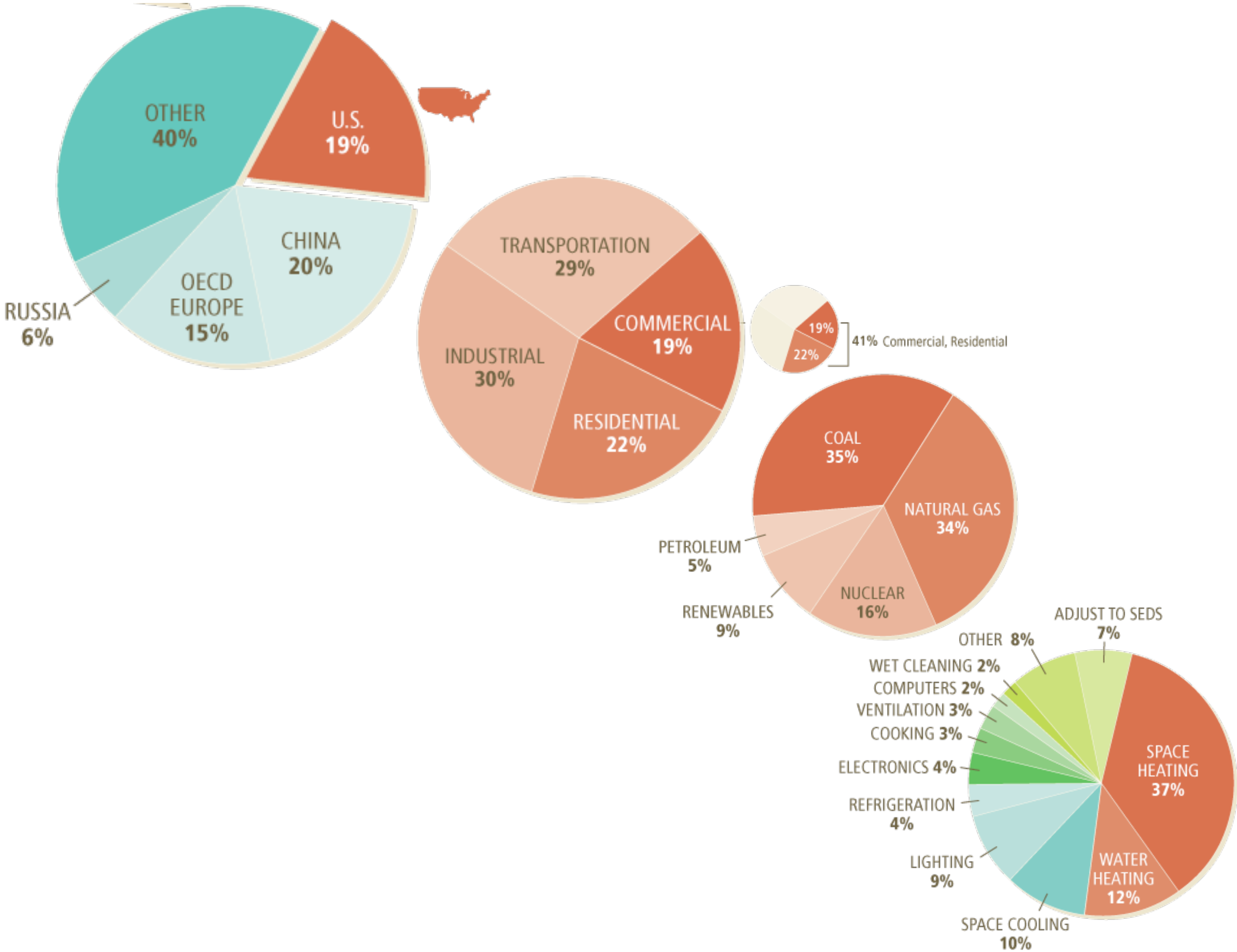
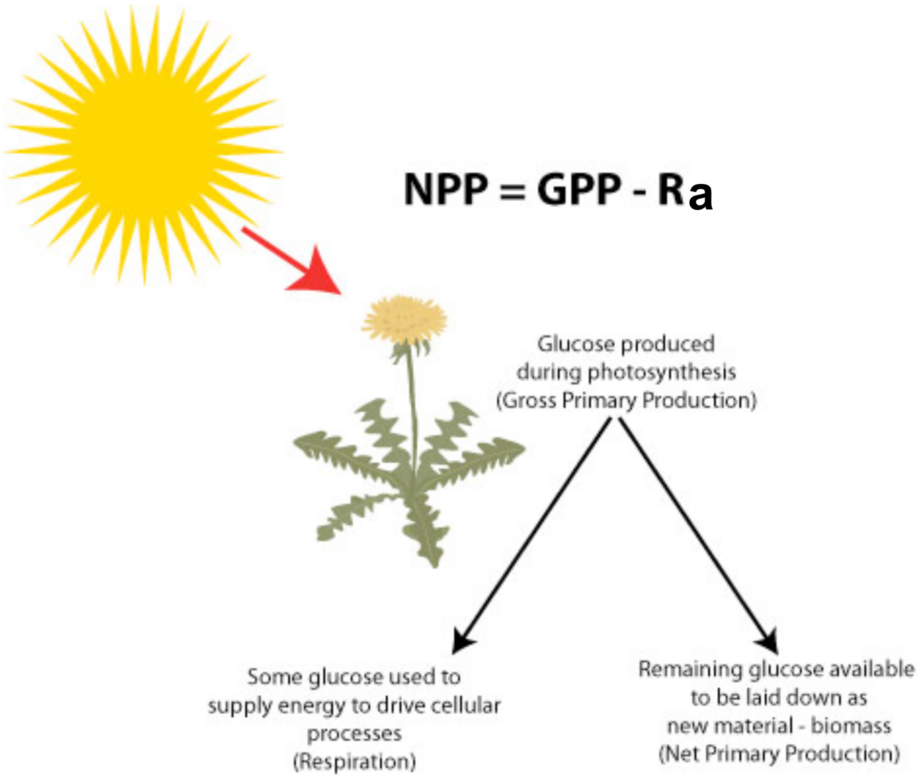
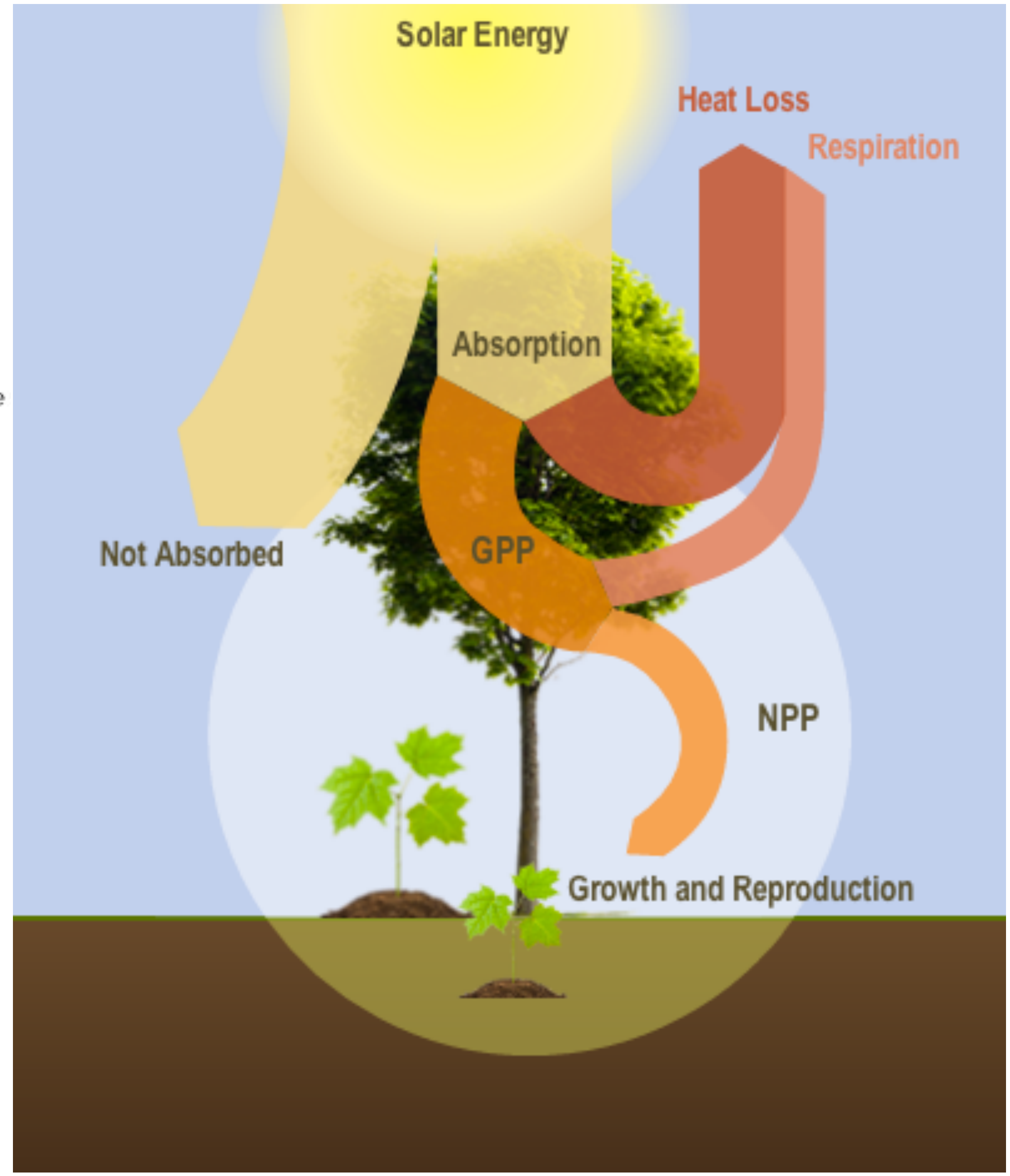
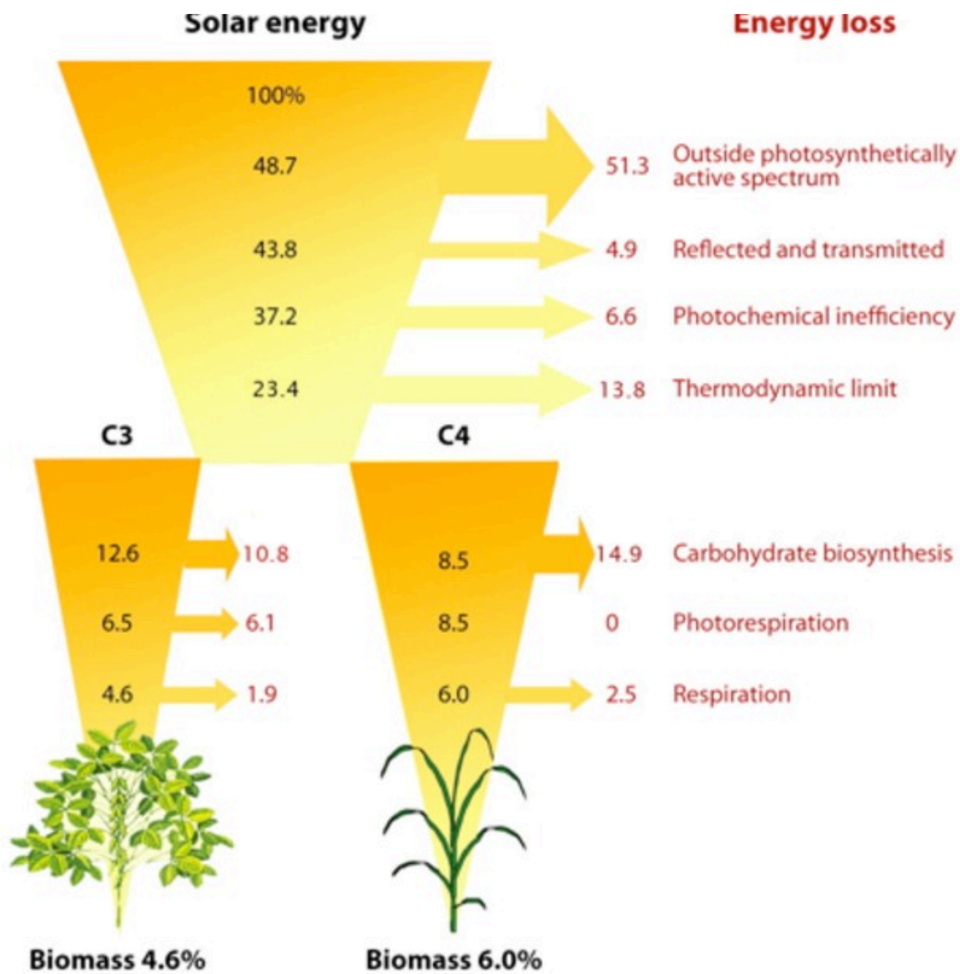

OTHER 40%
U.S. 19%
CHINA 20%
OECD EUROPE 15%
RUSSIA 6%
TRANSPORTATION 29%
COMMERCIAL 19%
INDUSTRIAL 30%
RESIDENTIAL 22%
19%
22%
41% Commercial, Residential
COAL 35%
NATURAL GAS 34%
PETROLEUM 5%
RENEWABLES 9%
NUCLEAR 16%
ADJUST TO SEDS 7%
OTHER 8%
WET CLEANING 2%
COMPUTERS 2%
VENTILATION 3%
COOKING 3%
ELECTRONICS 4%
REFRIGERATION 4%
LIGHTING 9%
SPACE COOLING 10%
WATER HEATING 12%
SPACE HEATING 37%

$NPP = GPP - R_a$


Glucose produced
during photosynthesis
(Gross Primary Production)
Some glucose used to
supply energy to drive cellular
processes
(Respiration)
Remaining glucose available
to be laid down as
new material - biomass
(Net Primary Production)


Solar Energy
Heat Loss
Respiration
Absorption
Not Absorbed
GPP
NPP
Growth and Reproduction



Zhu X-G, Long SP, Ort DR (2008) What is the maximum efficiency with which photosynthesis can convert solar energy into biomass? Current Opinion in Biotechnology 19: 153-159

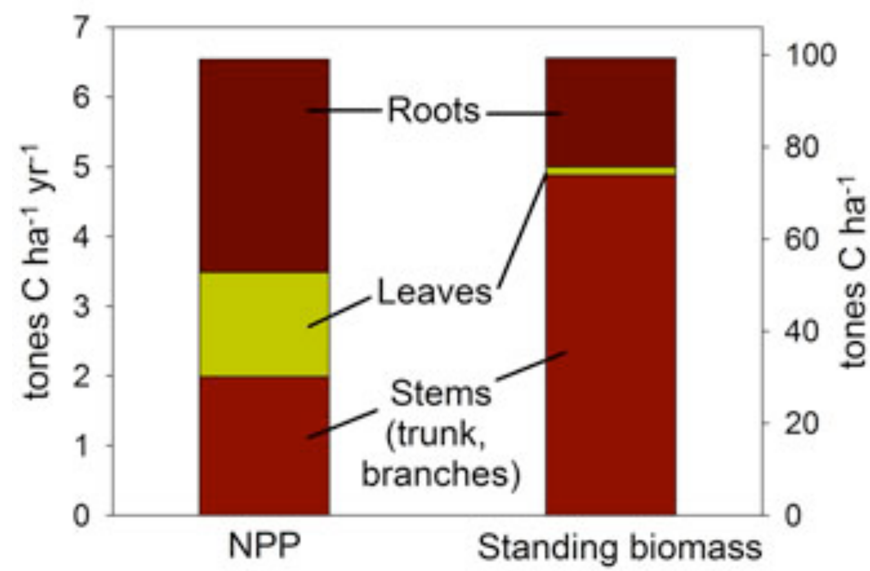
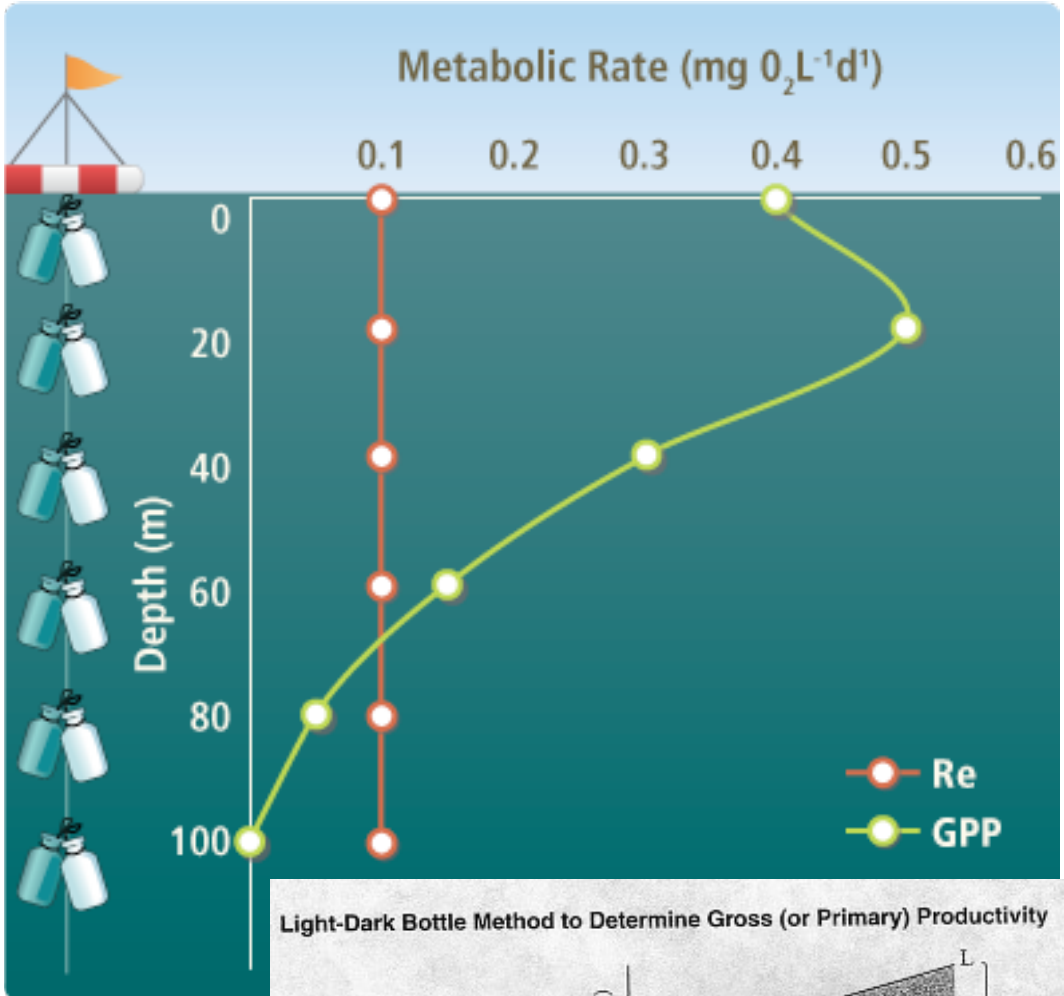
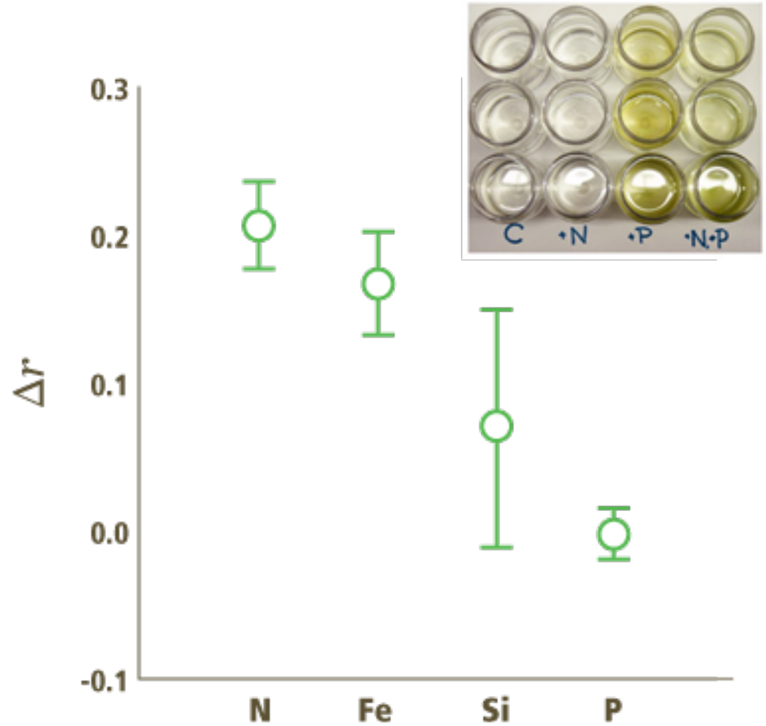


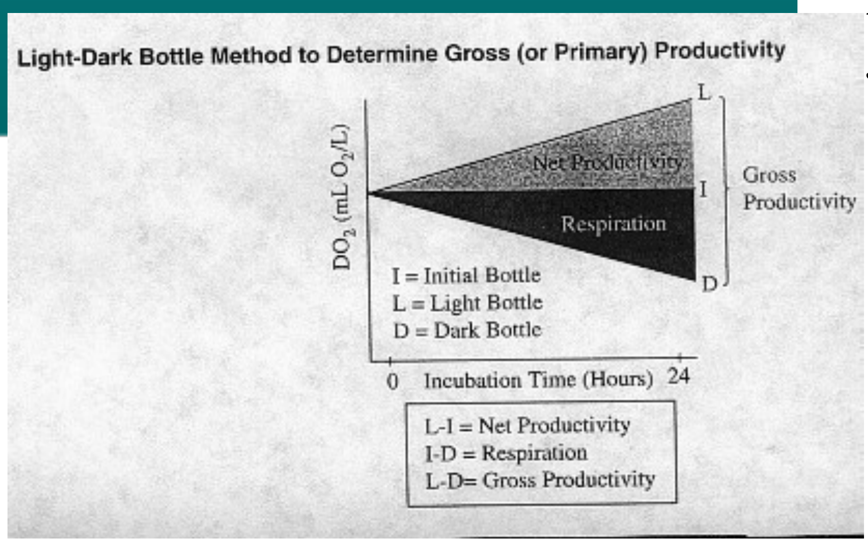
Figure 1: Net primary production (NPP) and standing biomass allocation for a 90-year-old Michigan forest estimated from inventory-based methods in which biomass growth is quantified over time (Gough et al. 2008)

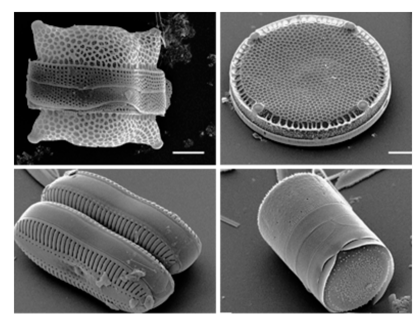
http://www.nature.com/scitable/knowledge/library/terrestrial-primary-production-fuel-for-life-17567411

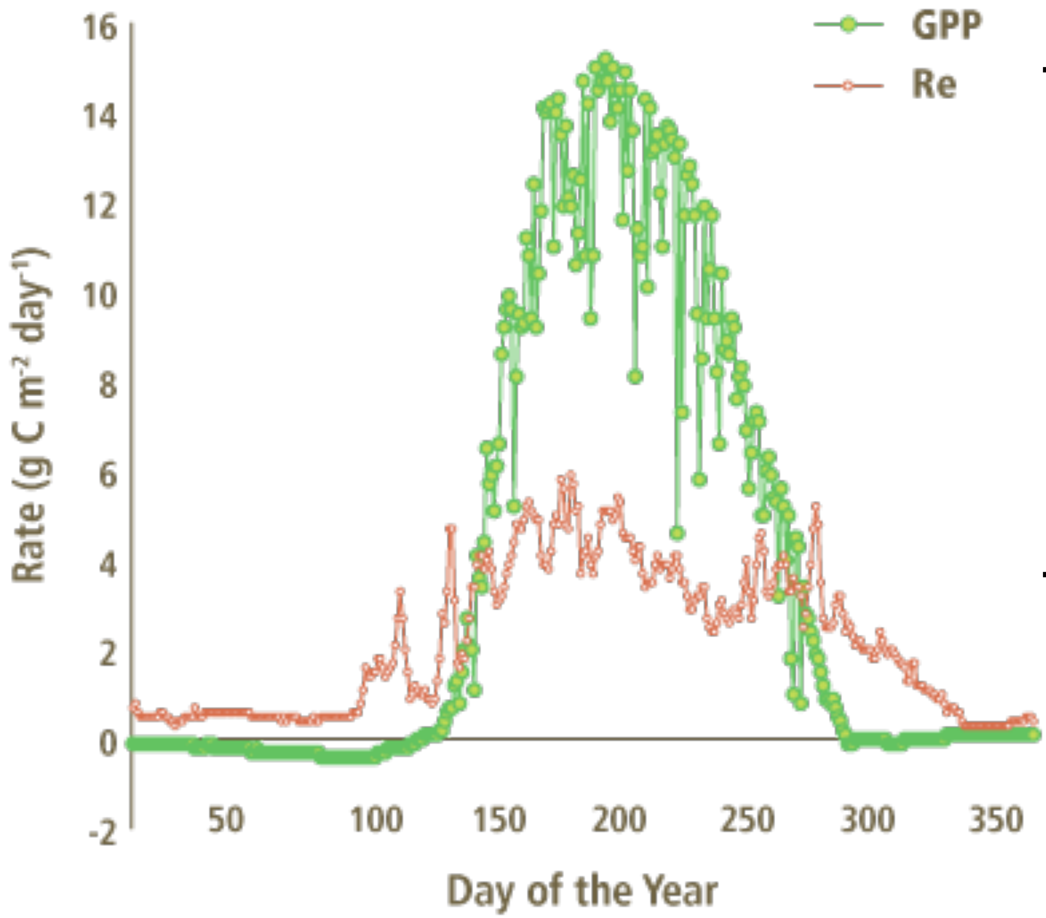




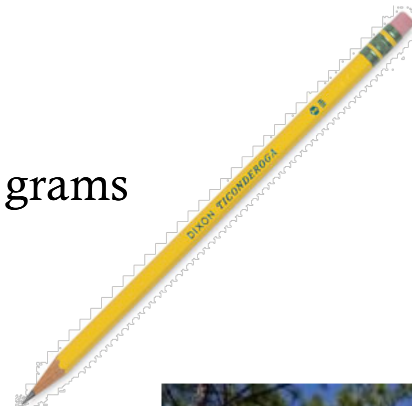
Average increase in algal growth relative to controls (Δr) when a given nutrient is added

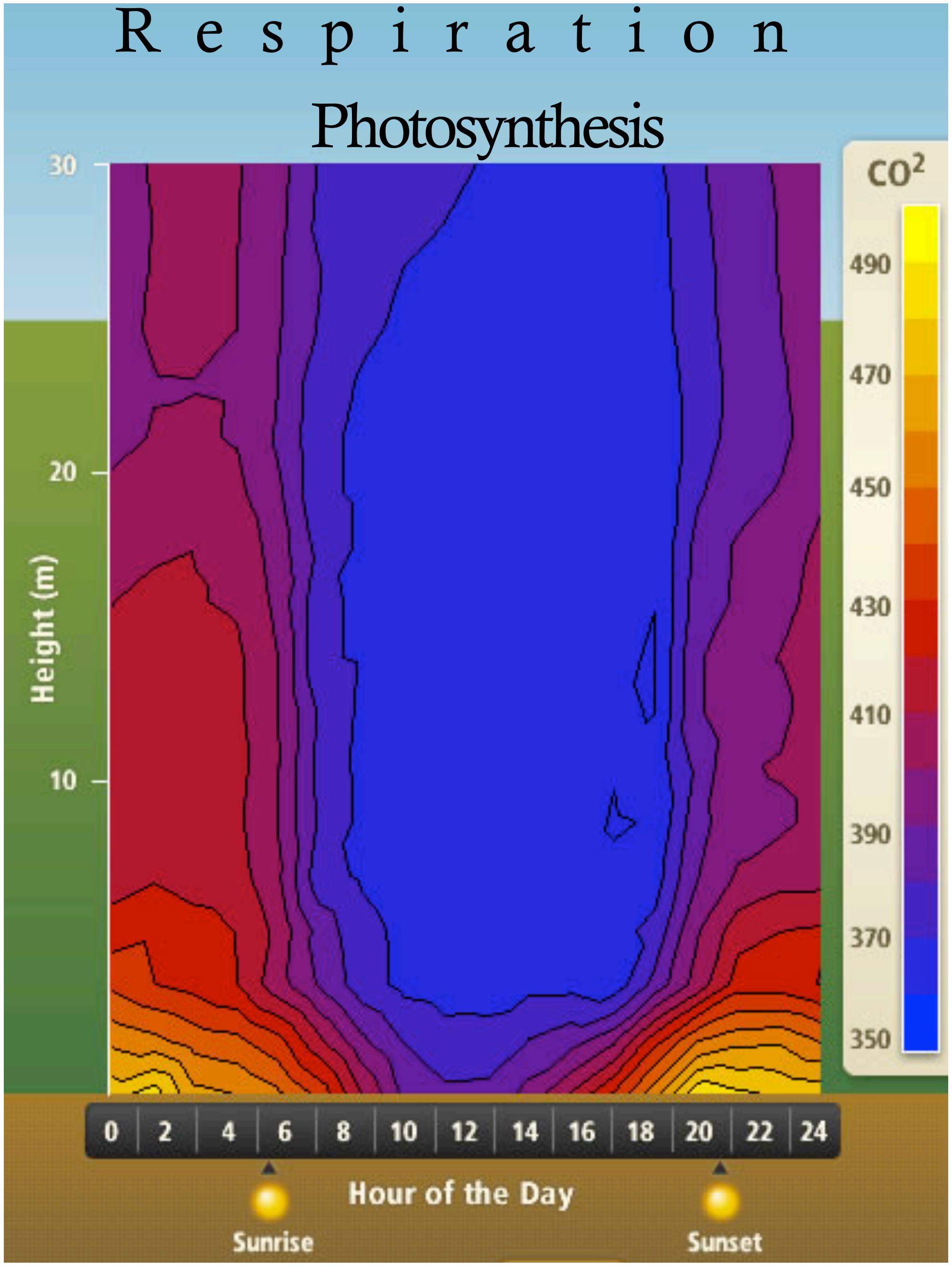


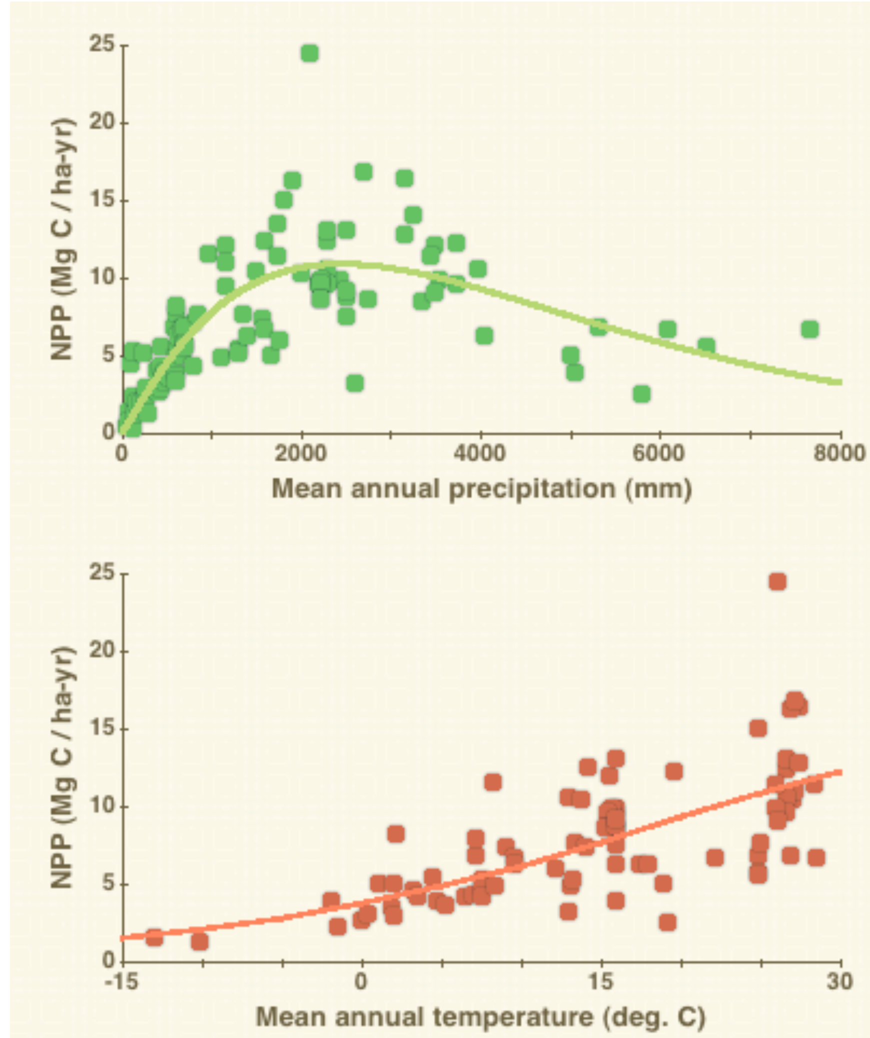



GPP
Re
Rate (g C m⁻² day⁻¹)
16
14
12
10
8
6
4
2
0
-2
50
100
150
200
250
300
350
Day of the Year

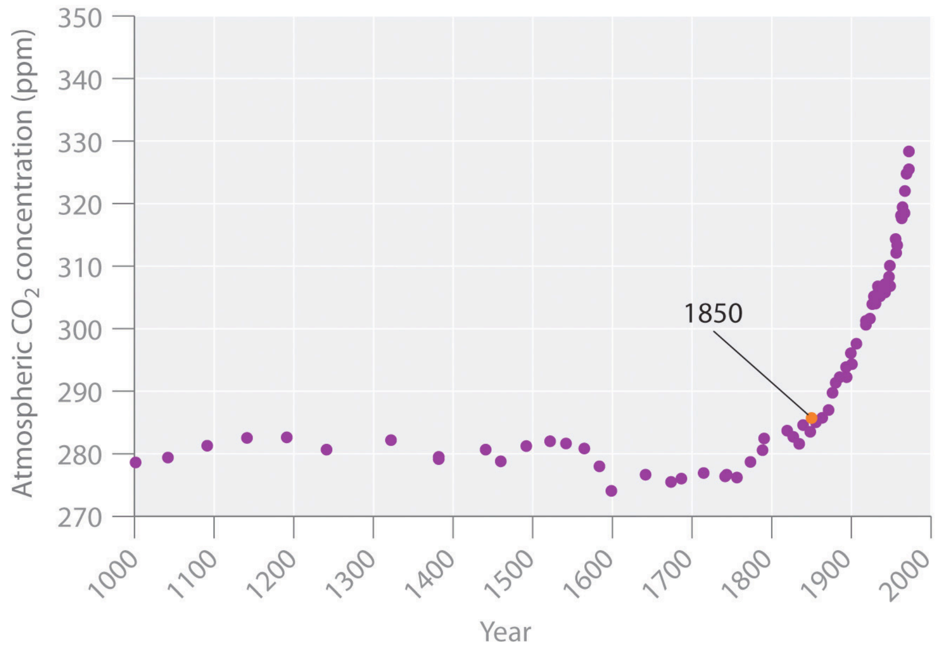
10 grams



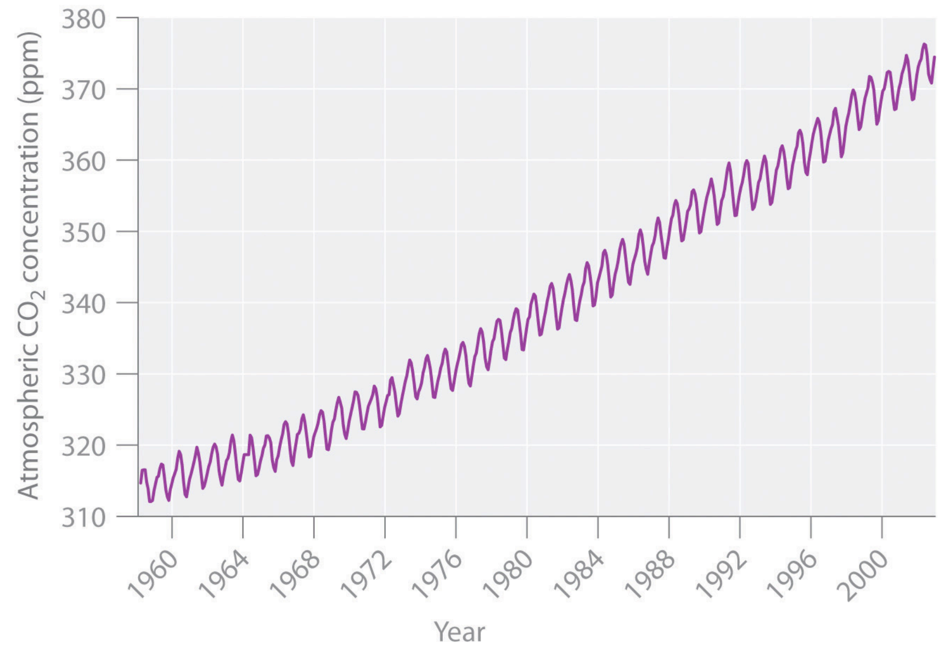




NPP vs. mean annual precipitation (top) and temperature (bottom). Curves are nonlinear best-fit regressions. Data compiled from multiple sites spanning 5 continents and Hawaii. Data courtesy E.A.G. Schuur (from Schuur 2003).

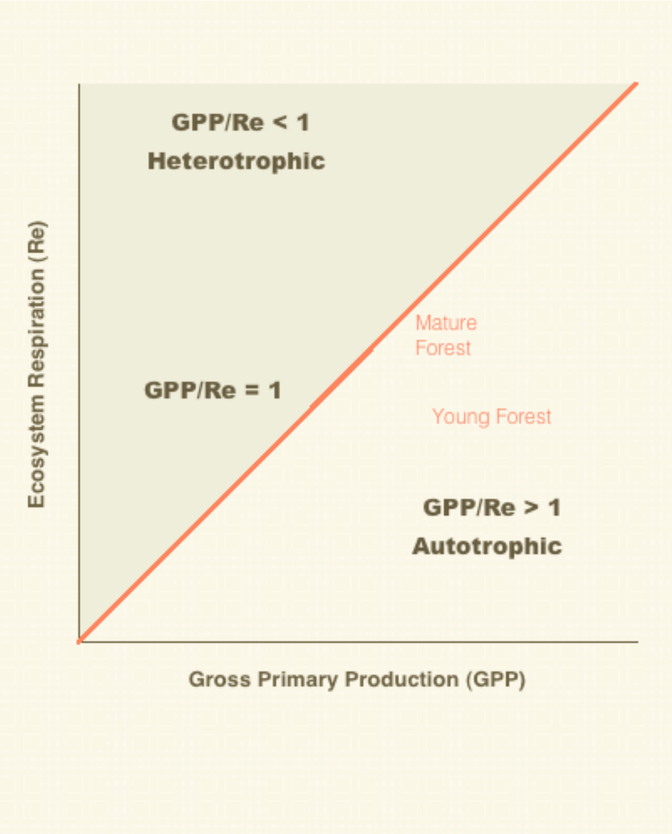


(a) Records from Antarctic ice cores (1006–1969)



(b) Records from monthly air samples, Mauna Loa Observatory, Hawaii (1958–2002)

General Chemistry: Principles, Patterns, and Applications, v. 1.0
by Bruce Averill and Patricia Eldredge



Ecosystems can be classified based on the ratio of ecosystem respiration (Re) to gross primary production (GPP). Adapted from Fisher and Likens (1973).

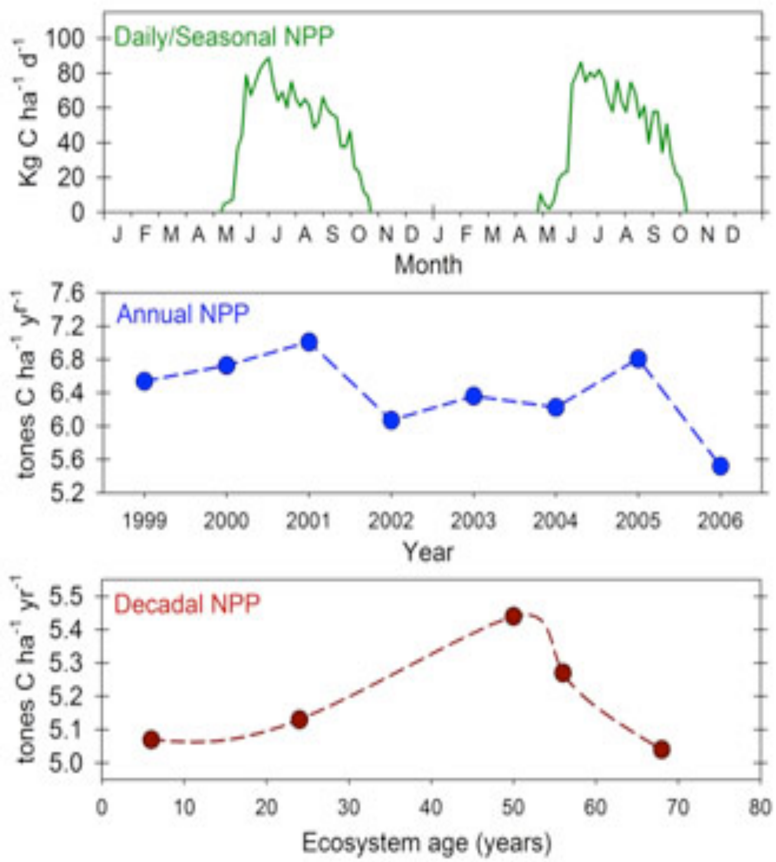
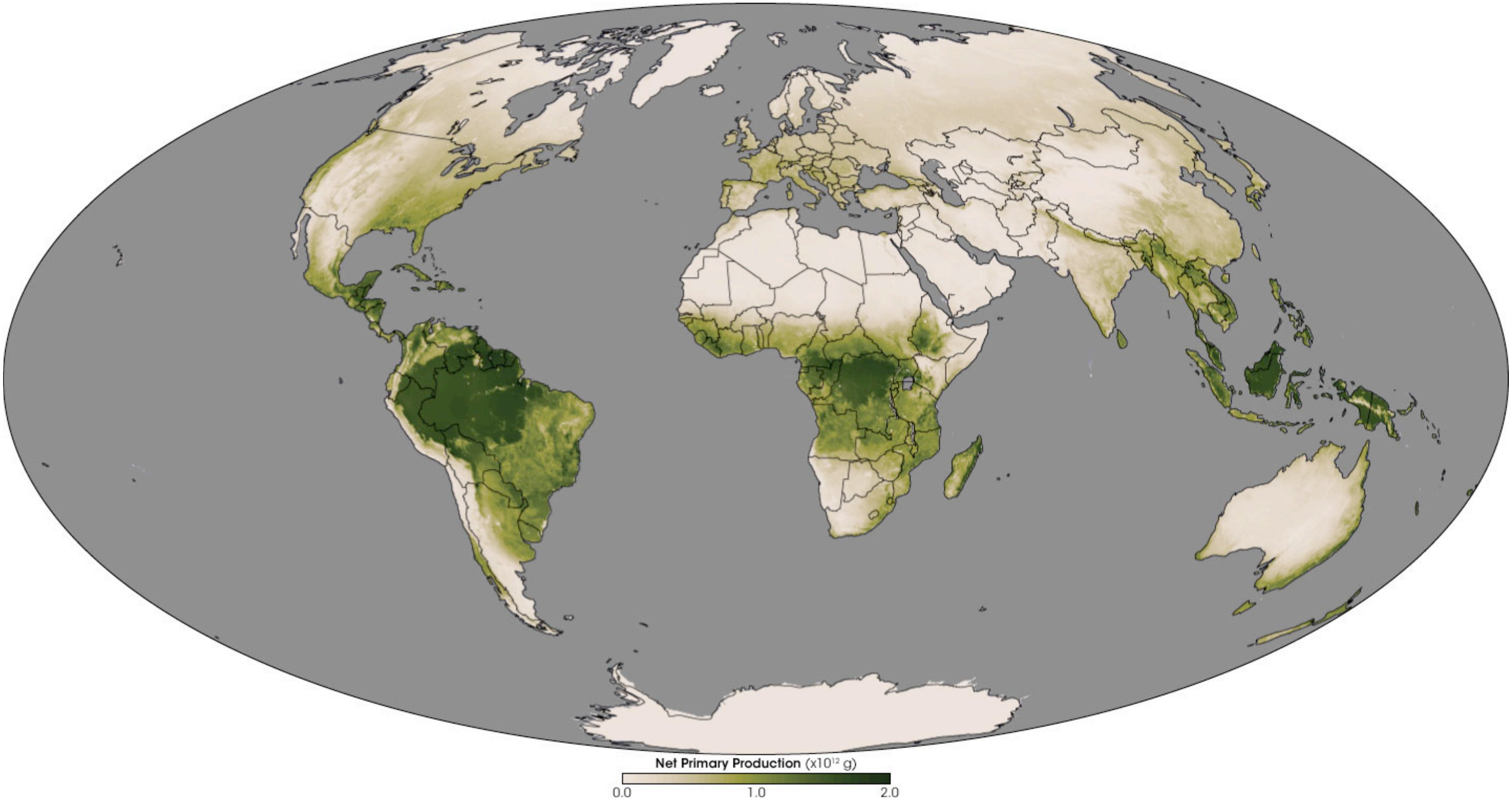


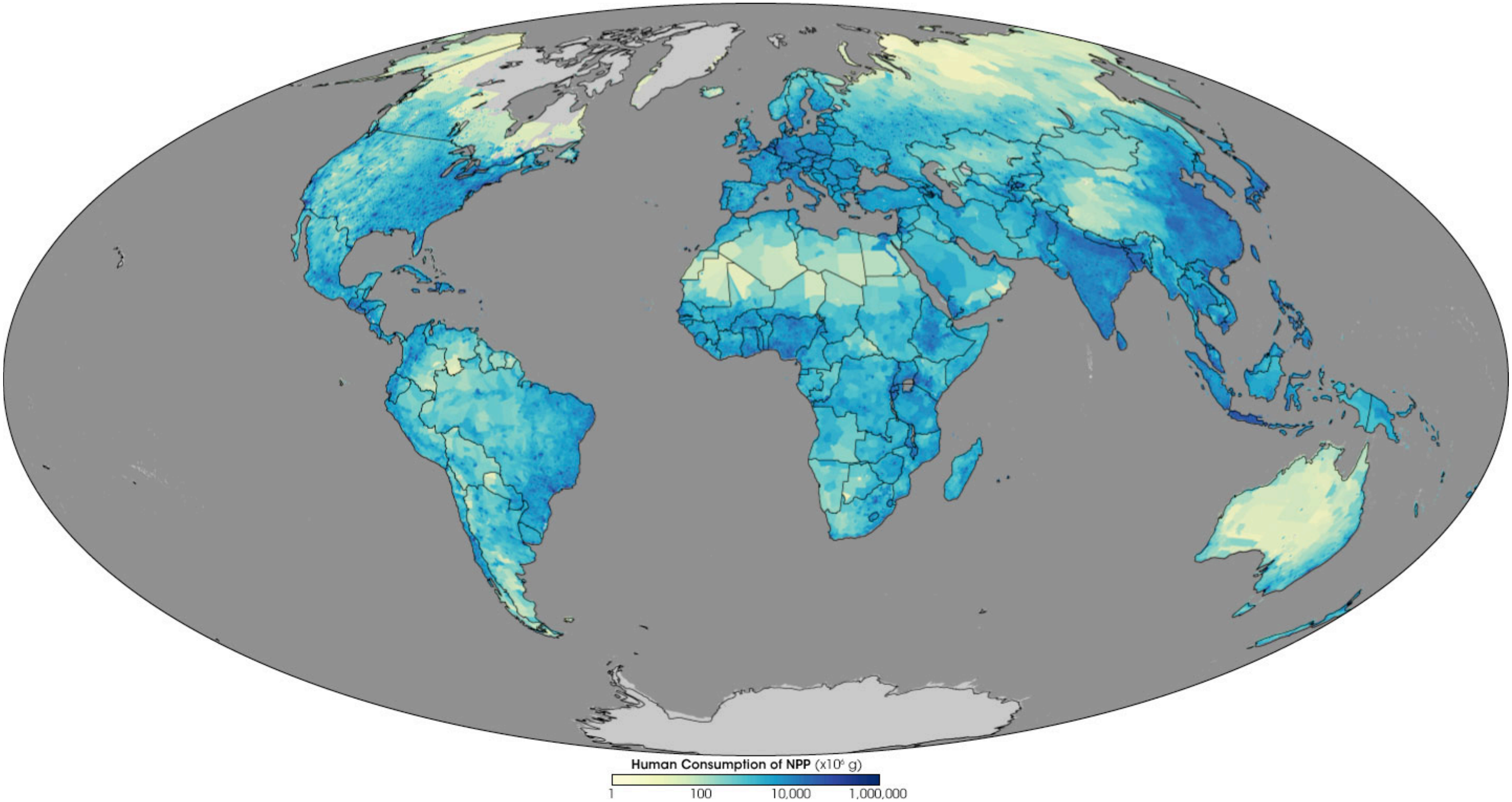
Figure 3: Patterns of terrestrial NPP at different timescales in a temperate forest: Daily net primary production (NPP) changes during the growing season in response to climate variables including solar radiation and precipitation, while the duration of NPP during the growing season (i.e., spring green-up to autumn leaf fall) is largely a function of photoperiod. Annual NPP changes from one year to the next in response to longer-term trends in climate, including shifts in total solar radiation caused by differences in cloud cover from year to year. Decadal patterns of NPP track changes in ecological succession (Gough et al. 2007, 2008).

Biome	Global GPP[1] Pg C / yr	Global NPP Pg C / yr	Ecosystem NPP g C / (ha·yr)
Tropical forest	40.8	16.0–23.1	871–1098
Temperate forest	9.9	4.6–9.1	465–741
Boreal forest	8.3	2.6–4.6	173–238
Tropical savannah and grasslands	31.3	14.9–19.2	343–393
Temperate grasslands and shrublands	8.5	3.4–7.0	129–342
Deserts	6.4	0.5–3.5	28–151
Tundra	1.6	0.5–1.0	80–130
Croplands	14.8	4.1–8.0	288–468
TOTAL	121.7	48.0–69.0	2377–3561

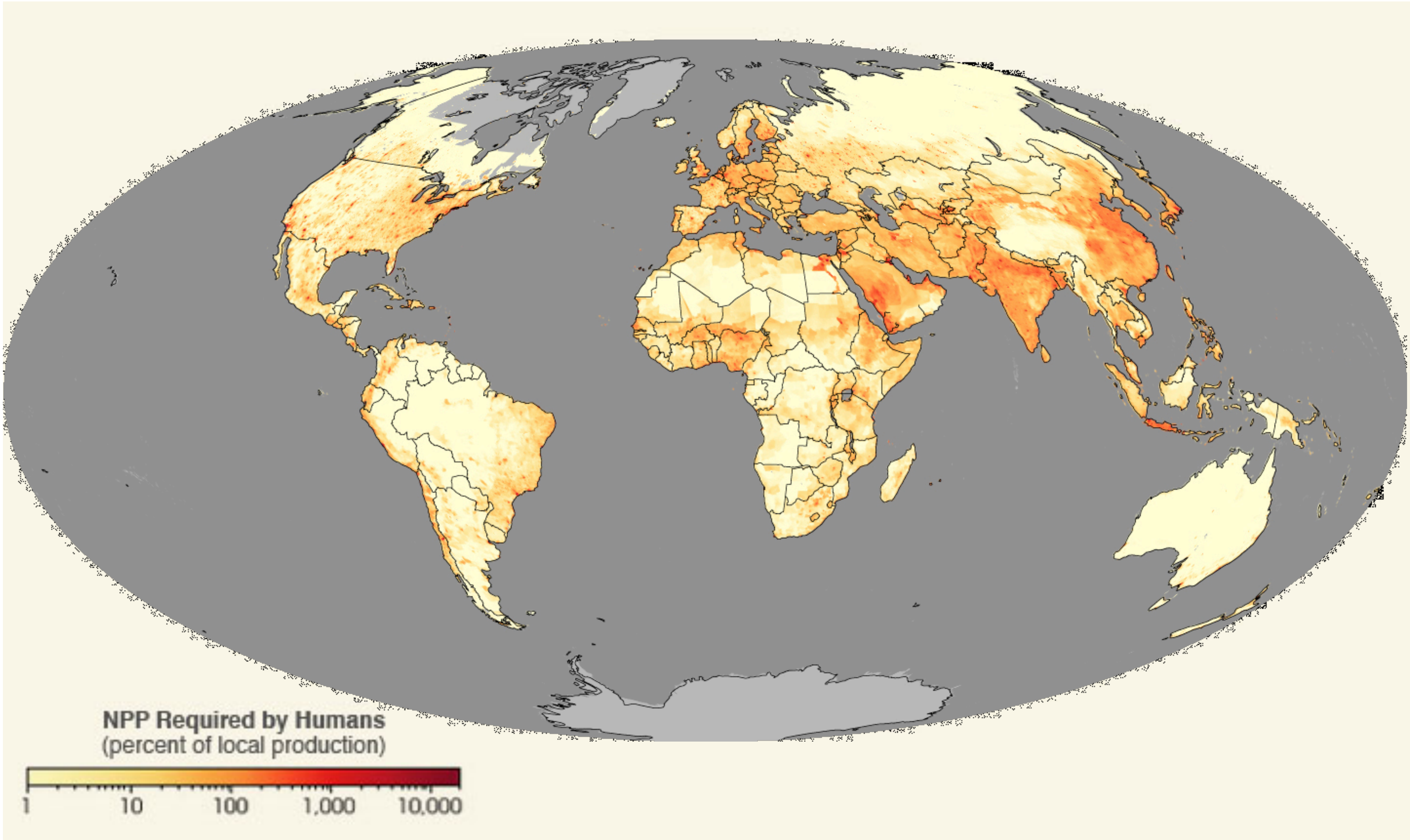
Table 1: Global and ecosystem-scale estimates of mean **terrestrial gross and net primary production for the Earth's major biomes from remotely sensed satellite data and modeling students.** 1 Petagram (Pg) = 10^{15} grams (g).

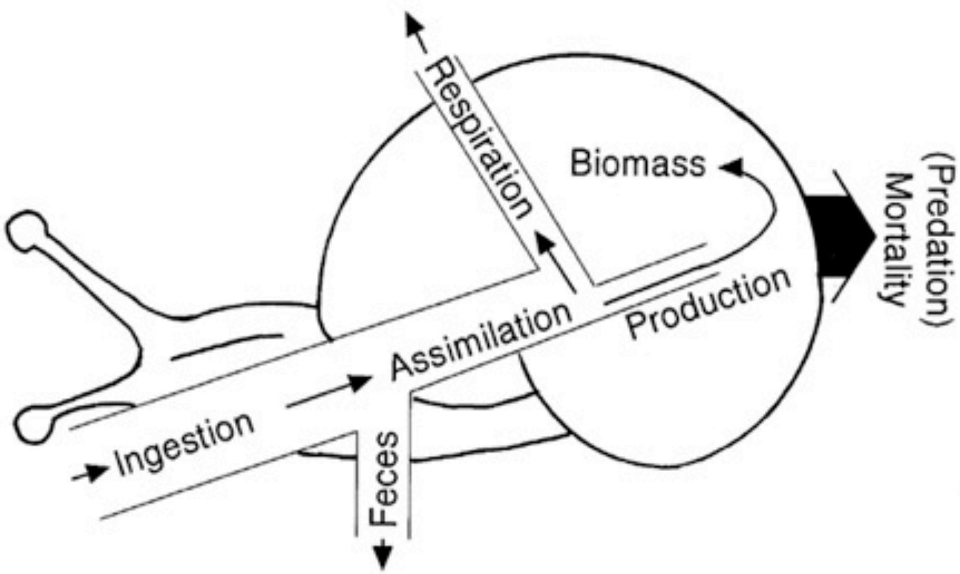


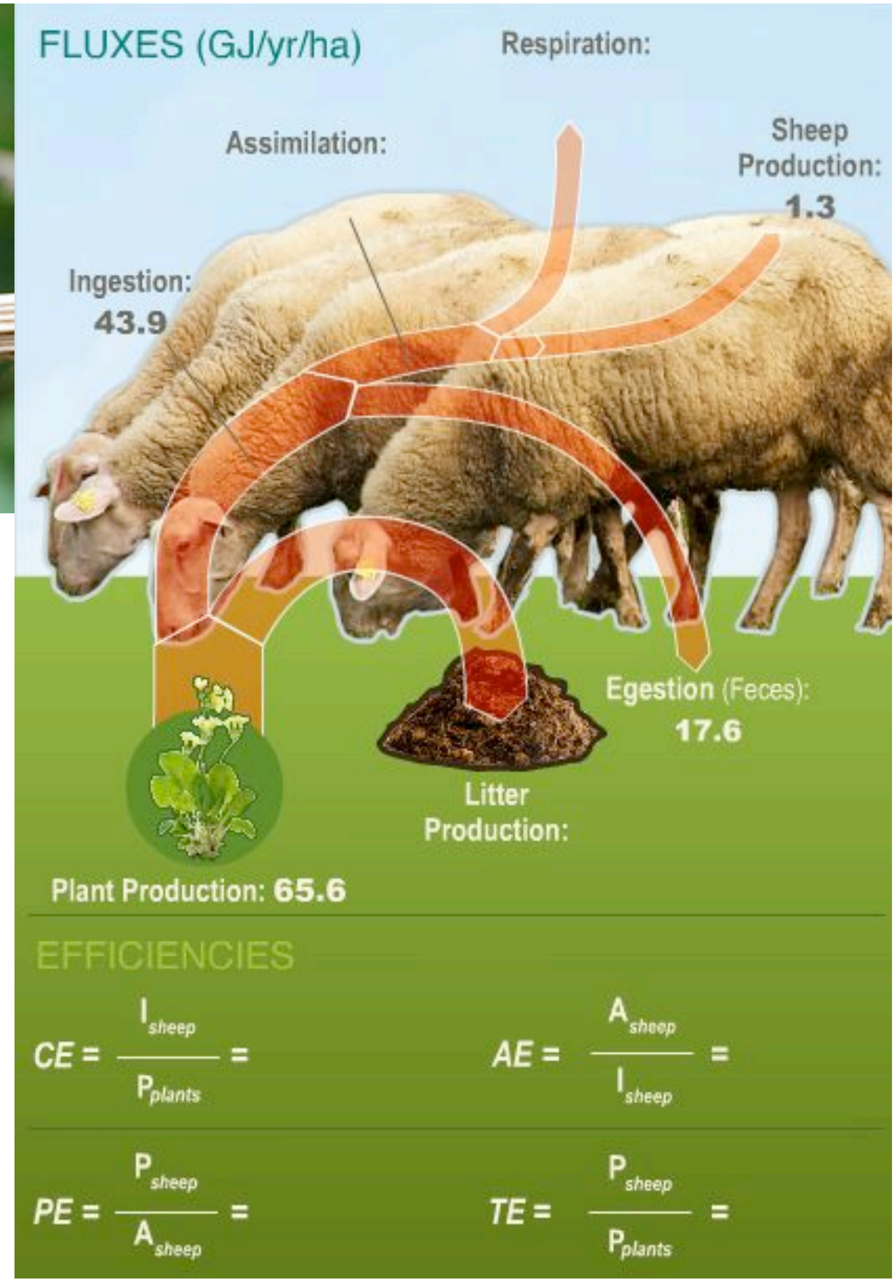
Net Primary Production (x10^12 g)
0.0
1.0
2.0

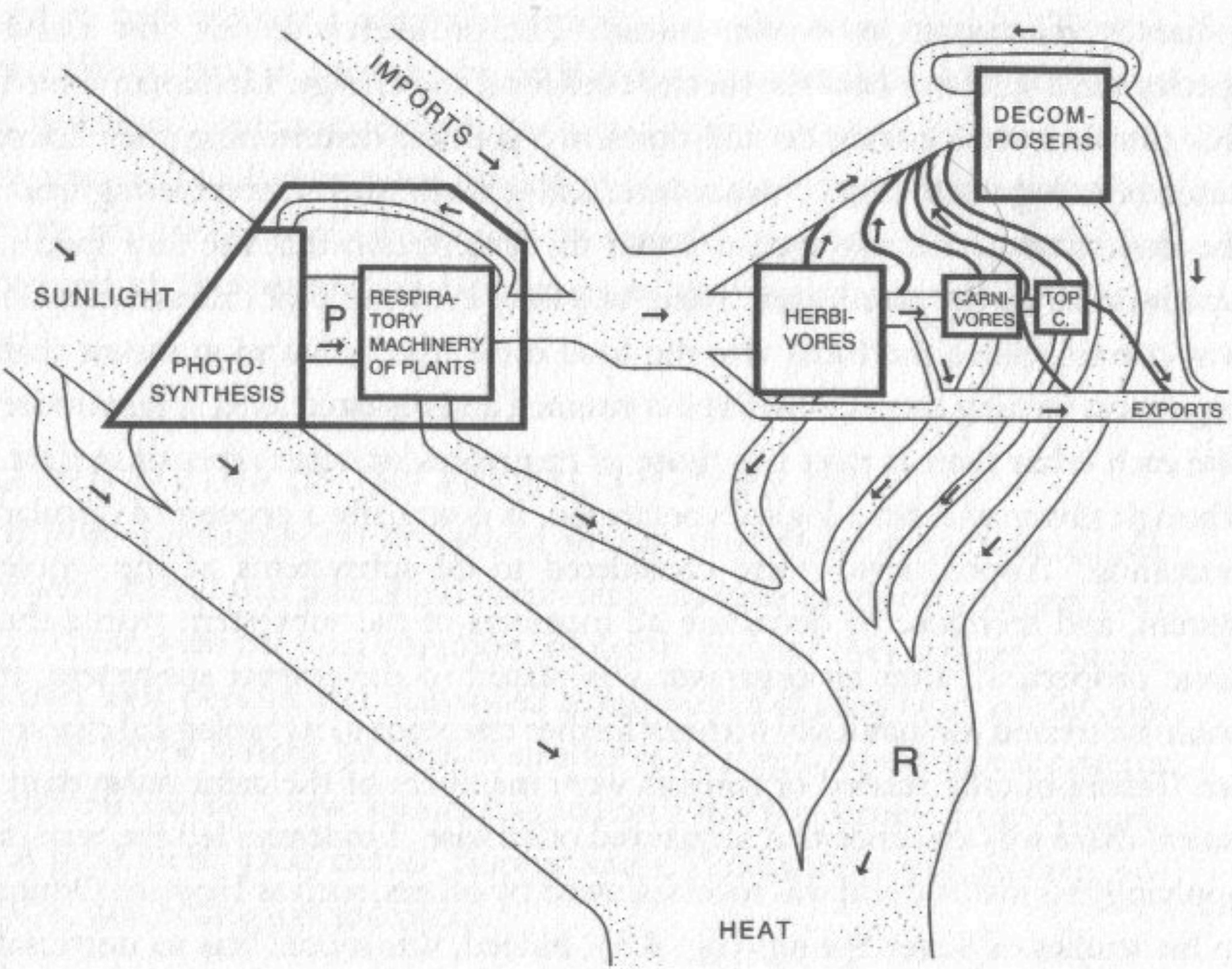


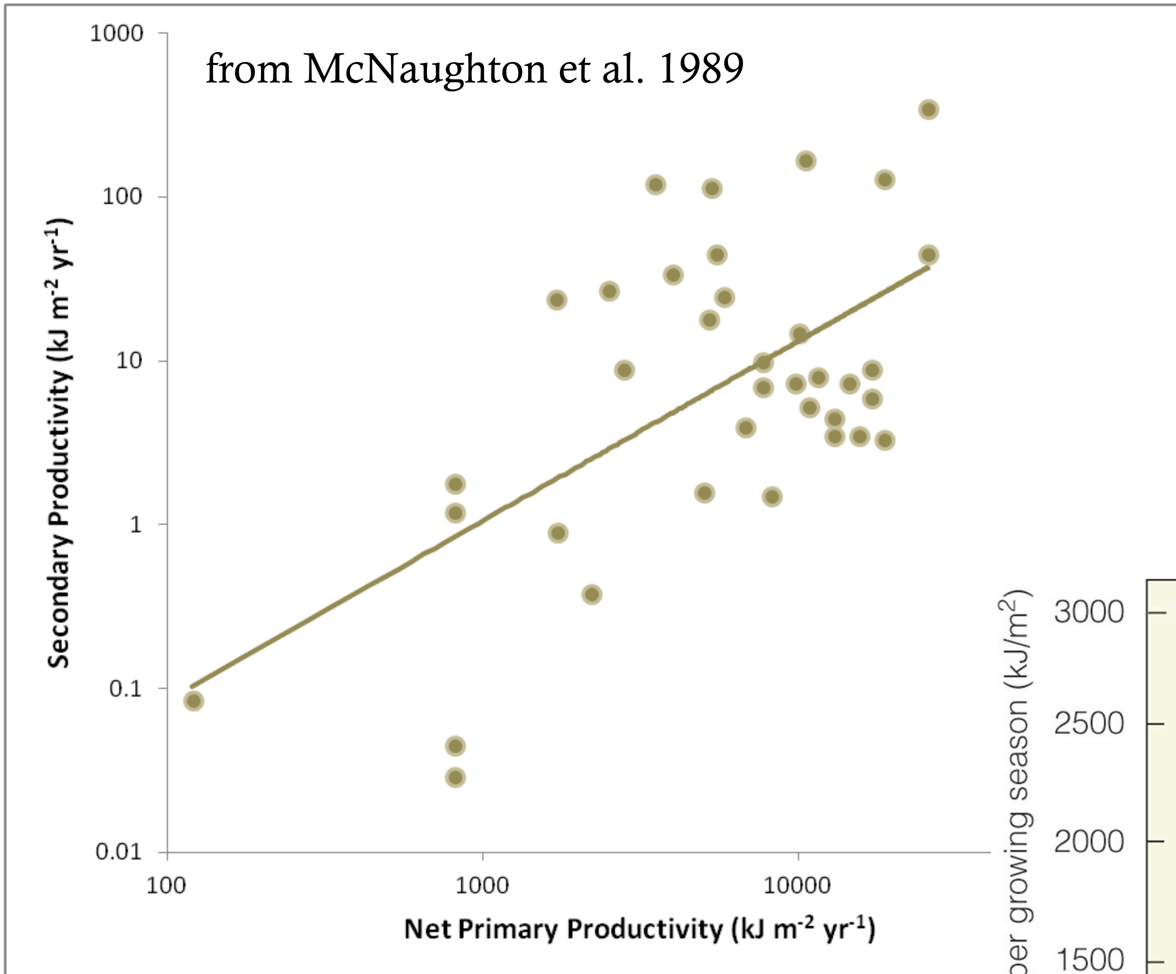
Human Consumption of NPP (x10^6 g)
1
100
10,000
1,000,000

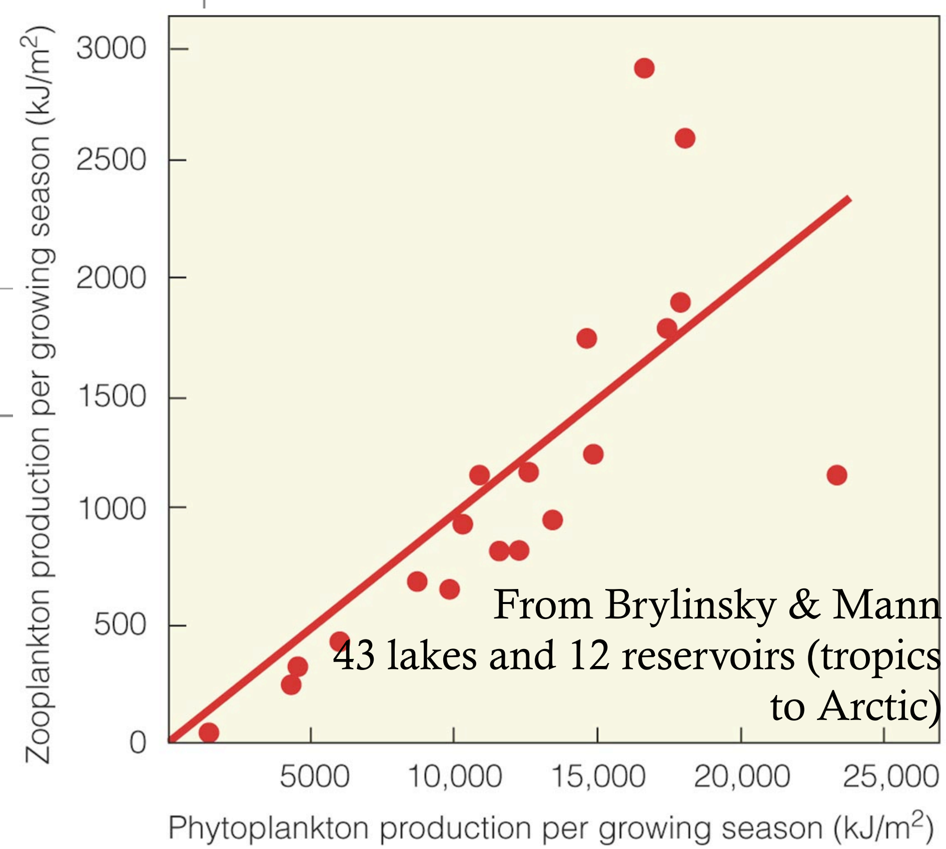

NPP Required by Humans
(percent of local production)
1
10
100
1,000
10,000

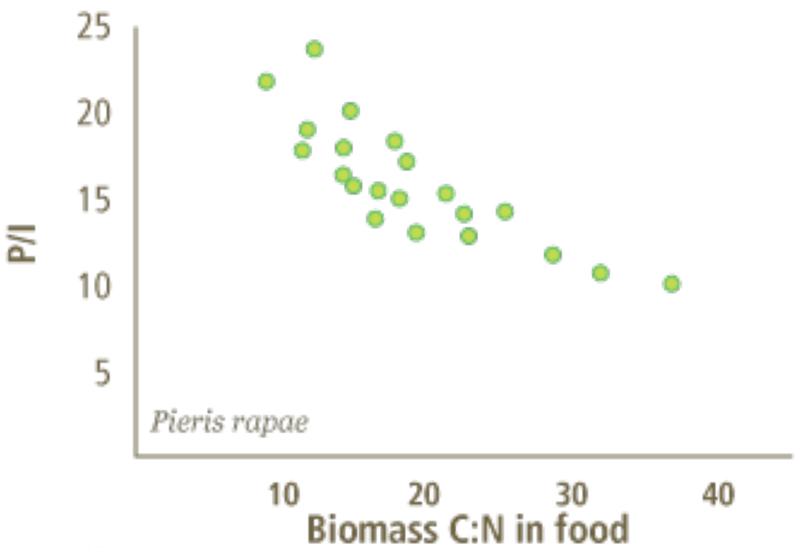

Respiration
Biomass
(Predation)
Mortality
Production
Assimilation
Ingestion
Feces

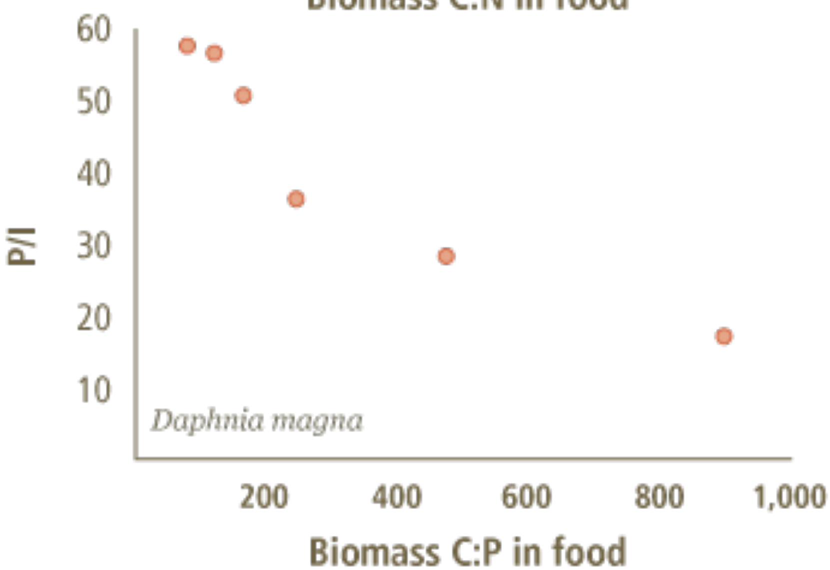

FLUXES (GJ/yr/ha)
Respiration:
Assimilation:
Sheep Production: 1.3
Ingestion: 43.9
Egestion (Feces): 17.6
Litter Production:
Plant Production: 65.6
EFFICIENCIES
$CE = \frac{I_{sheep}}{P_{plants}} =$
$AE = \frac{A_{sheep}}{I_{sheep}} =$
$PE = \frac{P_{sheep}}{A_{sheep}} =$
$TE = \frac{P_{sheep}}{P_{plants}} =$


IMPORTS
SUNLIGHT
P
RESPIRA-
TORY
MACHINERY
OF PLANTS
PHOTO-
SYNTHESIS
HERBI-
VORES
CARNI-
VORES
TOP
C.
DECOM-
POSERS
EXPORTS
R
HEAT


from McNaughton et al. 1989
Secondary Productivity (kJ m-2 yr-1)
Net Primary Productivity (kJ m-2 yr-1)
1000
100
10
1
0.1
0.01
100
1000
10000


From Brylinsky & Mann
43 lakes and 12 reservoirs (tropics to Arctic)
Zooplankton production per growing season (kJ/m2)
Phytoplankton production per growing season (kJ/m2)
3000
2500
2000
1500
1000
500
0
5000
10,000
15,000
20,000
25,000





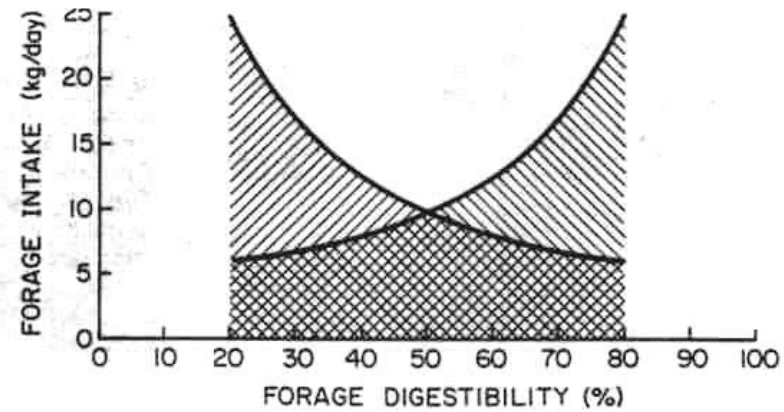


Figure 2.13. Relationship between forage digestibility and long-term forage intake patterns. The descending curve shows the required forage intake to yield 5 kg of digestible dry matter as forage digestibility increases from 20% to 80%. The ascending curve depicts the maximum possible (approximate) forage intake by an adult cow as forage digestibility increases.

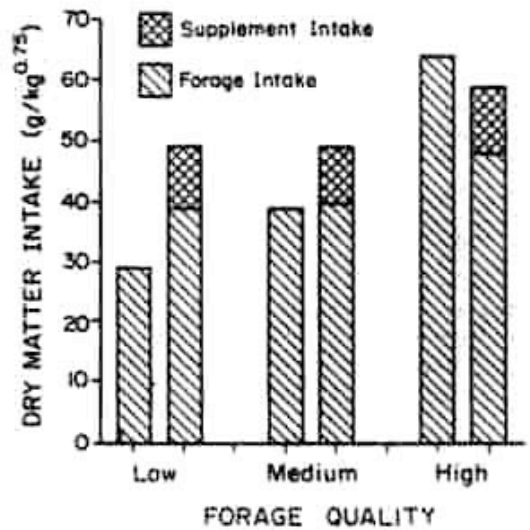
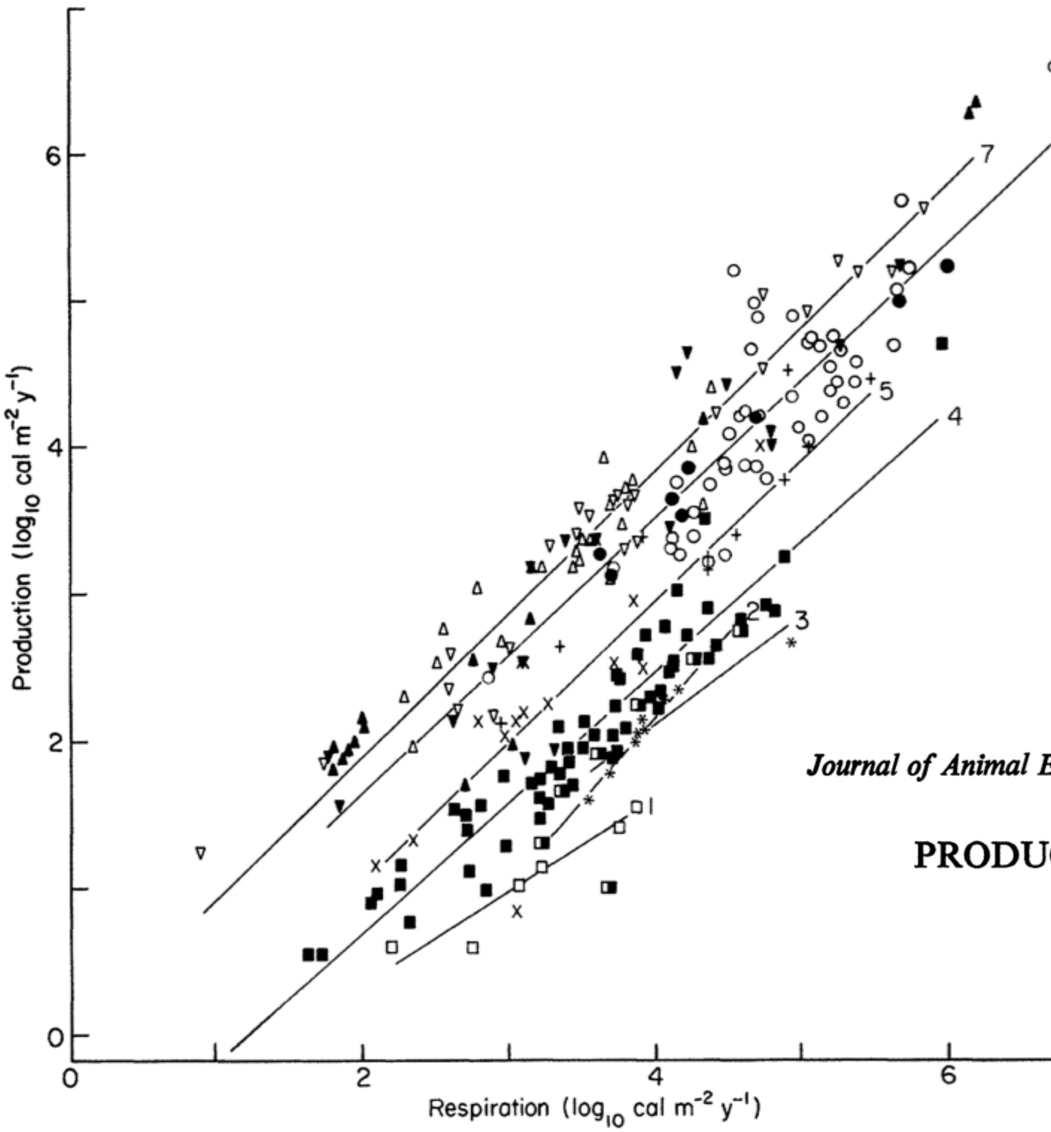
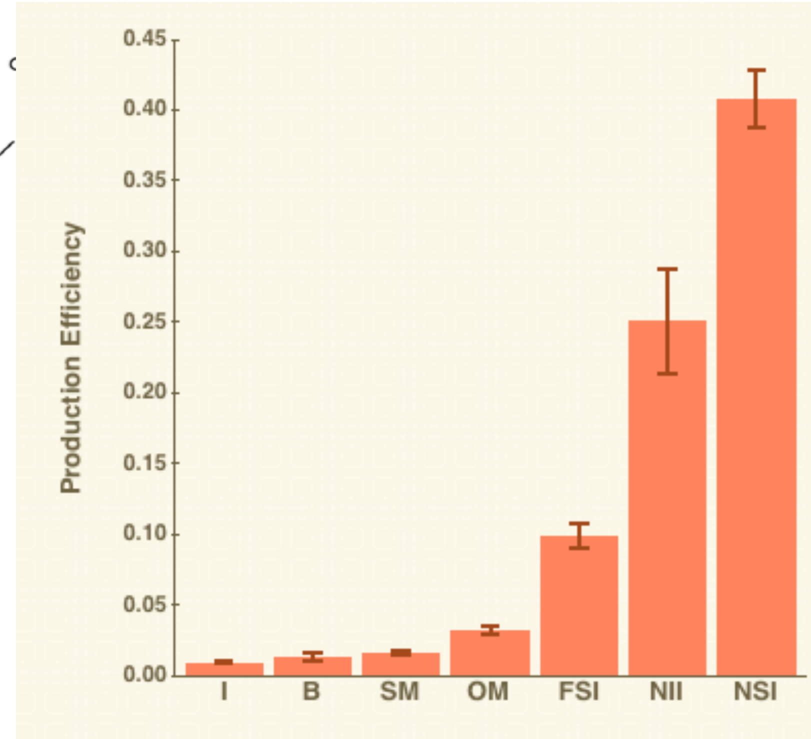


Figure 2.14. Effect of forage quality on intake responses to supplemental feeding. This is the result of an experiment in which sheep were offered forages of different quality ad libitum either with or without supplemental feed (Huston et al. 1988). The low-, medium- and high-quality forages were wheat straw (3.4% CP and 41% IVDMD), sorghum hay (5.9% CP and 54% IVDMD), and oat hay (13.6% CP and 65% IVDMD), respectively. The supplement contained 28% CP and approximately 3.3 Mcal/kg DE. Supplement feeding level provided 60 g CP per sheep per day.

http://cnrit.tamu.edu/rlem/textbook/Chapter2.htm





Journal of Animal Ecology (1979), **48**, 427–453

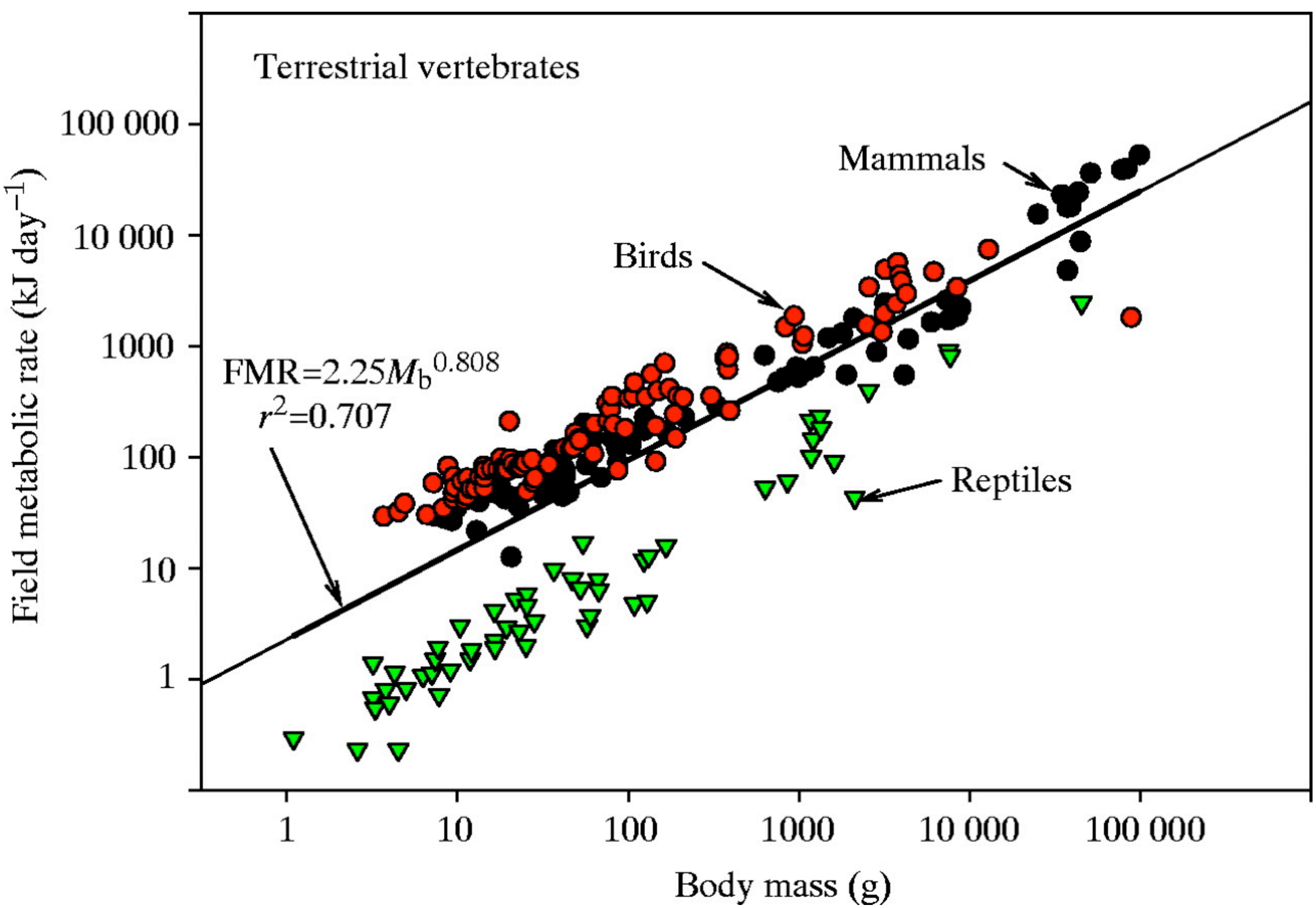
PRODUCTION AND RESPIRATION IN ANIMAL POPULATIONS

BY W. F. HUMPHREYS

FIG. 1. The relationship between respiration and production (both as log$_{10}$ cal m^{-2} in natural populations of animals. The regression lines, not adjusted for common sl the seven derived groups (Table 2) are shown. The points for *Perognathus penicillatis* and *P. baileyi* (Appendix) are not plotted. The lines are numbered 1 = insectivores, 2 = small mammal communities, 3 = birds, 4 = other mammals, 5 = fish and social insects, 6 = non-insect invertebrates and 7 = non-social insects. The symbols denote: □ insectivores, ◨ small mammal communities, ■ other mammals, ✱ birds, + fish, × social insects, ○ molluscs, ● Crustacea, ▼ other non-insect invertebrates, △ Orthoptera, ▲ Hemiptera, ▽ other non-social insects.

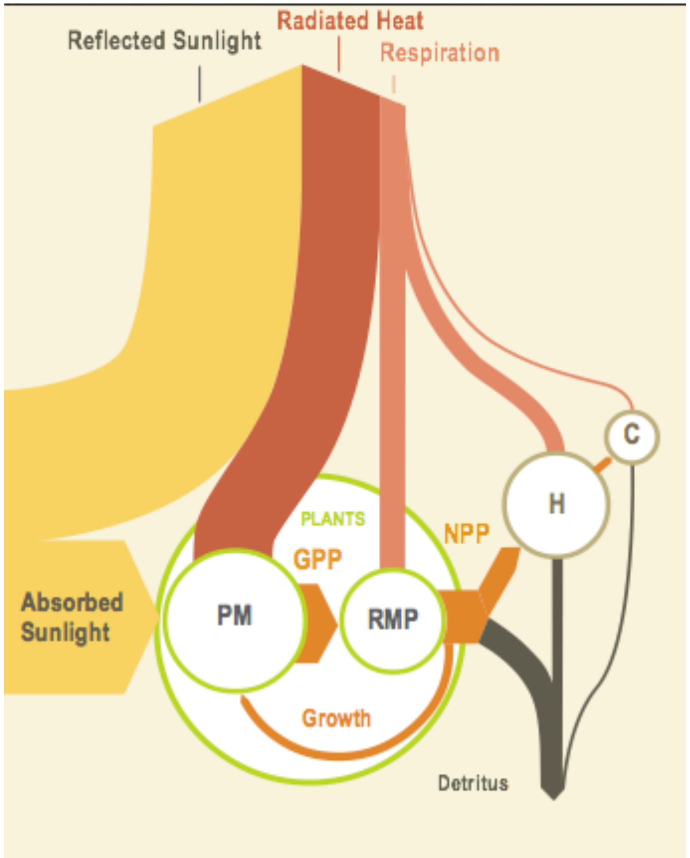
Mean production effciency and standard error of major consumer groups: insectivores (I), birds (B), small mammals (SM), other mammals (OM), fish and social insects (FSI), non-insect invertebrates (NII), and non-social insects (NSI). Adapted from

Log-log relationship of field metabolic rate to body mass in 229 species of terrestrial vertebrates.



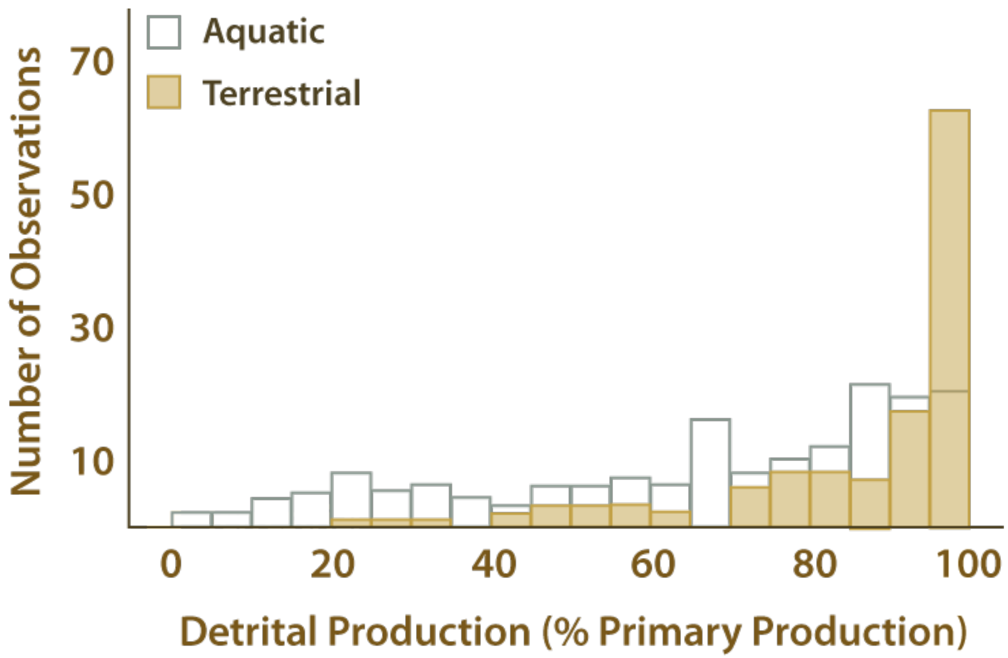
Nagy K A J Exp Biol 2005;208:1621-1625

The Journal of Experimental Biology

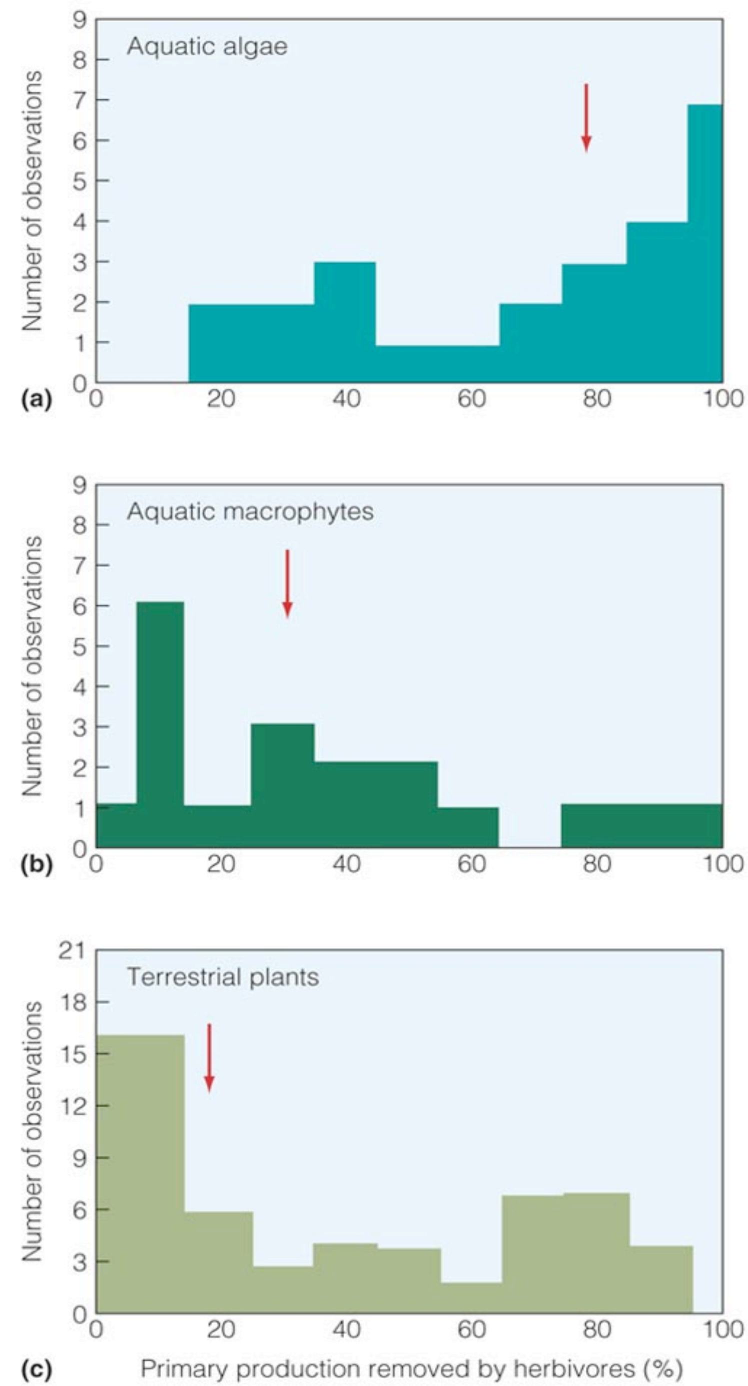


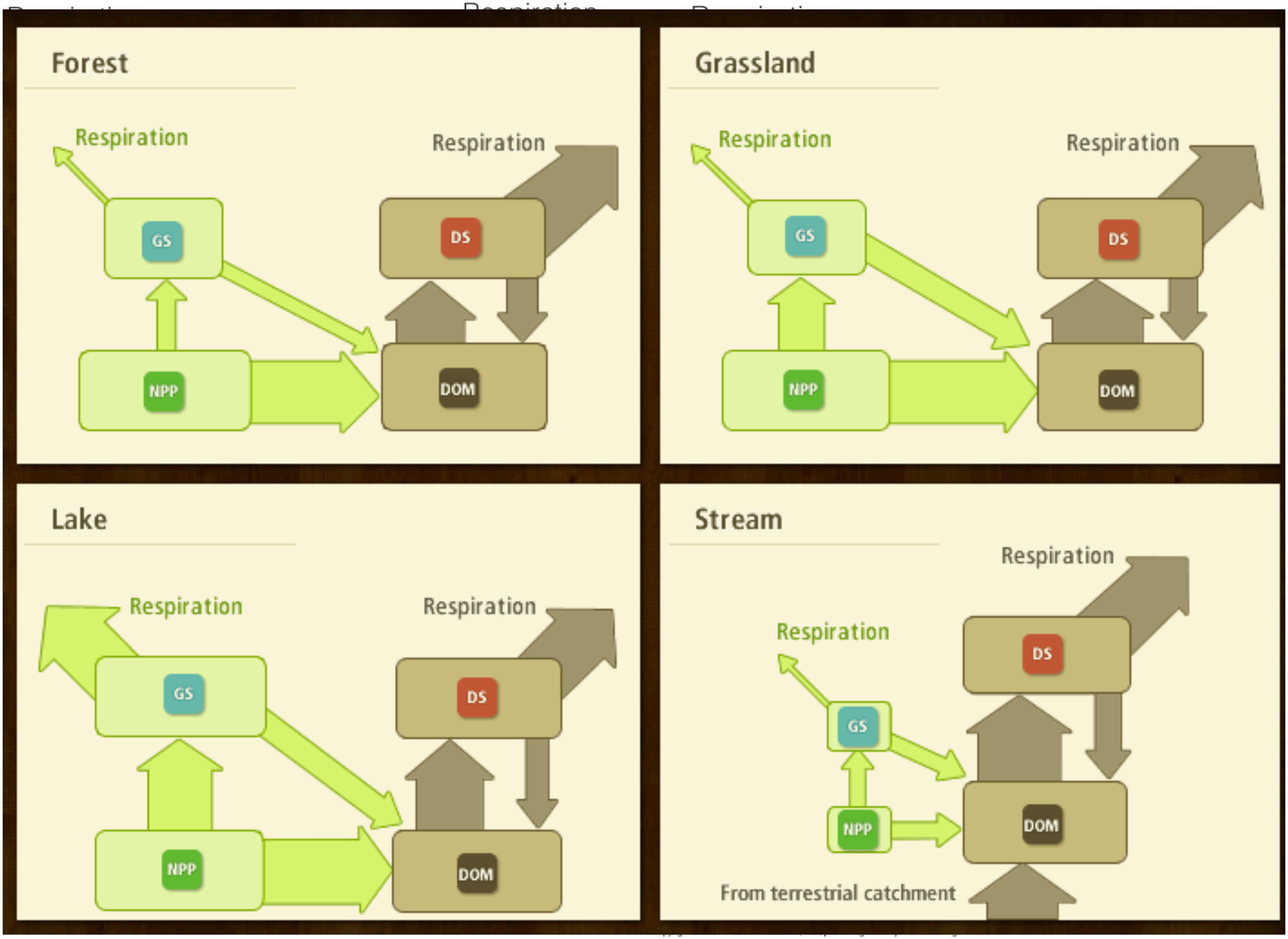
LEGEND

PM Photosynthetic Machinery
RMP Respiratory Machinery of Plants
H Herbivores
C Carnivores

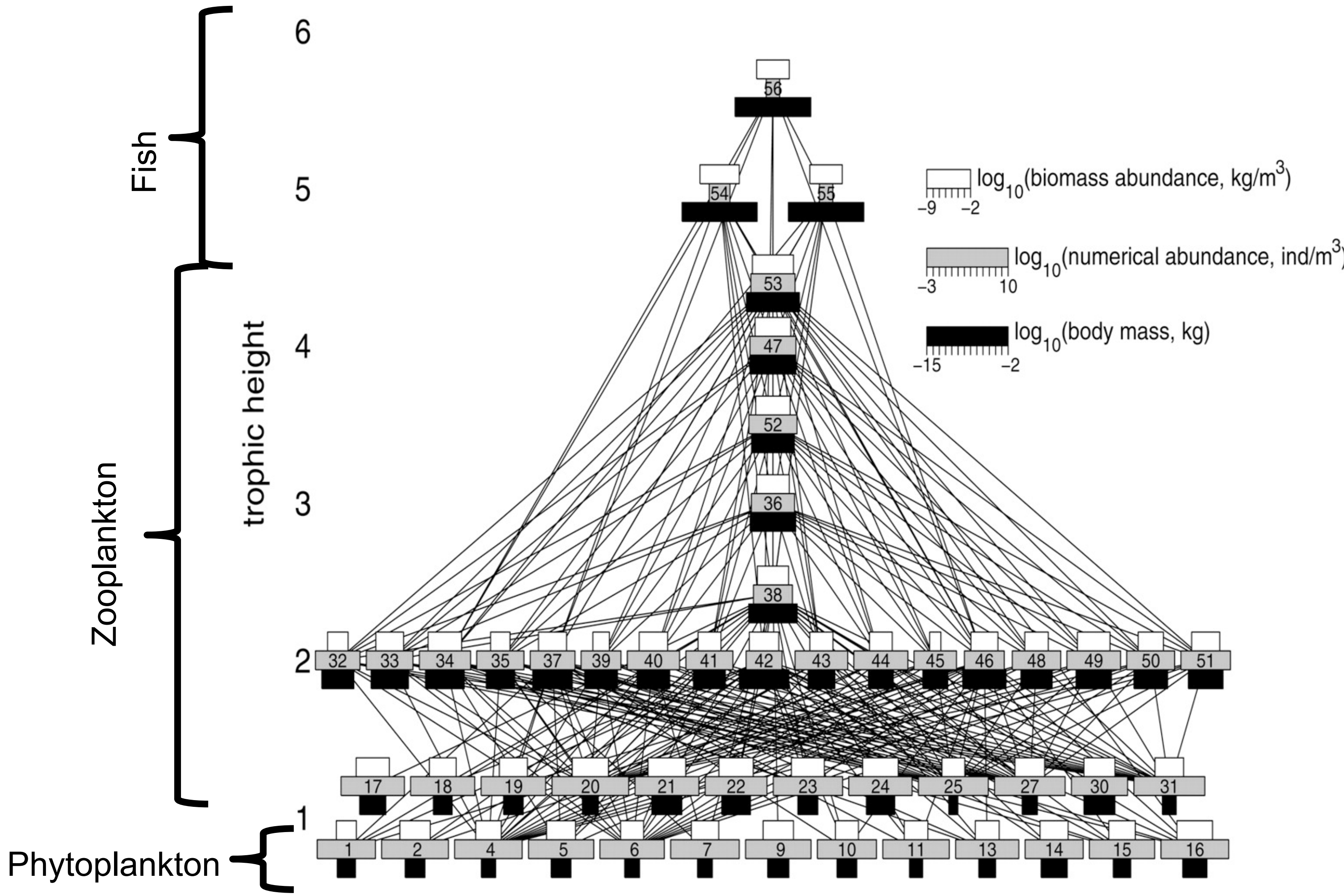


ᏟᏒThe percentage of NPP that enters the decomposer system for a range of different terrestrial (shaded) and aquatic (clear) ecosystems. For the majority of terrestrial systems, well over half of primary production enters the detrital component. Overall, in aquatic systems, a greater percentage of primary production ends up being consumed by herbivores. (Redrawn from Cebrian and Lartigue, 2004.)

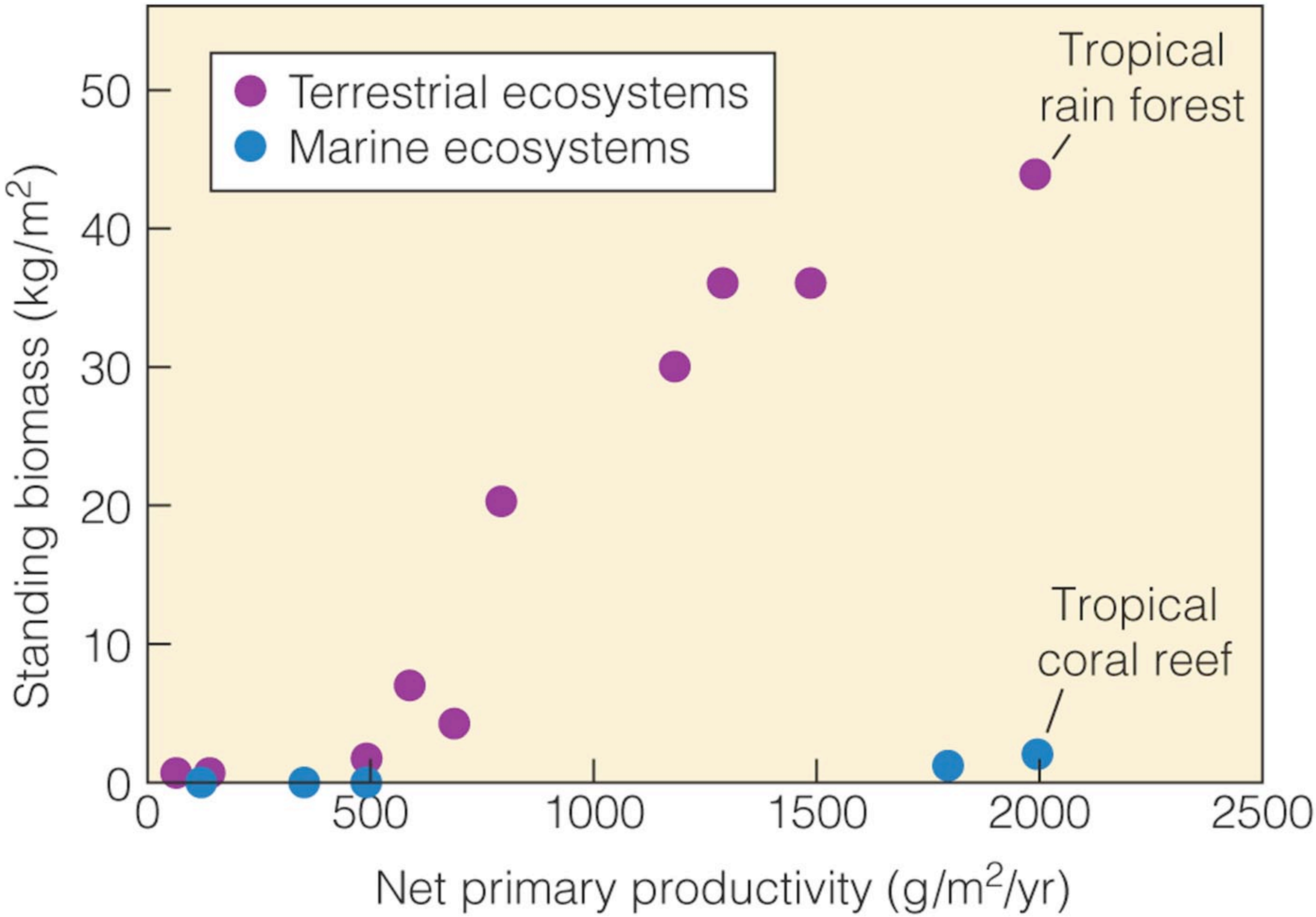



Forest
Respiration
Respiration
GS
DS
NPP
DOM
Grassland
Respiration
Respiration
GS
DS
NPP
DOM
Lake
Respiration
Respiration
GS
DS
NPP
DOM
Stream
Respiration
Respiration
DS
GS
NPP
DOM
From terrestrial catchment

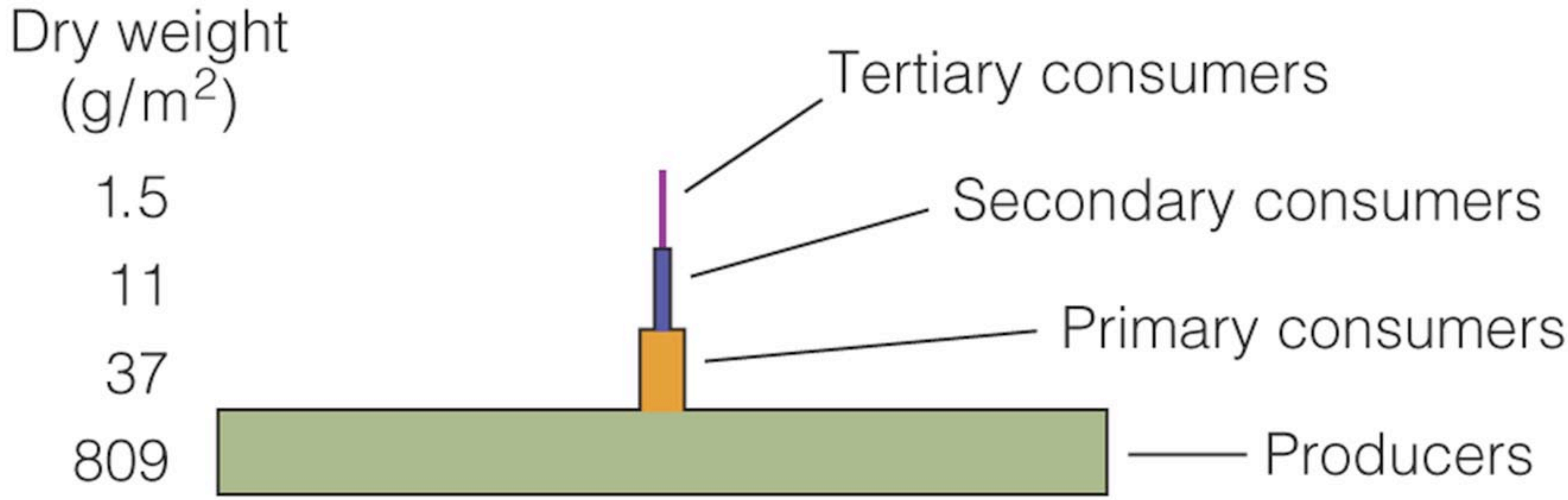
The food web of Tuesday Lake in 1984.



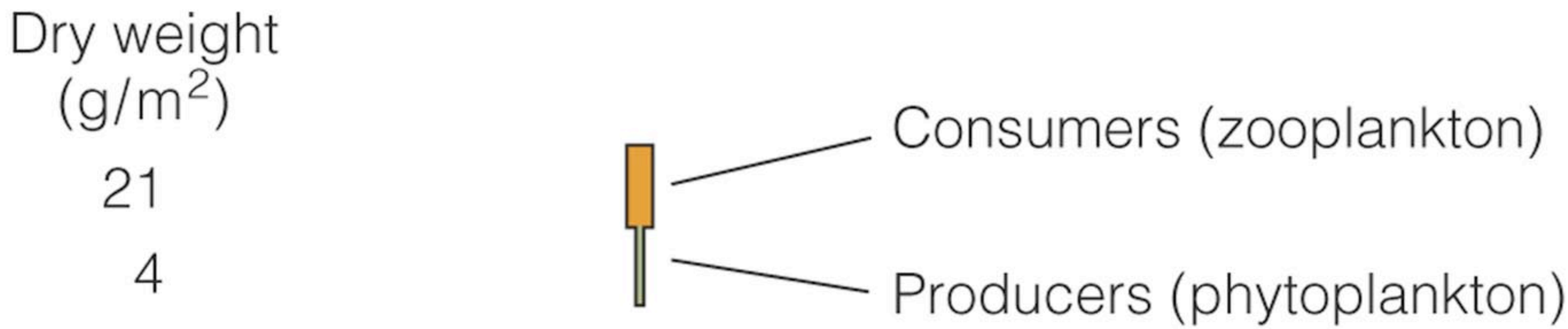
Cohen J E et al. PNAS 2003;100:1781-1786



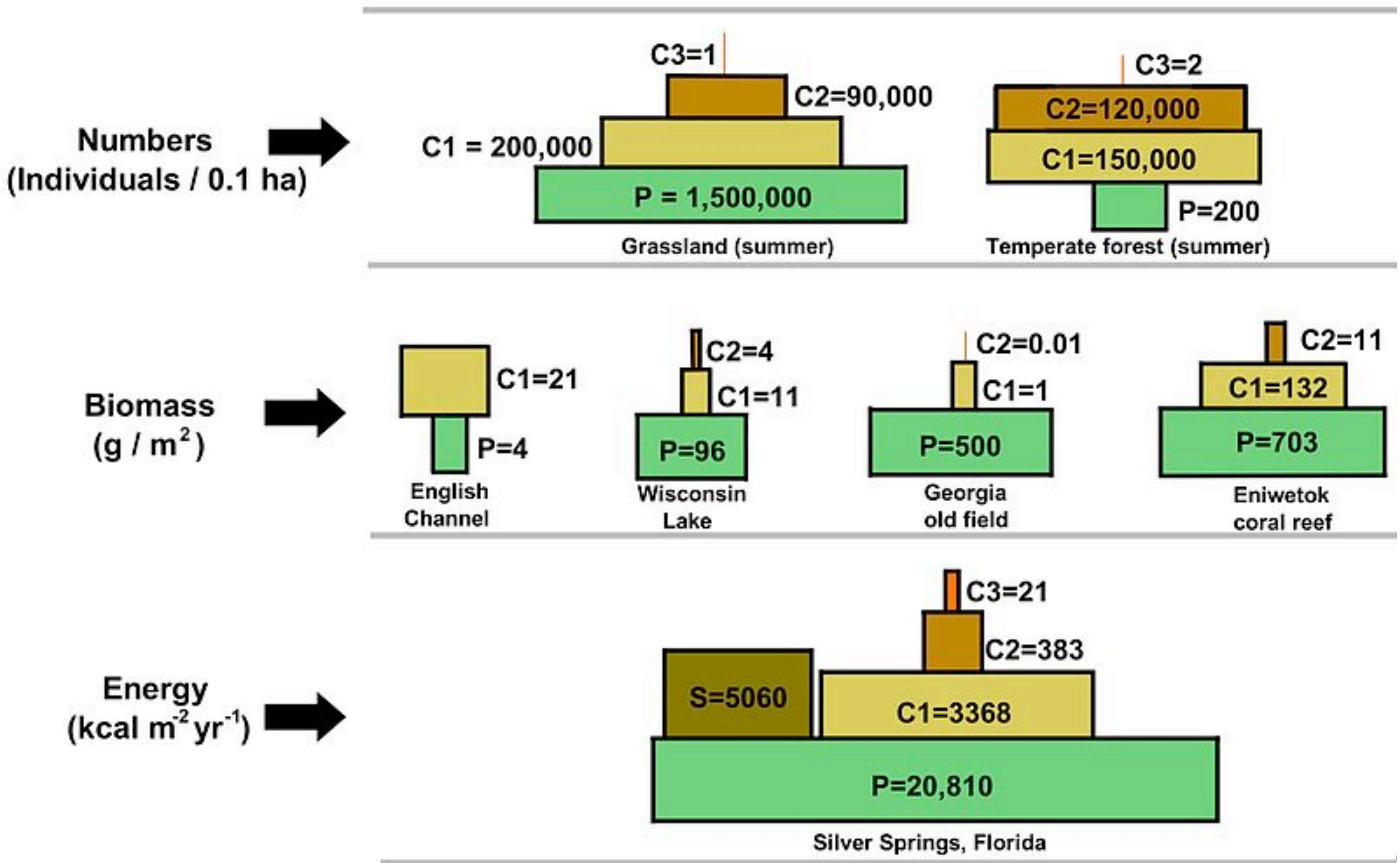
Terrestrial ecosystems
Marine ecosystems
Tropical rain forest
Tropical coral reef
Standing biomass (kg/m2)
Net primary productivity (g/m2/yr)
0
10
20
30
40
50
0
500
1000
1500
2000
2500



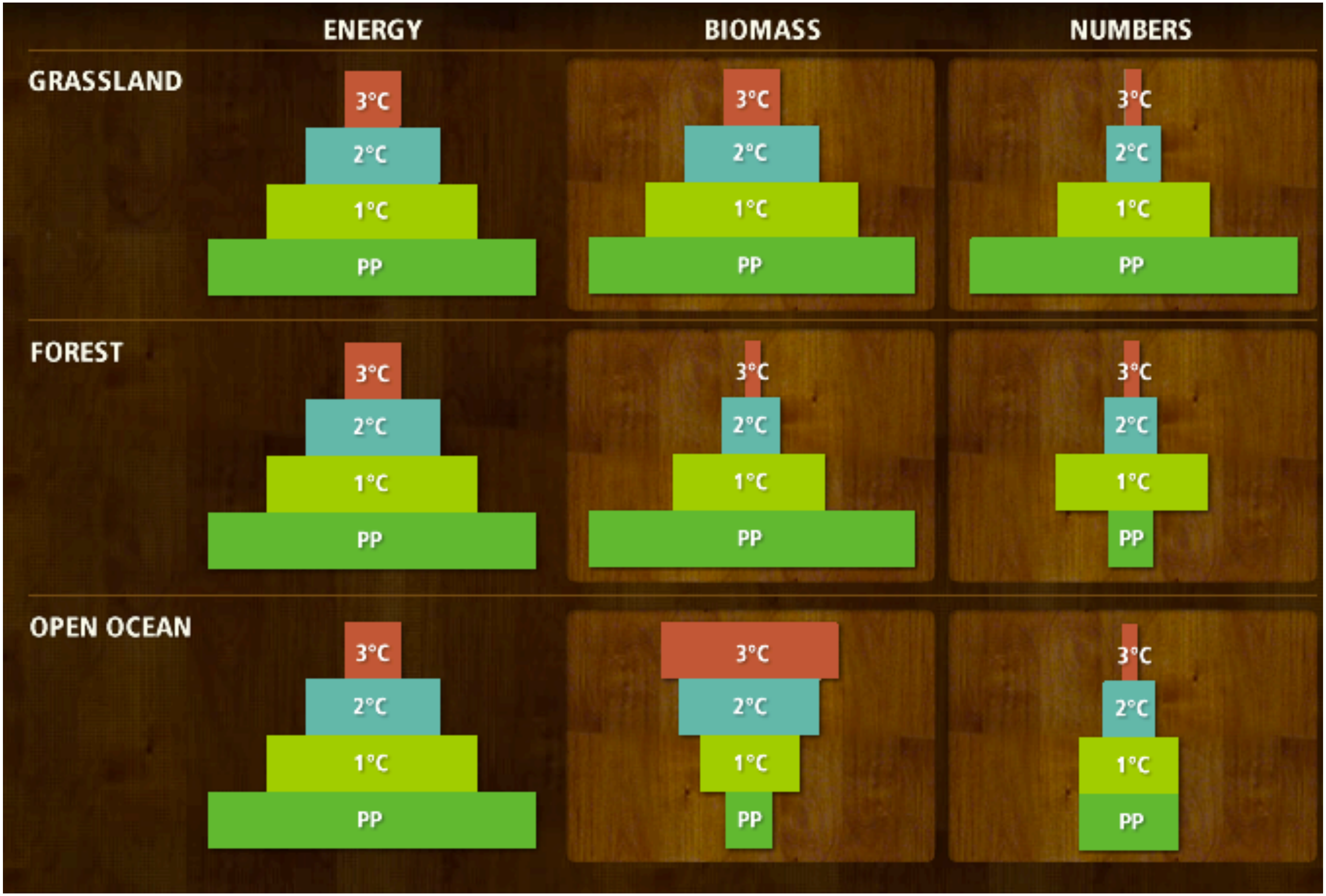
(a) Florida bog

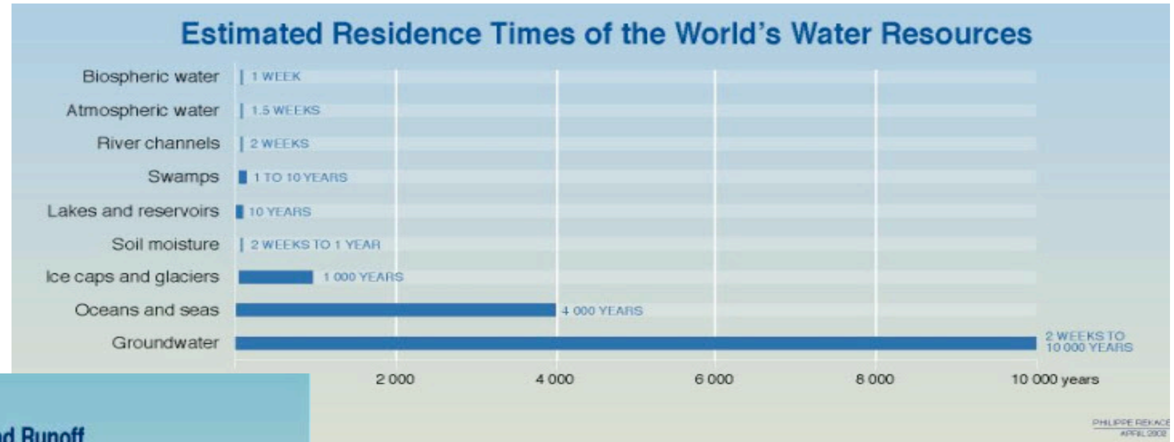


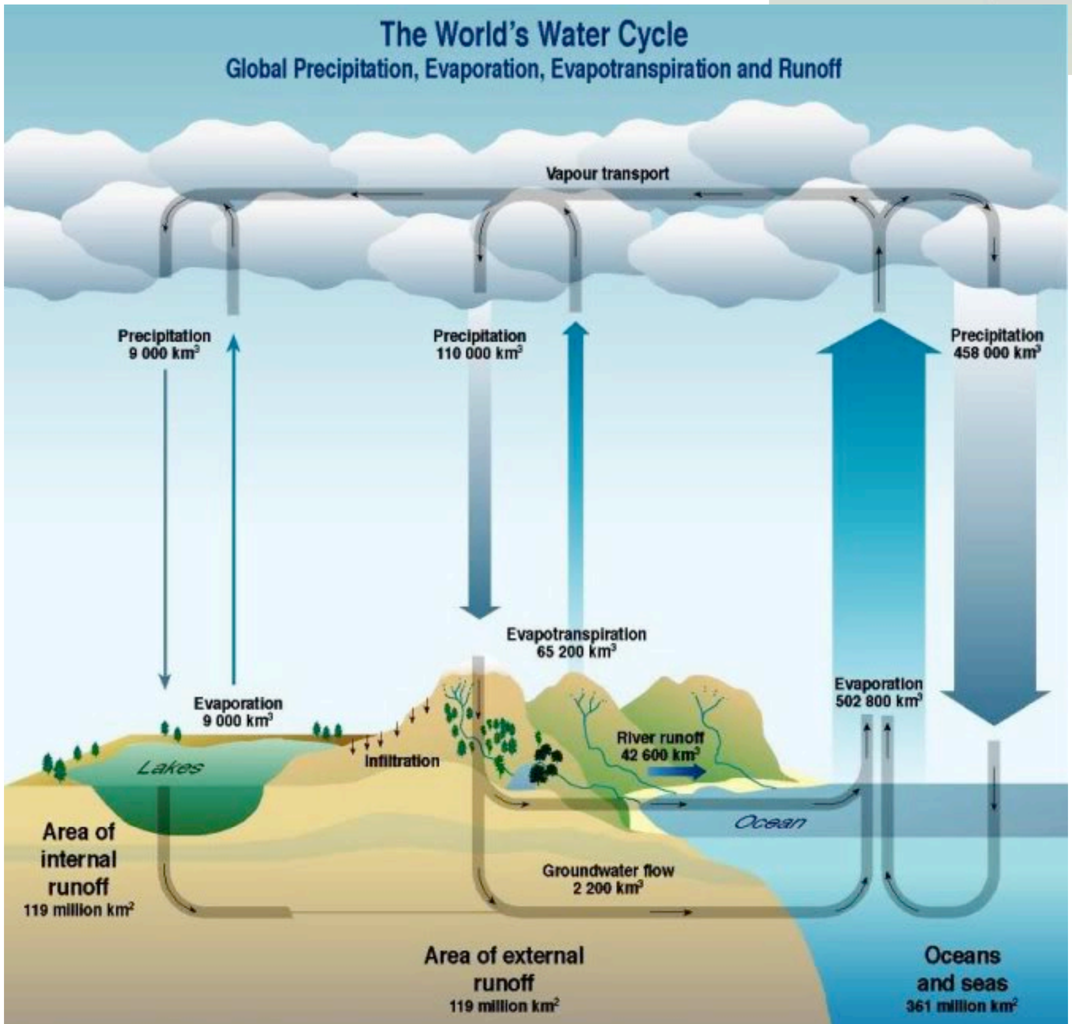
(b) English Channel



The illustration is not drawn to scale and is redrawn from figure 3-12 in (2005) Fundamentals of ecology, Brooks Cole, pp. 598 ISBN: 9780534420666. , which is based on published experimental data. Notation: P=Producer, C1=primary consumer, C2=secondary consumer, C3=tertiary consumer, S=saprotroph http://en.wikipedia.org/wiki/Food_web

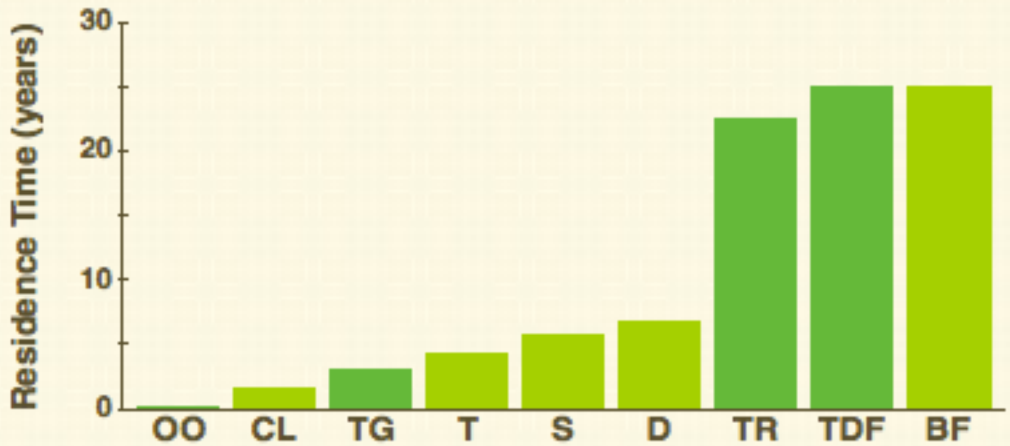

ENERGY
BIOMASS
NUMBERS
GRASSLAND
3°C
2°C
1°C
PP
FOREST
OPEN OCEAN



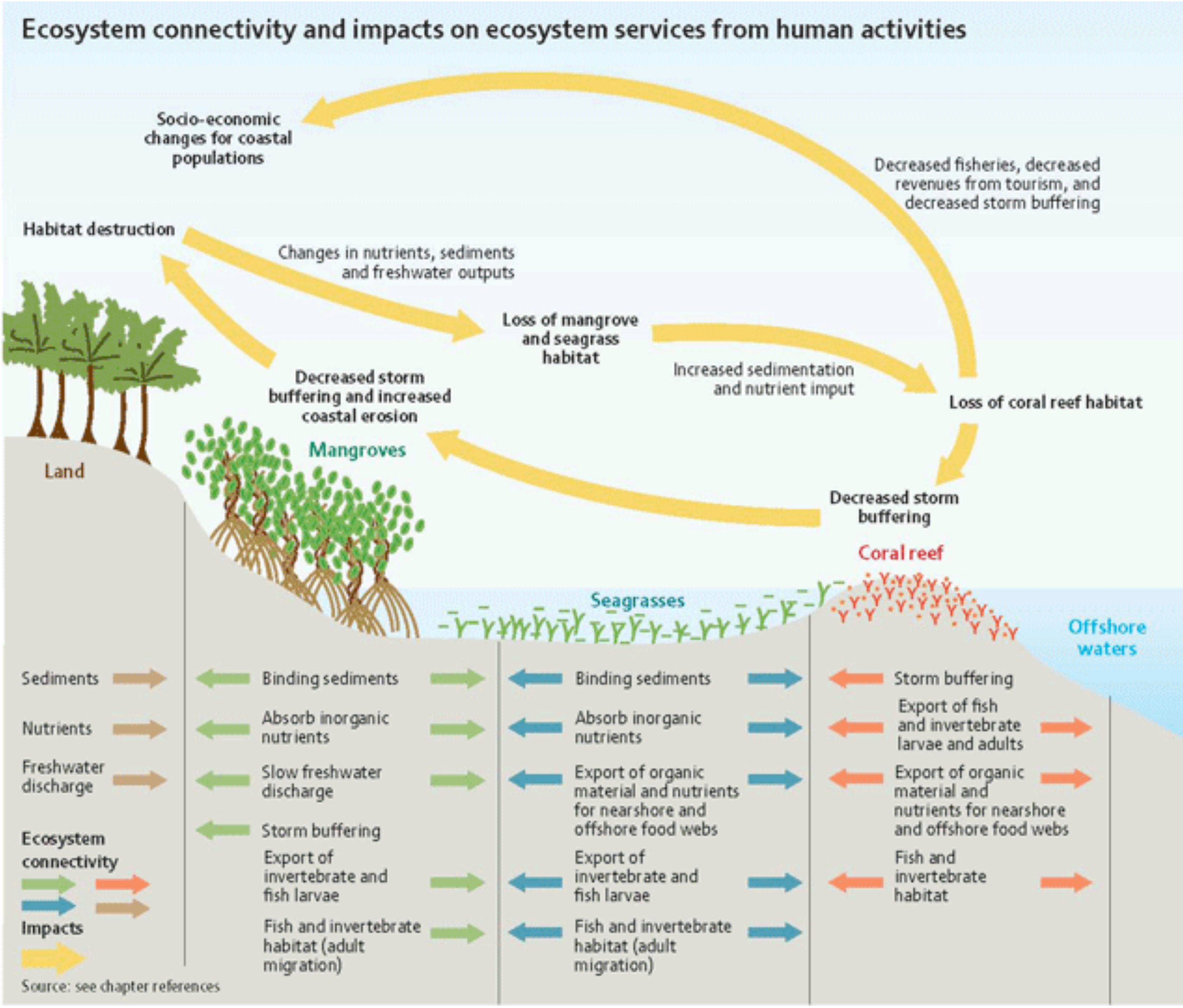


Note: The width of the blue and grey arrows are proportional to the volumes of transported water

Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999; Max Planck, Institute for Meteorology, Hamburg, 1994; Freeze, Allen, John, Cherry, *Groundwater*, Prentice-Hall: Engle wood Cliffs NJ, 1979.



Biomass residence times of open ocean (OO), cultivated land (CL), temperate grassland (TG), tundra (T), savanna (S), desert (D), tropical rainforest (TR), temperate deciduous forest (TDF), and boreal forest (BF). Adapted from Whittaker and Likens (1973).



Ecosystem connectivity and impacts on ecosystem services from human activities
Socio-economic changes for coastal populations
Decreased fisheries, decreased revenues from tourism, and decreased storm buffering
Habitat destruction
Changes in nutrients, sediments and freshwater outputs
Loss of mangrove and seagrass habitat
Increased sedimentation and nutrient imput
Loss of coral reef habitat
Decreased storm buffering and increased coastal erosion
Decreased storm buffering
Land
Mangroves
Seagrasses
Coral reef
Offshore waters
Sediments
Nutrients
Freshwater discharge
Ecosystem connectivity
Impacts
Binding sediments
Absorb inorganic nutrients
Slow freshwater discharge
Storm buffering
Export of invertebrate and fish larvae
Fish and invertebrate habitat (adult migration)
Binding sediments
Absorb inorganic nutrients
Export of organic material and nutrients for nearshore and offshore food webs
Export of invertebrate and fish larvae
Fish and invertebrate habitat (adult migration)
Storm buffering
Export of fish and invertebrate larvae and adults
Export of organic material and nutrients for nearshore and offshore food webs
Fish and invertebrate habitat
Source: see chapter references