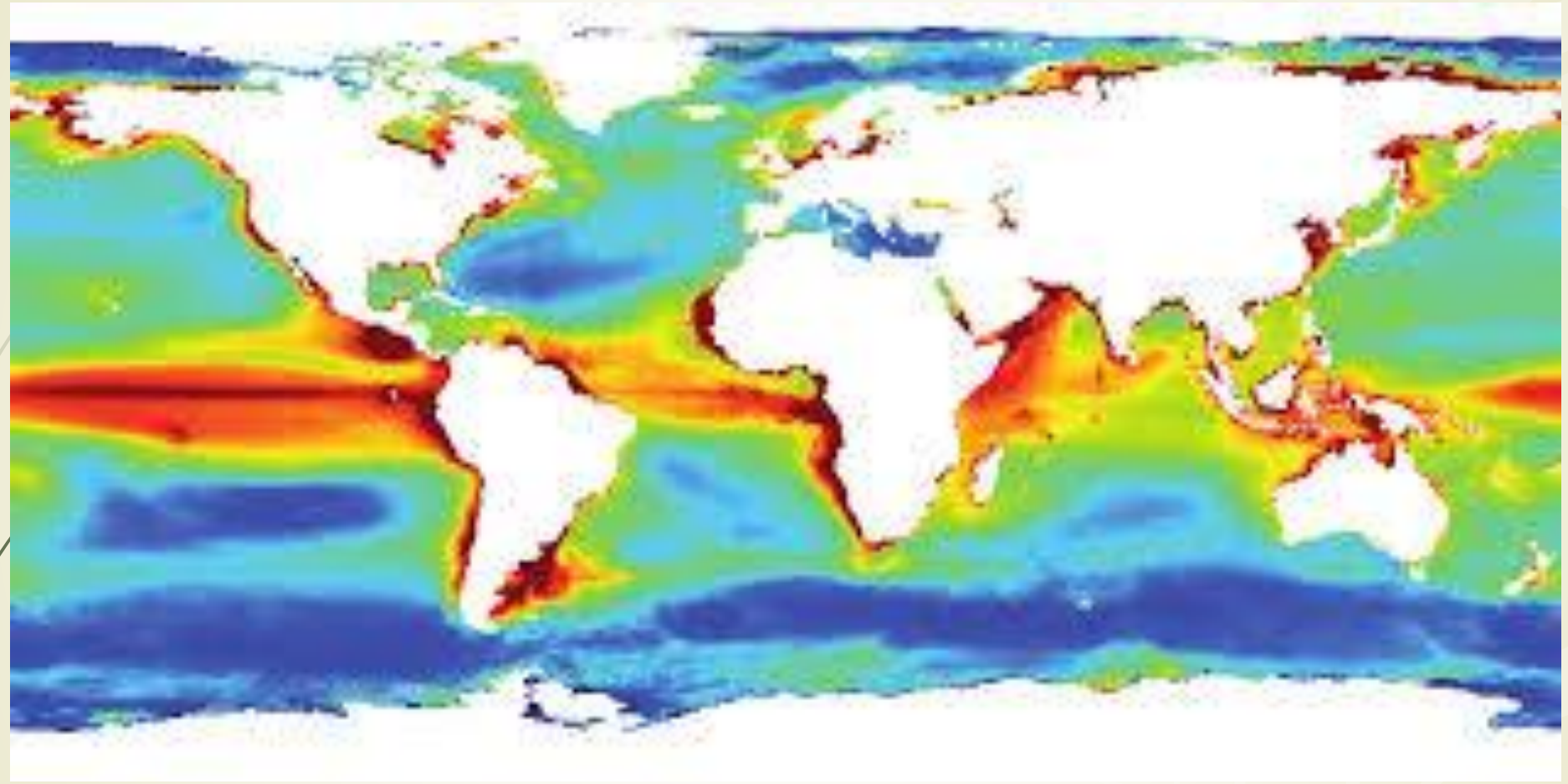


Global Terrestrial NPP



NPP increases with temperature and precipitation on land

Global Marine NPP



NPP increases with light and nutrients in aquatic ecosystems

Light, Water, CO_2 Effect Primary Productivity

In Terrestrial Ecosystems

- **Solar radiation**
  - The amount of light energy available to be absorbed by producers
  - Temperature is a good indicator for how much solar energy is absorbed in a given area.
  - In general, warmer temperatures correlate with higher productivity
- **Precipitation**
  - Plants need water to carry out photosynthesis
  - Areas of higher rainfall tend to be more productive than drier areas

In Aquatic Ecosystems

- **Solar Radiation**
  - The amount of solar radiation absorbed by producers will be further impacted by water depth
    - Water filters out sunlight (especially red light)
    - Photosynthesis decreases with increasing depth
  - **Nutrients**
    - Areas of high run off (river deltas) or areas of coastal upwelling are high in nutrients

Productivity Of Ecosystems

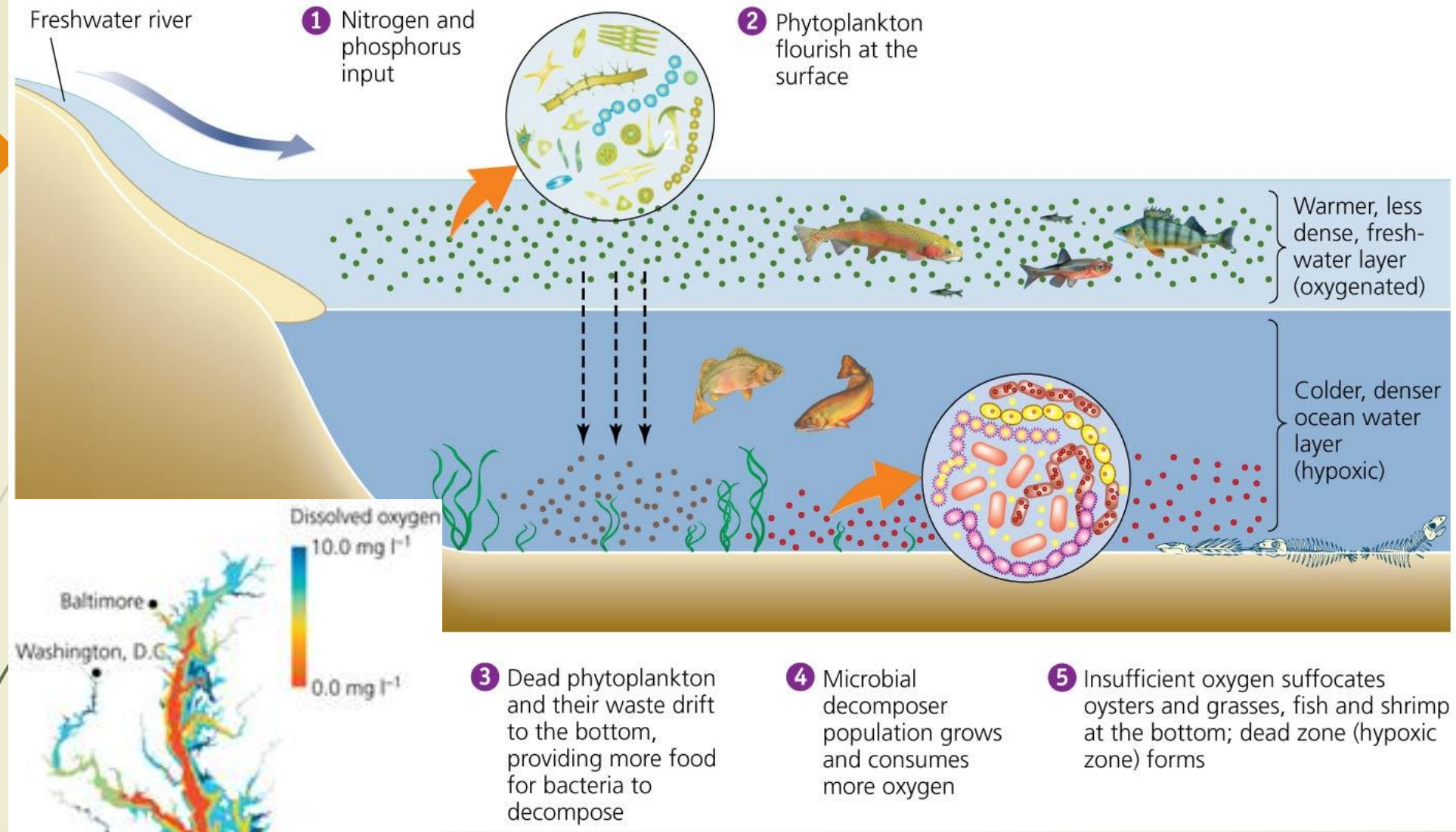
- The **least** productive ecosystems are those with one or more of the following:
  - limited solar energy
  - limited water
  - and/or limited nutrients
- The **most** productive ecosystems are those with one or more of the following:
  - high inputs of solar energy
  - lots of precipitation
  - and/or plenty of nutrients

Low Productivity

High Productivity

Nutrients influence productivity

- **The Chesapeake Bay is fed by river systems**
- **Precipitation over the surrounding farms, cities, and forests leads to runoff that flows over land and into waterways**
  - Moves nutrients from land to rivers to the bay
- **Increasing the availability of once limiting nutrients can lead to:**
  - Blooms of algae
  - Increased production of organic matter that dies and sinks
  - Decomposition and loss of dissolved oxygen
- **Inputs to the Chesapeake Bay from adjacent systems cause *eutrophication* and loss of oxygen (*hypoxia*) resulting in *dead zones***
  - Systems interact with and influence each other



Eutrophication in the Chesapeake Bay

Hypoxic Dead Zones and Global Footprints