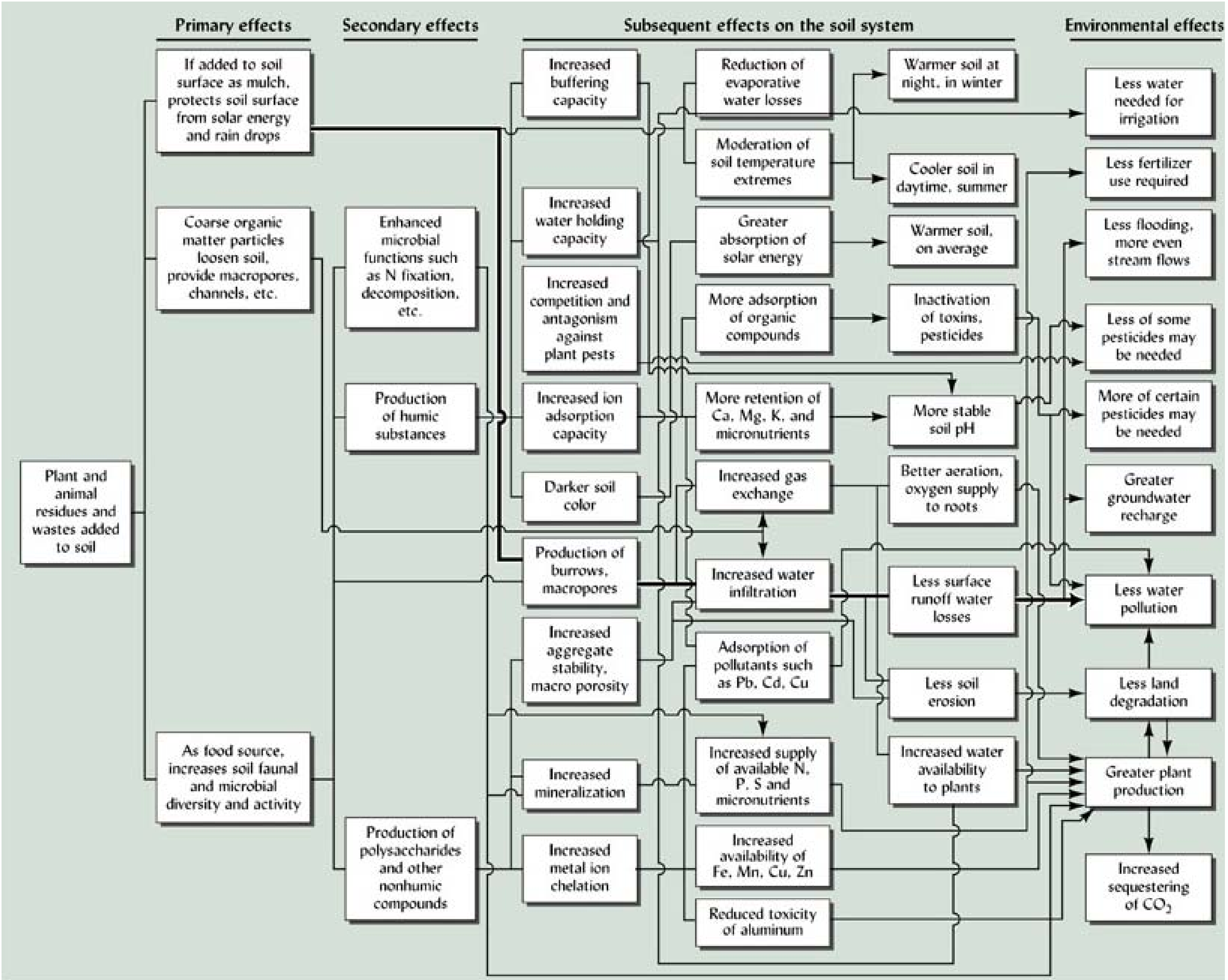
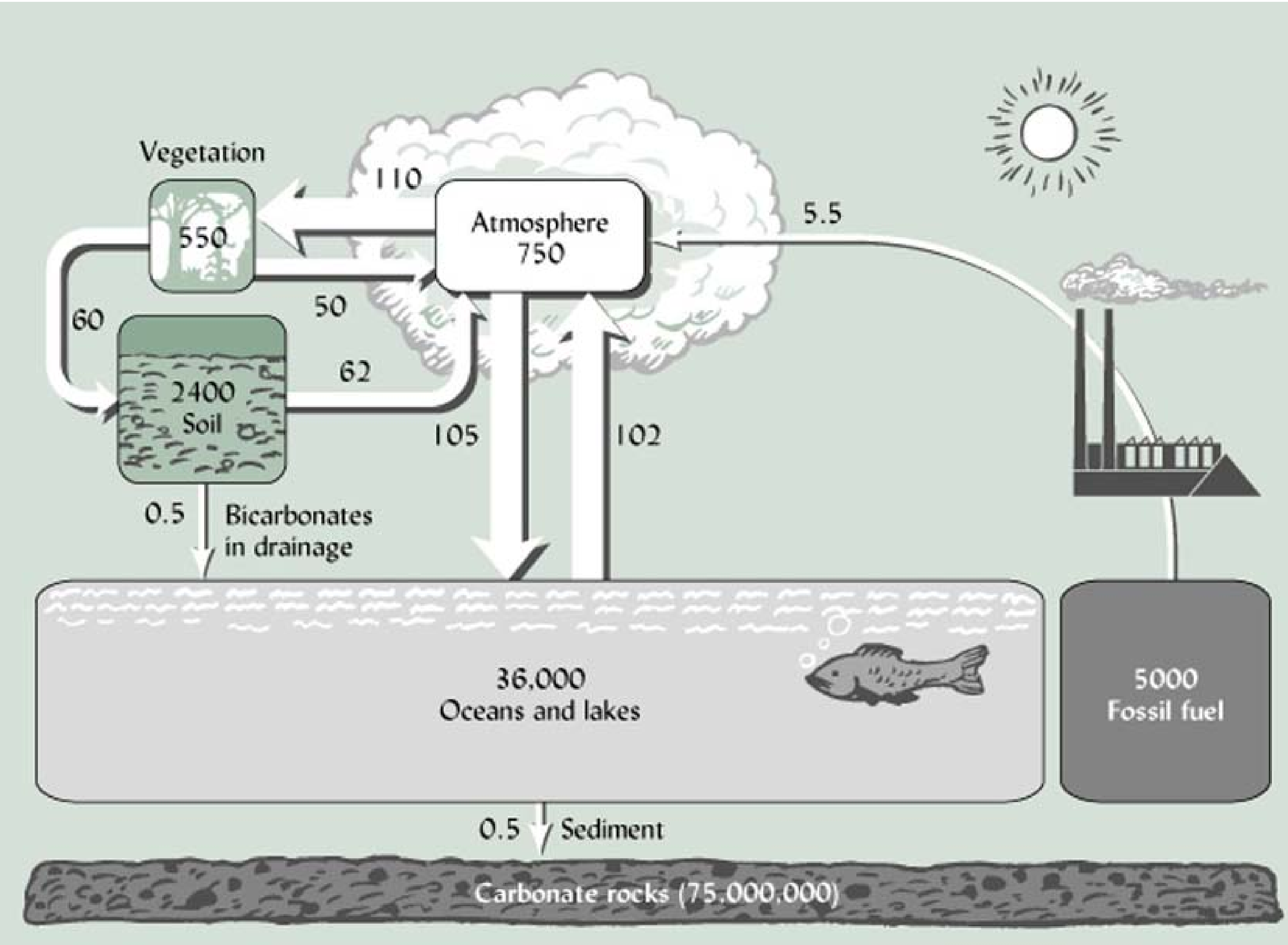
Soil Organic Matter

Figure 12.15



Global Carbon Cycle

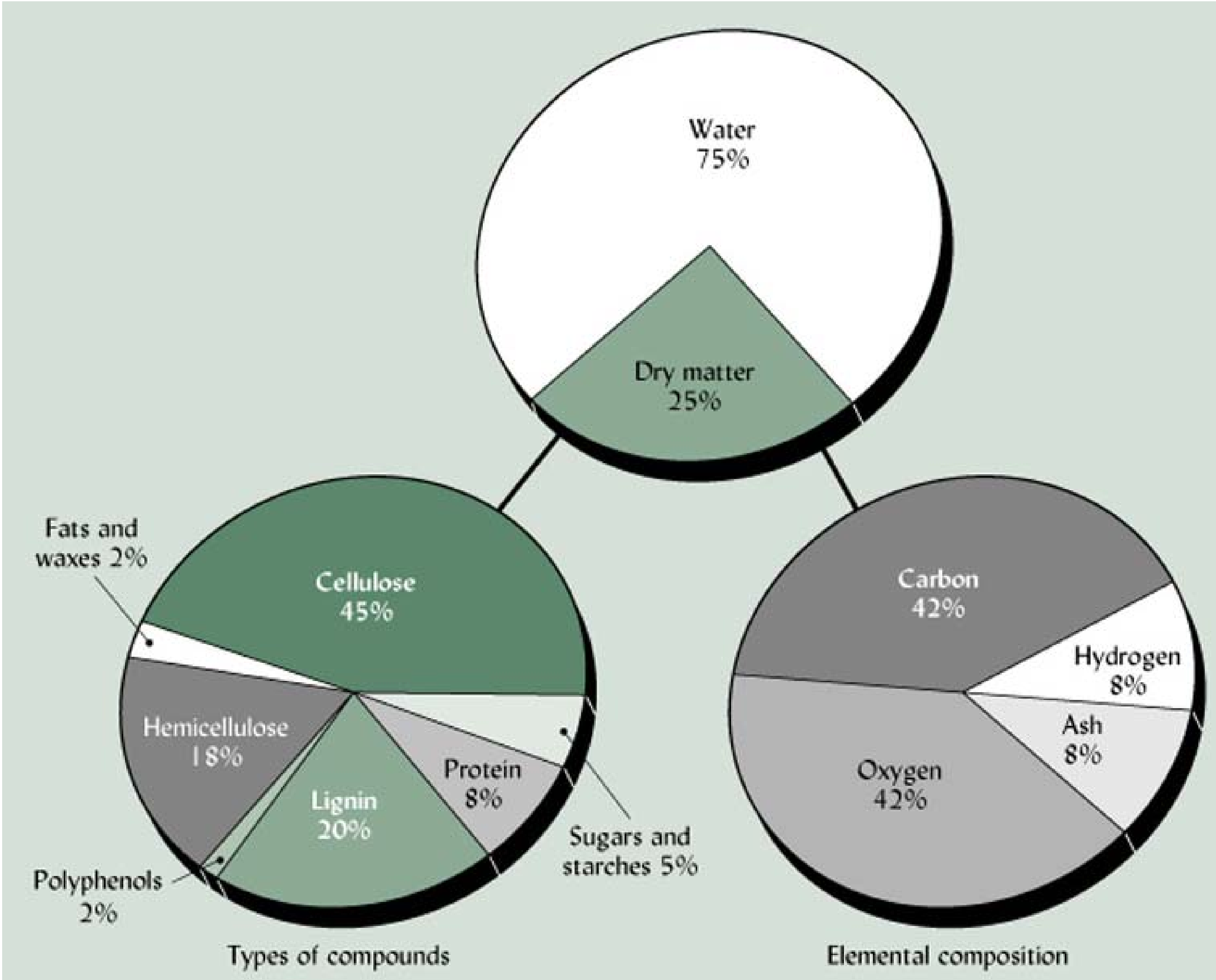


(1) More C is entering the atmosphere than is being absorbed by the oceans and (2) more C is leaving the soil than is entering

What is causing this and what might be the consequence of this?

Petagrams = Pg = 10^{15} g

Organic Matter – what is it?



Why is this important – this is the source of soil C

SOIL ORGANIC MATTER

Mineral soils generally have 2-5% organic matter (by weight).

Organic matter profoundly affects soil properties.

Elemental composition: mostly carbon (C)
lesser amounts of H,O,P,N,S

Main source of N & S for plants in unfertilized soils.

Forms of Organic Matter:

- living & dead plant material
- soil microorganisms
- humus -> derived from plant decay
  -> complex colloidal molecules
  -> no visible features of plant tissue

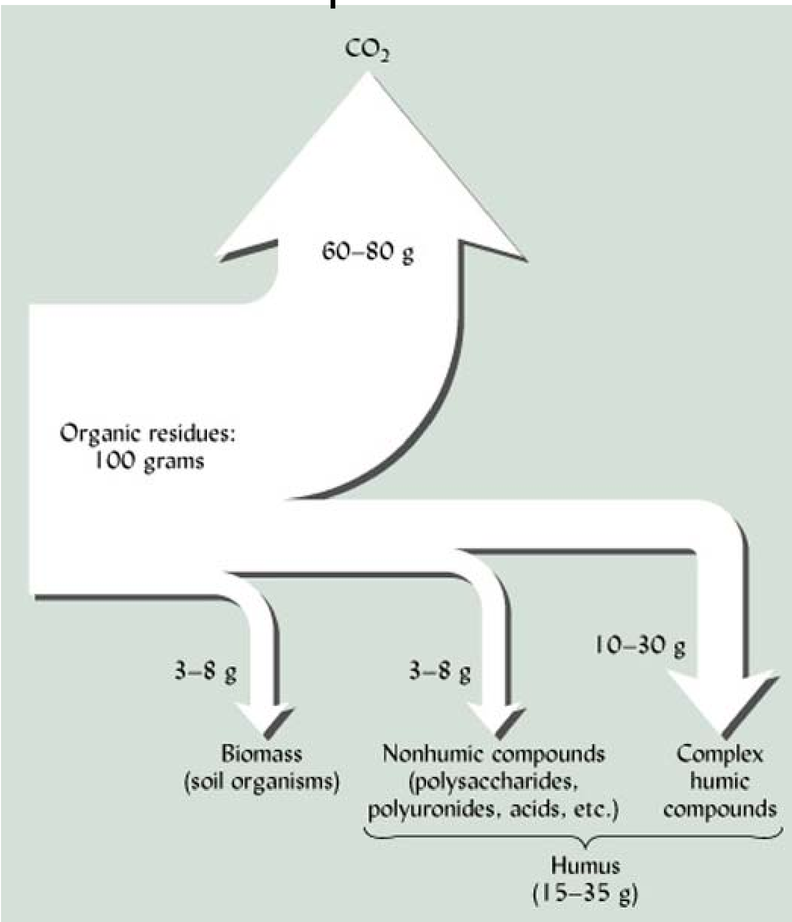
TABLE 12.1 Mass of Organic Carbon in the World's Soils

Values for the upper 1 m represent most of the carbon in the soil profile. The upper 15 cm generally represents the surface soil, which is most readily influenced by land use and soil management.

		Organic carbon[a] in upper 100 cm			Organic carbon[a] in upper 15 cm	
Soil order	*Global area, 10^3 km^2*	*Mg/ha*	*Global Pg[b]*	*% of global*	*Range,[c] %*	*Typical,[c] %*
Entisols	14,921	99	148	9	0.06–6.0	—[d]
Inceptisols[e]	21,580	163	352	22	0.06–6.0	—[d]
Histosols[e]	1,745	2,045	357	23	12–57	47
Andisols	2,552	306	78	5	1.2–10	6
Vertisols	3,287	58	19	1	0.5–1.8	0.9
Aridisols	31,743	35	110	7	0.1–1.0	0.6
Mollisols	5,480	131	73	5	0.9–4.0	2.4
Spodosols	4,878	146	71	5	1.5–5.0	2.0
Alfisols	18,283	69	127	8	0.5–3.8	1.4
Ultisols	11,330	93	105	7	0.9–3.3	1.4
Oxisols	11,772	101	119	8	0.9–3.0	2.0
Misc. land	7,644	24	18	1	—	—
Total	135,215		1576	100		

[a] Organic matter may be roughly estimated as 1.7 to 2.0 times this value. The value traditionally used is 1.72. Organic nitrogen may also be estimated from organic carbon values by dividing by 12 for most soils, but see Section 12.3.
[b] Petagram = 10^{15} g.
[c] Percent on mass basis (i.e., g/100 g).
[d] These soils are too variable to suggest a typical value.
[e] Carbon stored in Gelisols is included with these soils.
Data calculated from Eswaran, et al. (1993) and Brady (1990).

We generally perceive OM decomposition as…



$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

1. **CONSUMES OXYGEN (O_2)**
2. **PRODUCES CARBON DIOXIDE (CO_2)**

and while the basic building blocks of all organic carbon structures are the same (C, H & O)

(1) not all organic carbon structures are the same

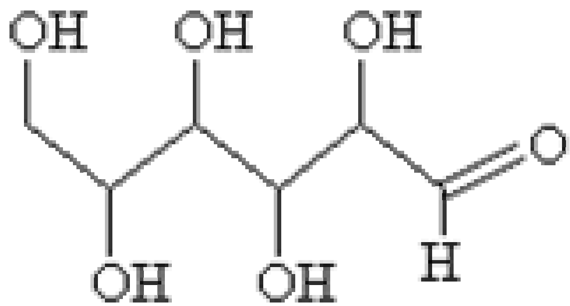
and

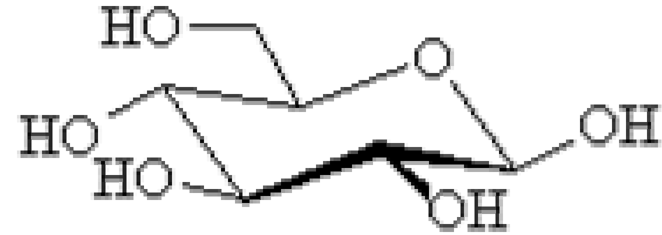
(2) not all are easy to break down

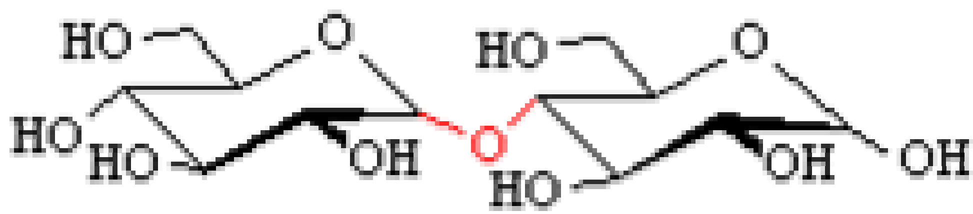
Terminology watch ~

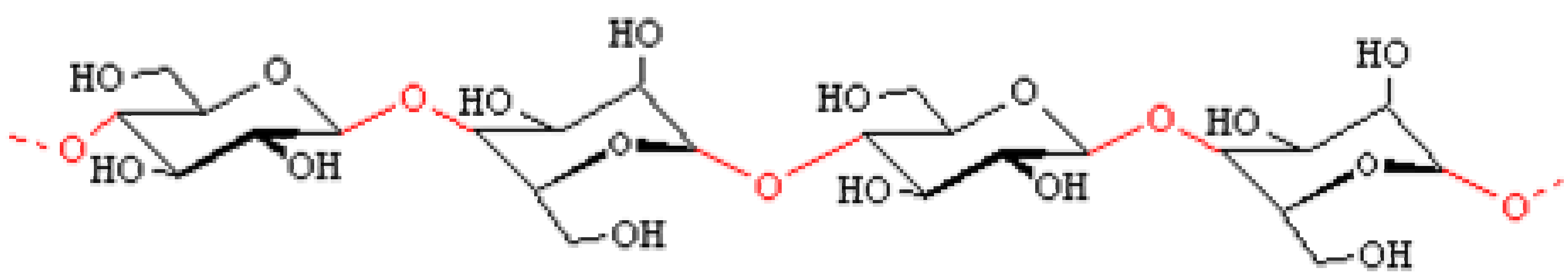
Mineralization = the conversion of an element from an organic state (biomass, etc.) to an inorganic state

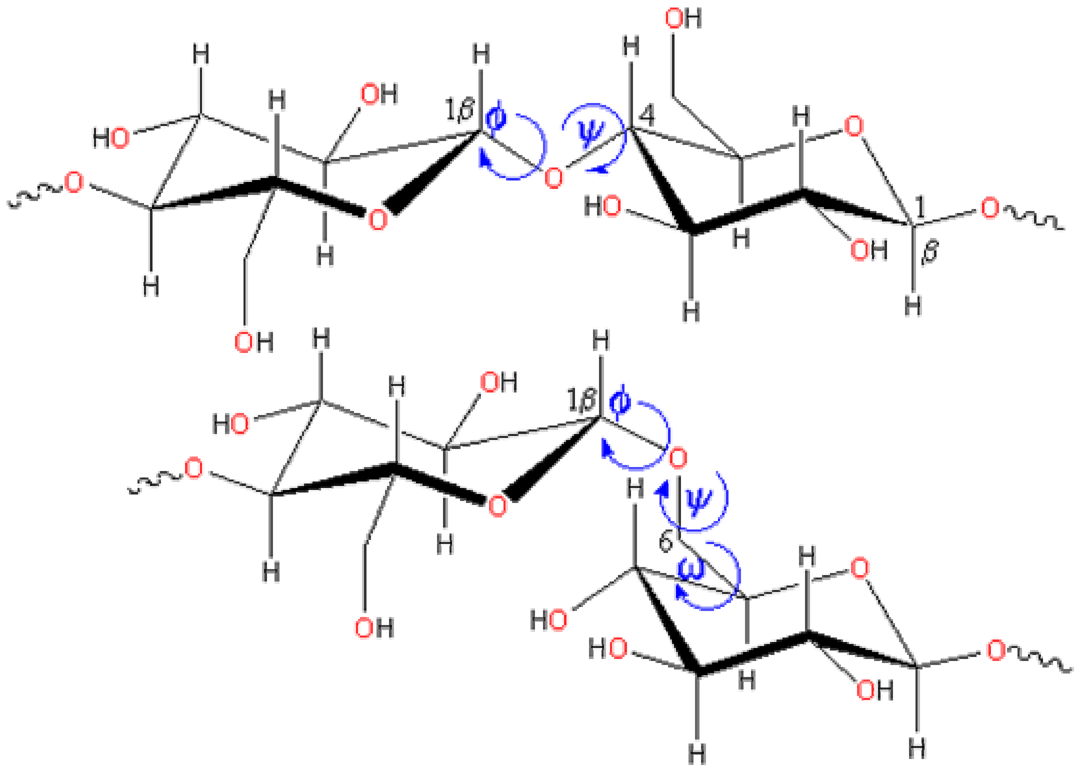
Immobilization = the conversion of an element from an inorganic state to an organic state (biomass)

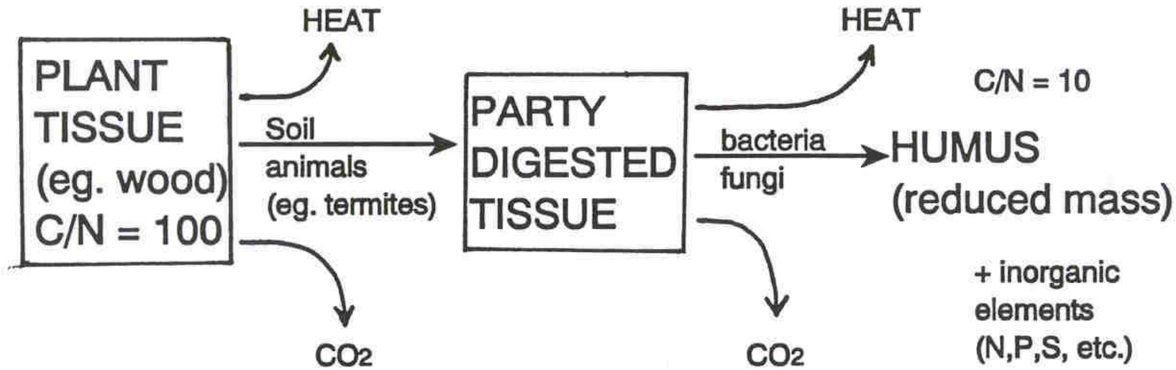












Respiration (aerobic):

$$\text{Carbohydrate} + O_2 \longrightarrow CO_2 + H_2O + \text{energy}$$

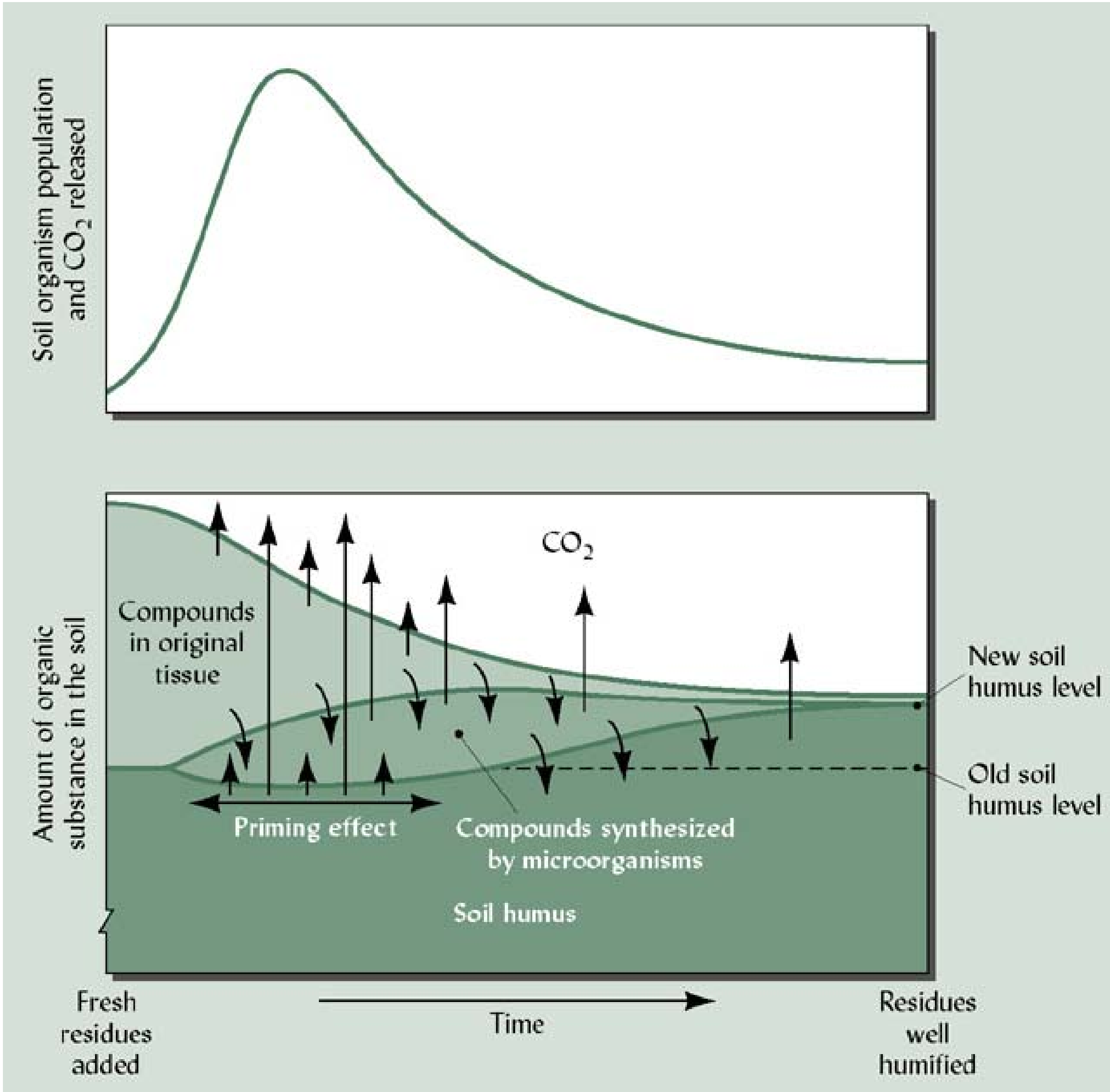
Fermentation (anaerobic):

$$\text{Carbohydrate} \longrightarrow CO_2 + \text{acid or alcohol} + \text{energy}$$

Rate of CO_2 release = measure of microbial activity

Effects of Respiration on Soil:

1. Raises CO_2 in soil air by 10-1000x
2. Lowers soil pH (carbonic acid)
3. Lowers O_2 level; potential for anoxia



Soil organism population and CO_2 released
CO_2
Compounds in original tissue
New soil humus level
Old soil humus level
Priming effect
Compounds synthesized by microorganisms
Soil humus
Amount of organic substance in the soil
Fresh residues added
Time
Residues well humified

Recognizable compounds-

Polysaccharides (Glucose, Starch, Protein, Cellulose & Hemicellulose)

rate of decomposition: rapid → very slow

Glucose - simple sugar

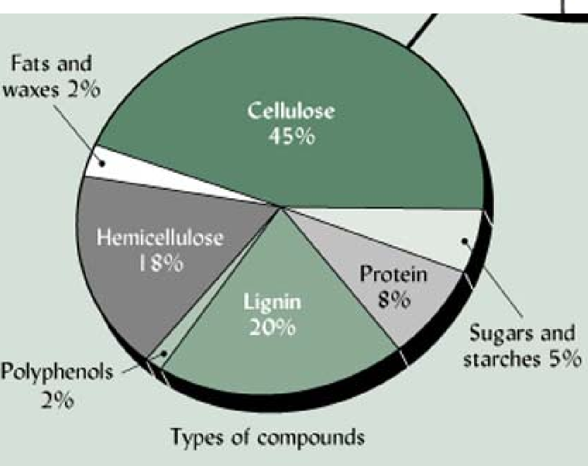
Starch - building block for cellulose

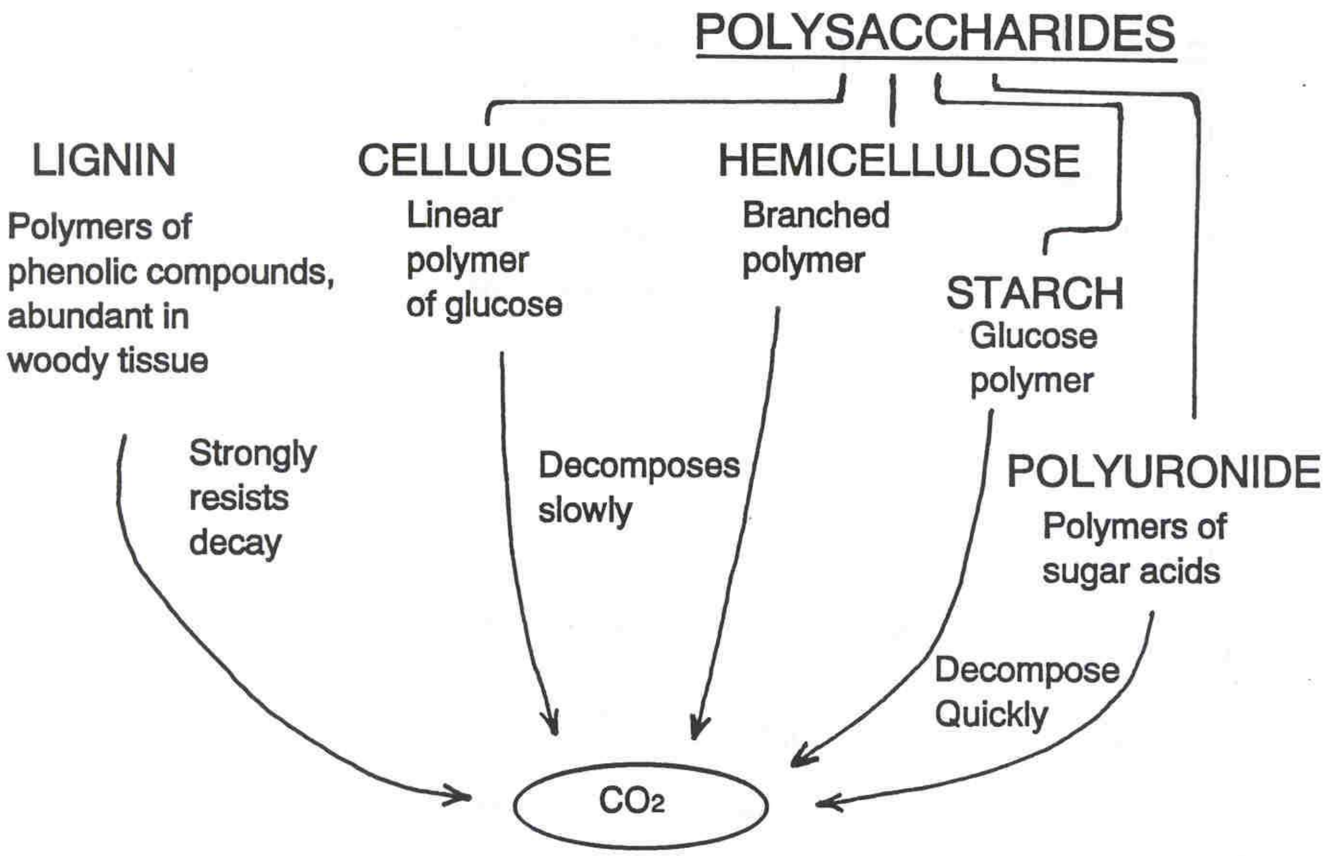
Protein - water soluble and crude protein

Cellulose & Hemicellulose -
- most abundant constituent of plant tissue
- source of food for soil microbes

Fats, waxes, and tannins-

Lignin - major constituent of plant tissue
- polymers (very large molecules) help to aggregate mineral grains
- slowly decompose, part of humus





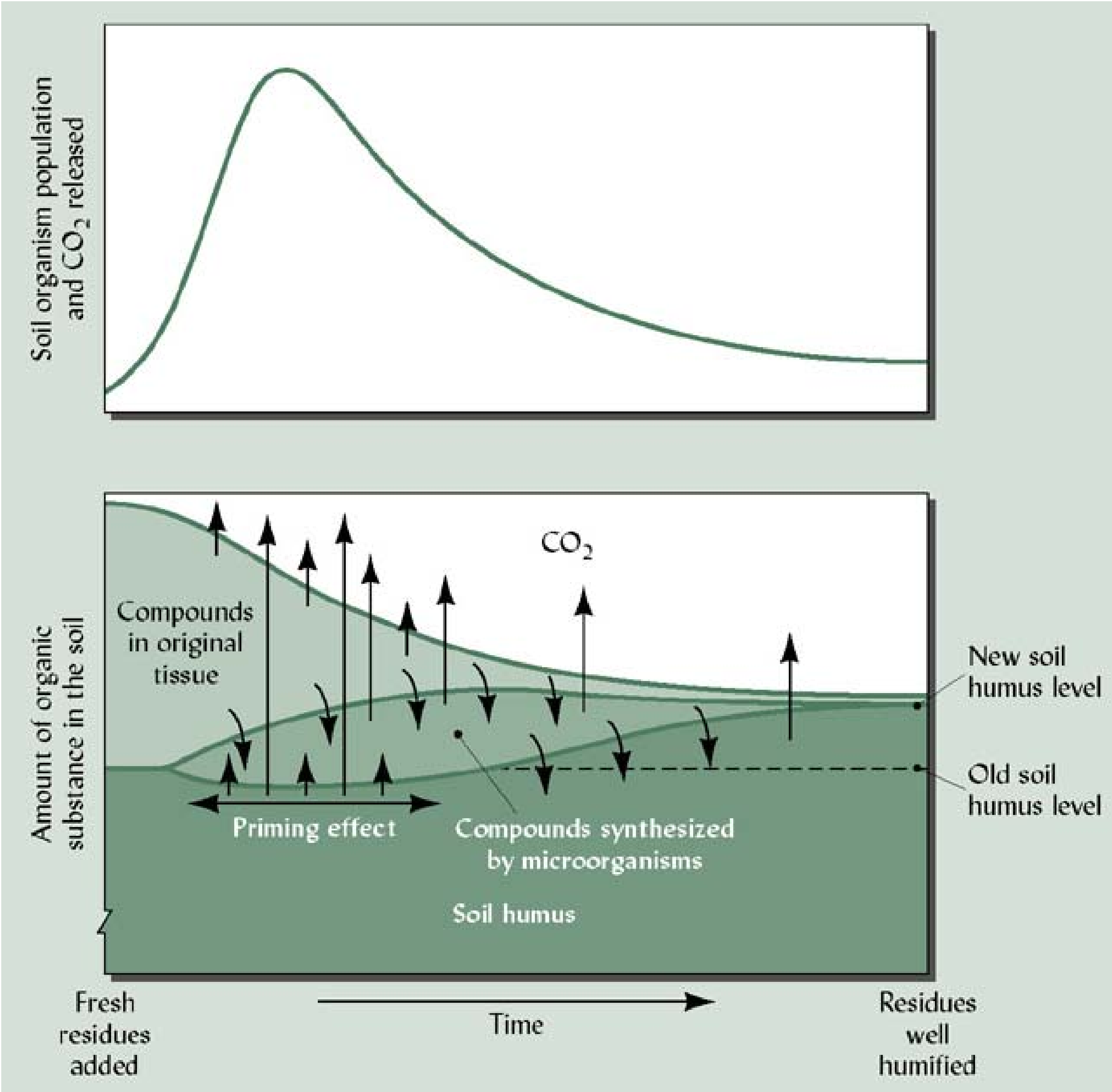
Result: Lignin-like compounds accumulate in humus because lignin is preserved.

Resistance of Lignin to decay because:

1. Microbes cannot absorb the polymer, must release EXTRACELLULAR ENZYMES (only specialized FUNGI & BACTERIA)

2. Woody tissue (lignin) is very low in nitrogen, inhibits biological activity.

3. Low exposed surface area.


Soil organism population and CO_2 released
Amount of organic substance in the soil
CO_2
Compounds in original tissue
New soil humus level
Old soil humus level
Priming effect
Compounds synthesized by microorganisms
Soil humus
Fresh residues added
Time
Residues well humified

Factors controlling the rate of OM decay

1 Placement

2 Size and Surface Area

3 C:N Ratio

4 Litter Quality

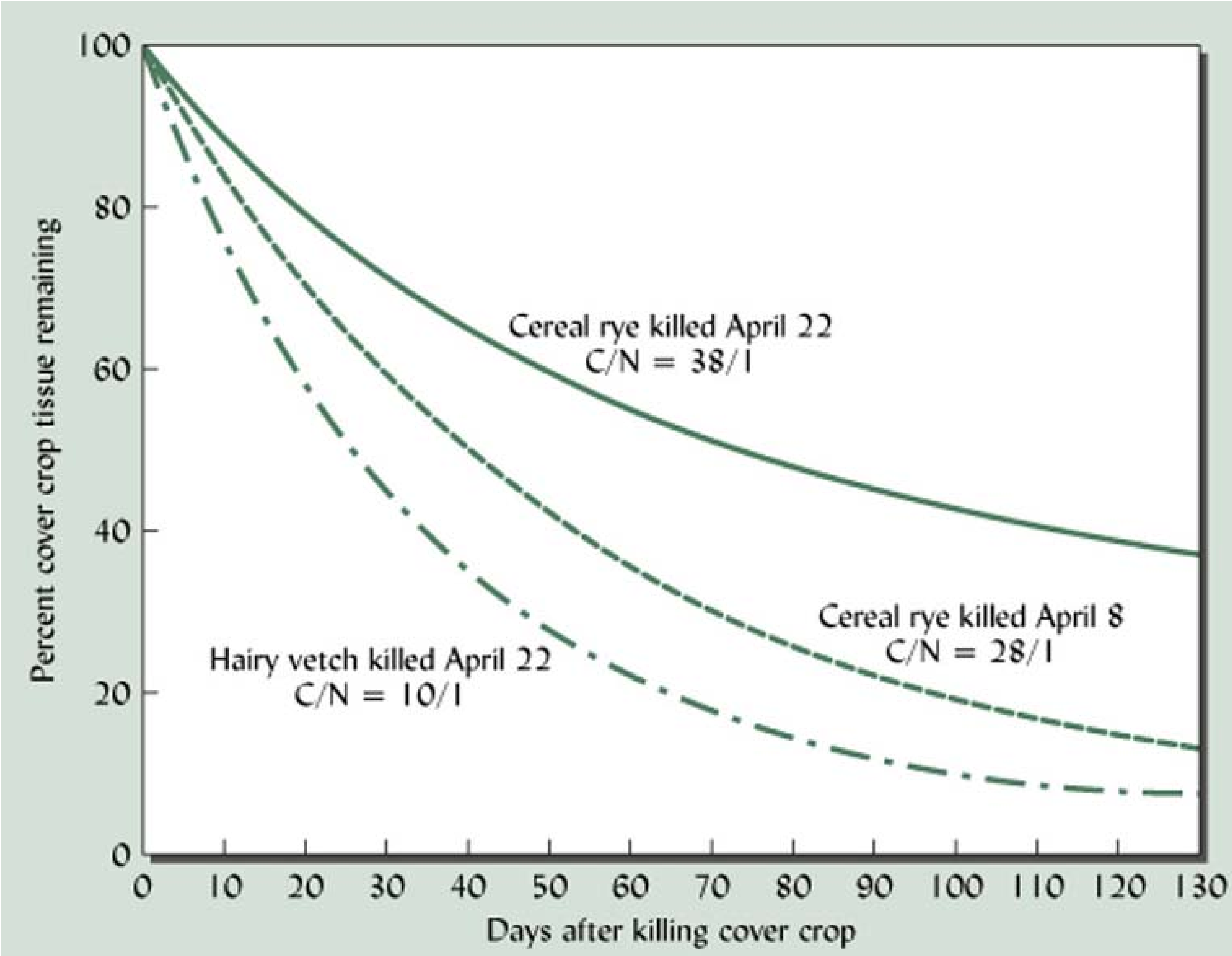
1. Placement
   – surface placement vs. incorporation into the soil

heating and cooling as well as wetting and drying
vs.
constant climatic conditions and intimate contact with soil organisms

2. Size and Surface Area
   – smaller vs. larger particles

Surface area increases with smaller particles, therefore more contact areas for organism doing the decomposition

3. C:N Ratio
   – intense competition for N & as such the ratio determines the rate of decay

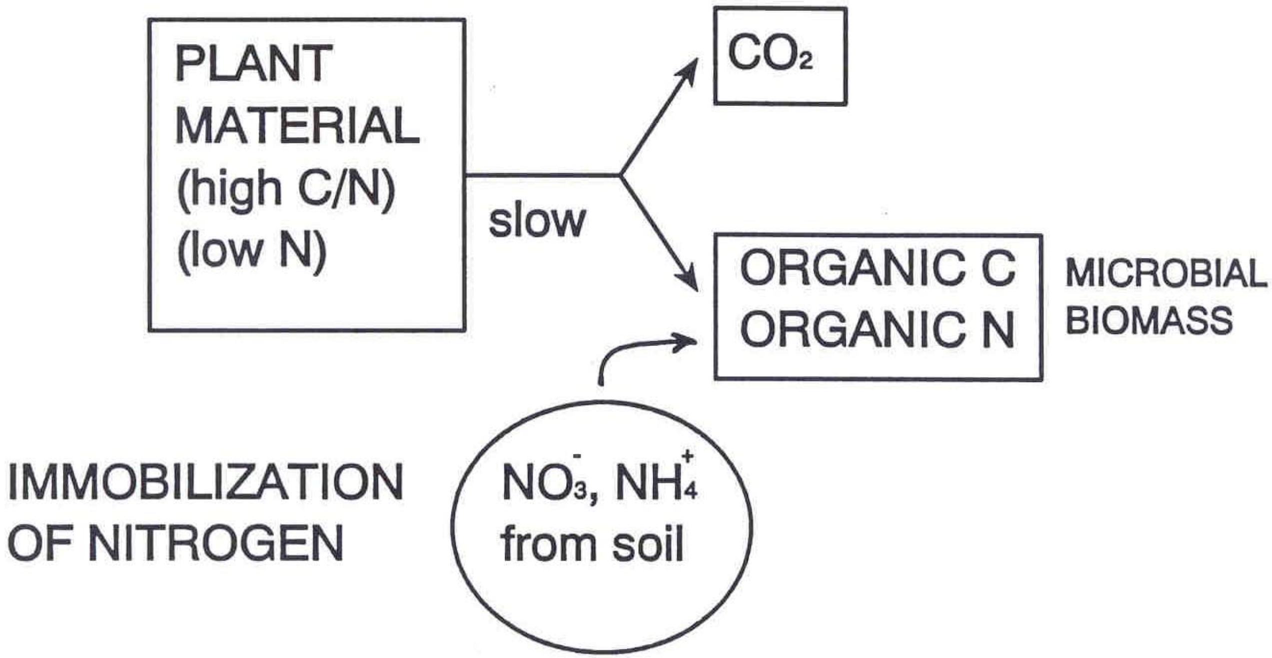

Cereal rye killed April 22
C/N = 38/1
Cereal rye killed April 8
C/N = 28/1
Hairy vetch killed April 22
C/N = 10/1
Percent cover crop tissue remaining
Days after killing cover crop
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90
100
110
120
130

Typical C/N Ratios	C/N
Tree leaves	45-70
Tree roots	60-90
Wood (oak)	130-400
Clover leaves	8-16
Grass shoots (young)	12-15
Bacteria	5-14

Look at Table 12.2 for a more complete listing!

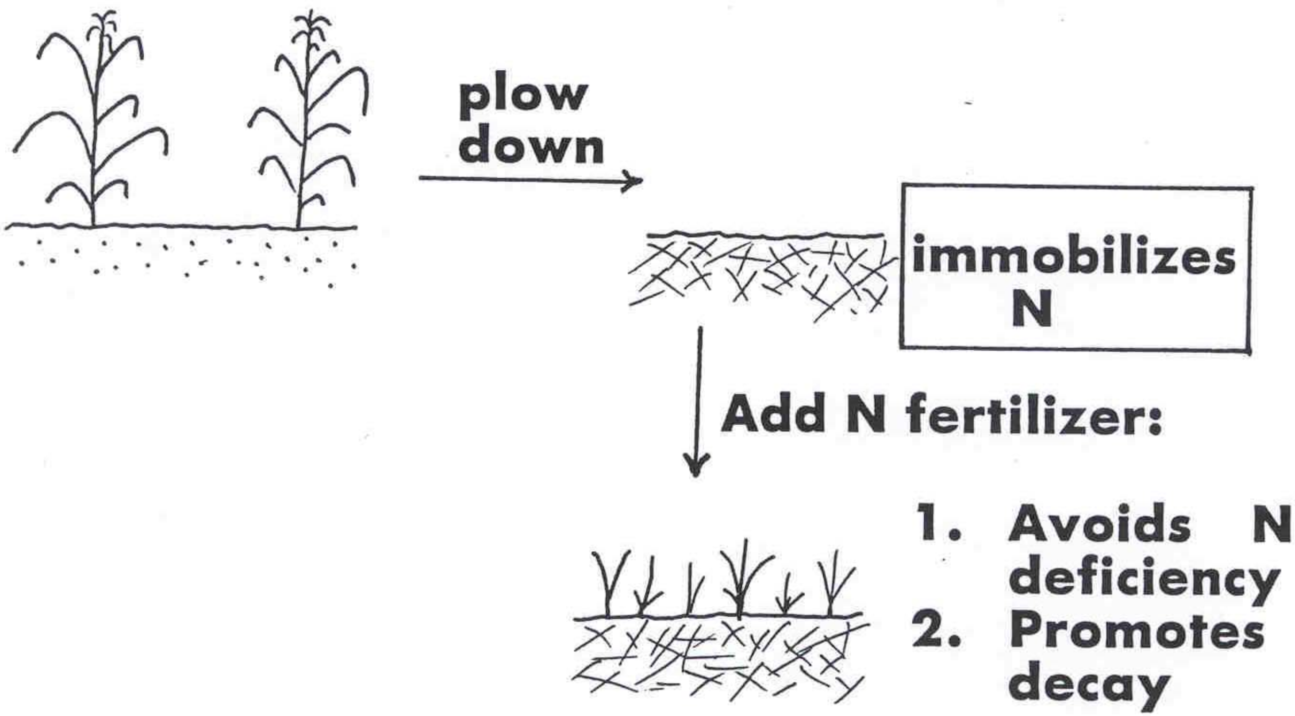
Nutrient Release and Immobilization

C/N > 20 (% N < 2.5) → N immobilized



Example:

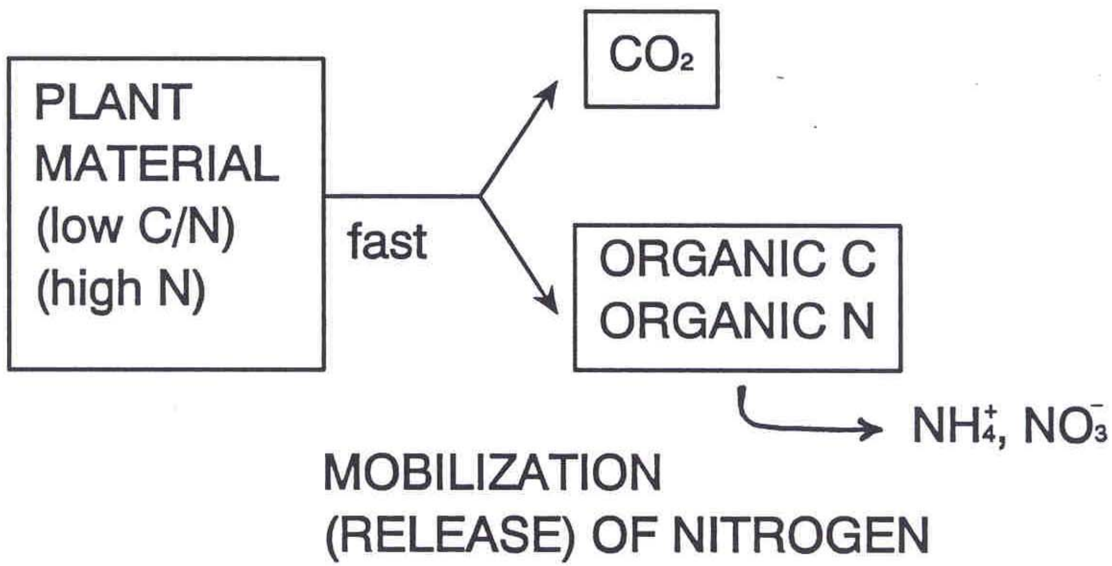
Corn Stover (high C/N ratio):



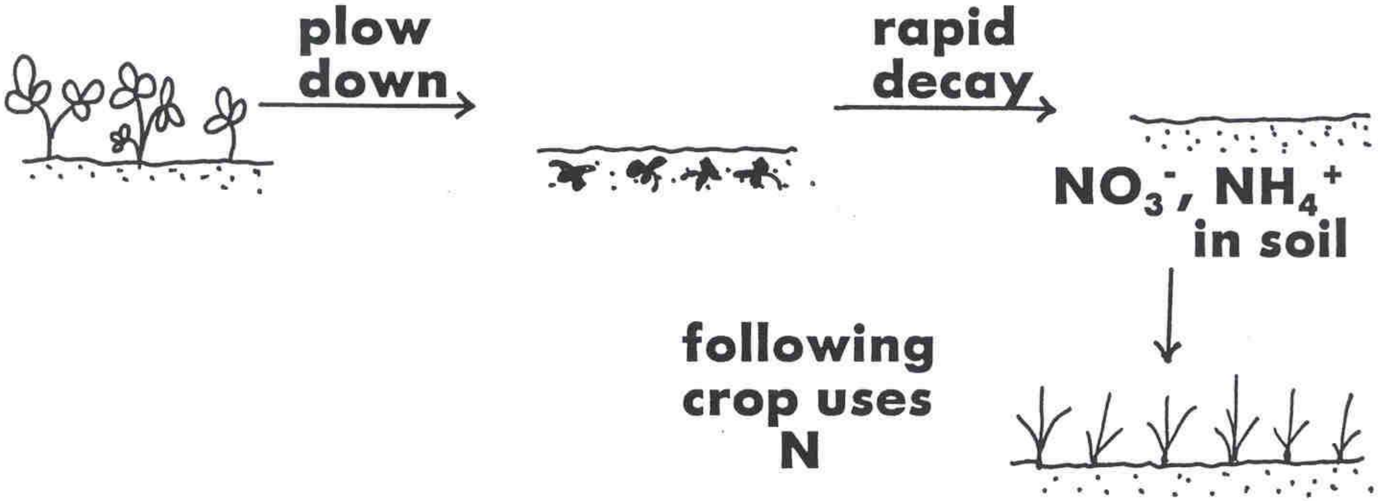
Materials inducing N deficiency:
Sawdust, wood chips, straw (not peat moss because of its slow decay)

Nutrient Release and Immobilization

C/N < 20 (% N > 2.5) $\rightarrow$ N release

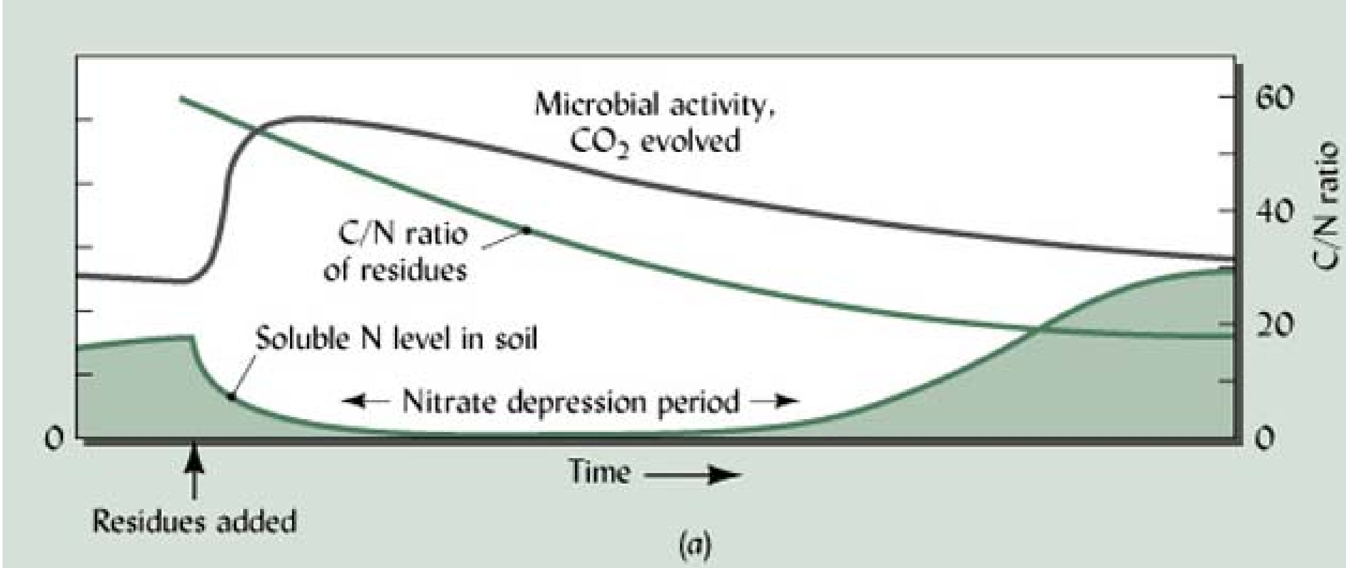


Example: Clover (low C/N ratio)

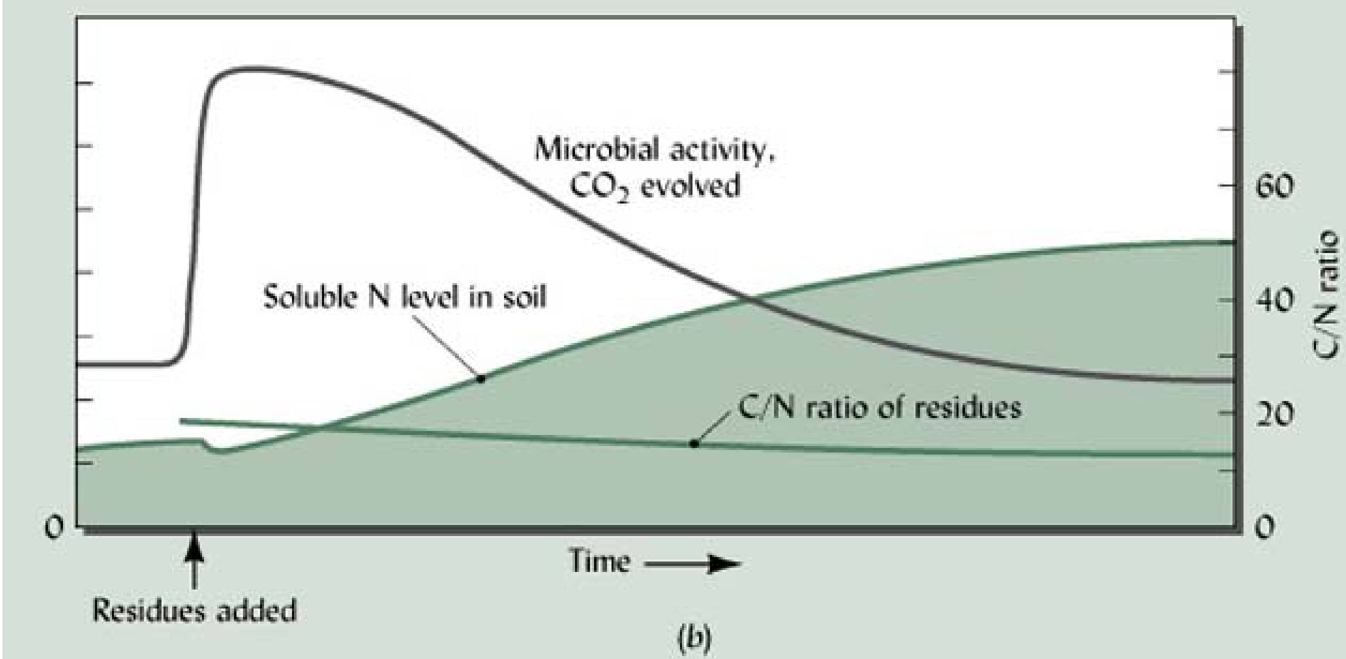


Materials inducing N release: legumes
(green manures)

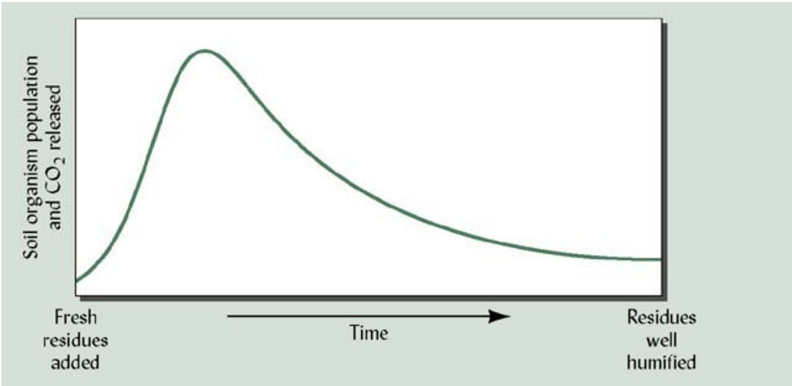
C:N ↑


Microbial activity, CO_2 evolved
C/N ratio of residues
Soluble N level in soil
← Nitrate depression period →
0
60
40
20
0
C/N ratio
Time →
Residues added
(a)

C:N ↓


Microbial activity, CO_2 evolved
Soluble N level in soil
C/N ratio of residues
0
60
40
20
0
C/N ratio
Time →
Residues added
(b)

Addendum: Influence on Soil Ecology



Something preys on the large decomposer population