SECONDARY PRODUCTION AND ECOLOGICAL EFFICIENCIES
A.R.E. Sinclair - Biology 302

1. Pn goes either to decomposers or herbivores. The latter consume (C) some. Of this part is passed out of the animal as urinary (U) or faecal (F) energy, and the rest is absorbed through the gut as assimilated (A) energy. This is used for body maintenance (=respiration R) and production (P).

2. A can be measured by a) lab studies of C,F,U since A = C - F - U, b) lab studies of R and field measures of P since A = R+P

3. R is affected by Basal Metabolic Rate (kcal/day).
   In mammals this BMR = 70*(Body Wt in kg)^0.75. Found by Brody (1945), Kleiber (1947).

4. Although absolute energy requirements go up with body size the energy per unit weight goes down with increasing body size because the surface area / volume ratio declines. Thus, heat loss/kg body weight also declines. This applies to both homeotherms (warm blooded animals) and poikilotherms (cold blooded).

Efficiency within a trophic level
5. Production Efficiency is the ratio of P to A. In poikilotherms more A goes to P in short lived species (<2yrs) because less is needed for R in nonreproductive periods, i.e. they have higher growth efficiency.

6. Respiration loss is the ratio of R to A. In carnivores more A goes to R due to higher searching rates and other activities. Thus, P/A declines with higher trophic levels.

7. More A goes to R in homeotherms than poikilotherms.

8. Assimilation Efficiency (=Digestibility) is the ratio of A to I. For herbivores it is 20-50%, carnivores 80%. Plants are not very digestible because of lignin and cellulose. Various herbivores have methods to digest cellulose (e.g. rumination, hind-gut digestion, coprophagy), lignin is completely indigestible.

9. Harvest Rates are determined by Growth Efficiency and vary from 5-60%. It is high in plankton, plants, insects, low in vertebrates, homeotherms and large mammals.

Efficiency between trophic levels
10. Gross Ecological Efficiency (Lindeman's efficiency) is the ratio of A at level 2 to A at level 1. GEC = A2/A1. This about 10%. Sometimes this is also measured as C2/C1.

11. Consumption Efficiency is the ratio Intake at level 2 to the Production at level 1. CE = C2/P1. This varies from very low in herbivores (1-5%) to higher in carnivores (up to 30%).

References
Krebs Chap. 26, 5th Edition
Kleiber, M. 1947. Body size and metabolic rate. Physiol. Rev. 17, 511-
1. One can think of communities in terms of the pathways that energy follows in the ecosystem. Simple pathways are called 'food chains', complex pathways with many species are called 'food webs'.
2. Energy moves from one level to another. These are called 'trophic levels'. This is a functional classification: the trophic level defines the position of energy in the food web.
3. The biomass or standing crop is the amount of material at a place at one moment of time. The productivity is the amount of material produced over a specified time interval, hence it is a rate. The turnover time is the time required to replace the biomass completely given the maximum productivity.
4. Trophic levels can be described in terms of a pyramid of numbers, biomass, or productivity, the last being most useful.
5. Primary producers are the plants. By trapping the sun's energy they produce carbohydrates. This is Gross Productivity (Pg). Plants use some energy in respiration (R) and the remaining energy is called net productivity (Pn) which is used in growth and reproduction.
6. Plants can use only a small fraction of the energy that falls on the earth's surface. Only the red wavelengths (0.4-0.7 microns) can be used by plants. Only about 1-2% of total light energy is realized as net productivity. The rest either cannot be used or is lost as heat energy.
7. Measurement of Pn: a) It can be measured through changes in CO\(_2\) (=Pg) and O\(_2\) (=R) in sealed containers in the laboratory. b) It can be measured by harvesting plants at two different times and calculating the growth in the interval, after accounting for plant decomposition and feeding by herbivores. This is a field method.
8. Pn in different areas of the world:

<table>
<thead>
<tr>
<th>Biome</th>
<th>Pn (g/m(^2)/yr)</th>
<th>Biomass (g/m(^2))</th>
<th>% green parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctic tundra</td>
<td>140</td>
<td>500</td>
<td>15</td>
</tr>
<tr>
<td>Northern conifer</td>
<td>800</td>
<td>20,000</td>
<td>8</td>
</tr>
<tr>
<td>Temperate beech wood</td>
<td>1300</td>
<td>30,000</td>
<td>1</td>
</tr>
<tr>
<td>Semi-desert</td>
<td>90</td>
<td>700</td>
<td>3</td>
</tr>
<tr>
<td>Savannah</td>
<td>900</td>
<td>4,000</td>
<td>12</td>
</tr>
<tr>
<td>Tropical forest</td>
<td>3500</td>
<td>45,000</td>
<td>8</td>
</tr>
<tr>
<td>Open ocean</td>
<td>125</td>
<td>3</td>
<td>--</td>
</tr>
<tr>
<td>Continental shelf</td>
<td>360</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>Agricultural land</td>
<td>650</td>
<td>1000</td>
<td>--</td>
</tr>
</tbody>
</table>

9. Pn and biomass is highest in forests. It is low in open oceans compared to continental shelf. Grasslands have the highest proportion of green material, the edible part.
10. Turnover times are high in forest, low in agricultural crops.
11. Factors affecting Pn are: light, CO\(_2\), water, nutrients, O\(_2\), temperature, predation, other causes of death.