Soil Architecture – Texture and Structure

Ecological Agriculture Program 1-12-06
TESC
Steve Scheuerell

Plant growth is directly limited by multiple soil physical properties. These properties further Interact with chemical and soil biotic factors.

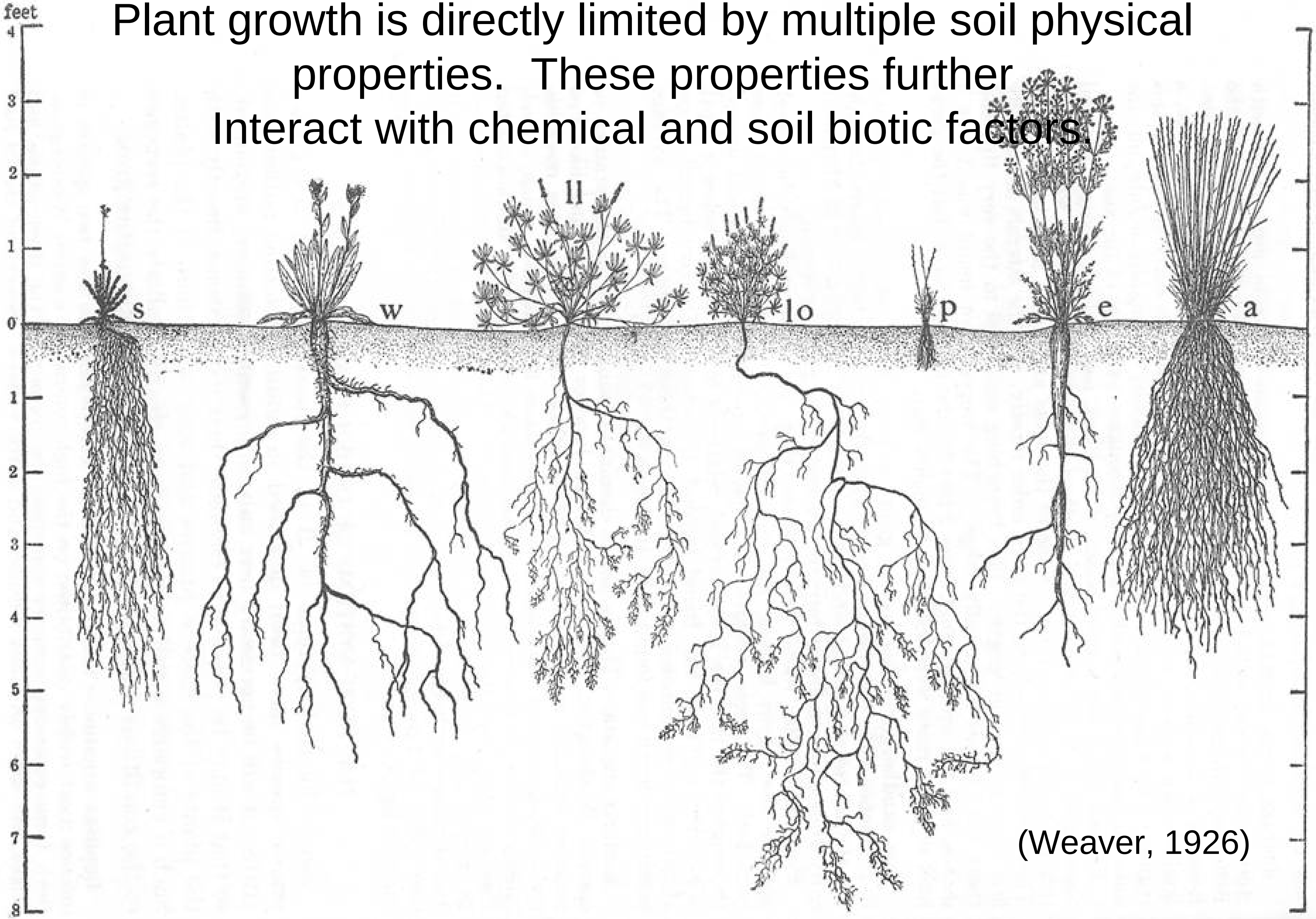

FIG. 7.—Schematic bisect: *s*, *Sieversia ciliata*; *w*, *Wyethia amplexicaulis*; *ll*, *Lupinus leucophyllus*; *lo*, *Lupinus ornatus*; *p*, *Poa sandbergii*; *e*, *Leptotænia multifida*; *a*, *Agropyrum spicatum*.

Soil Physical Properties

- Soil Color
- Soil Texture
- Soil Structure

- Not covering heat transfer
- Hydrology will be covered later
- Soil as an engineering medium – opposite goals than for growing plants in the soil

Soil physical properties

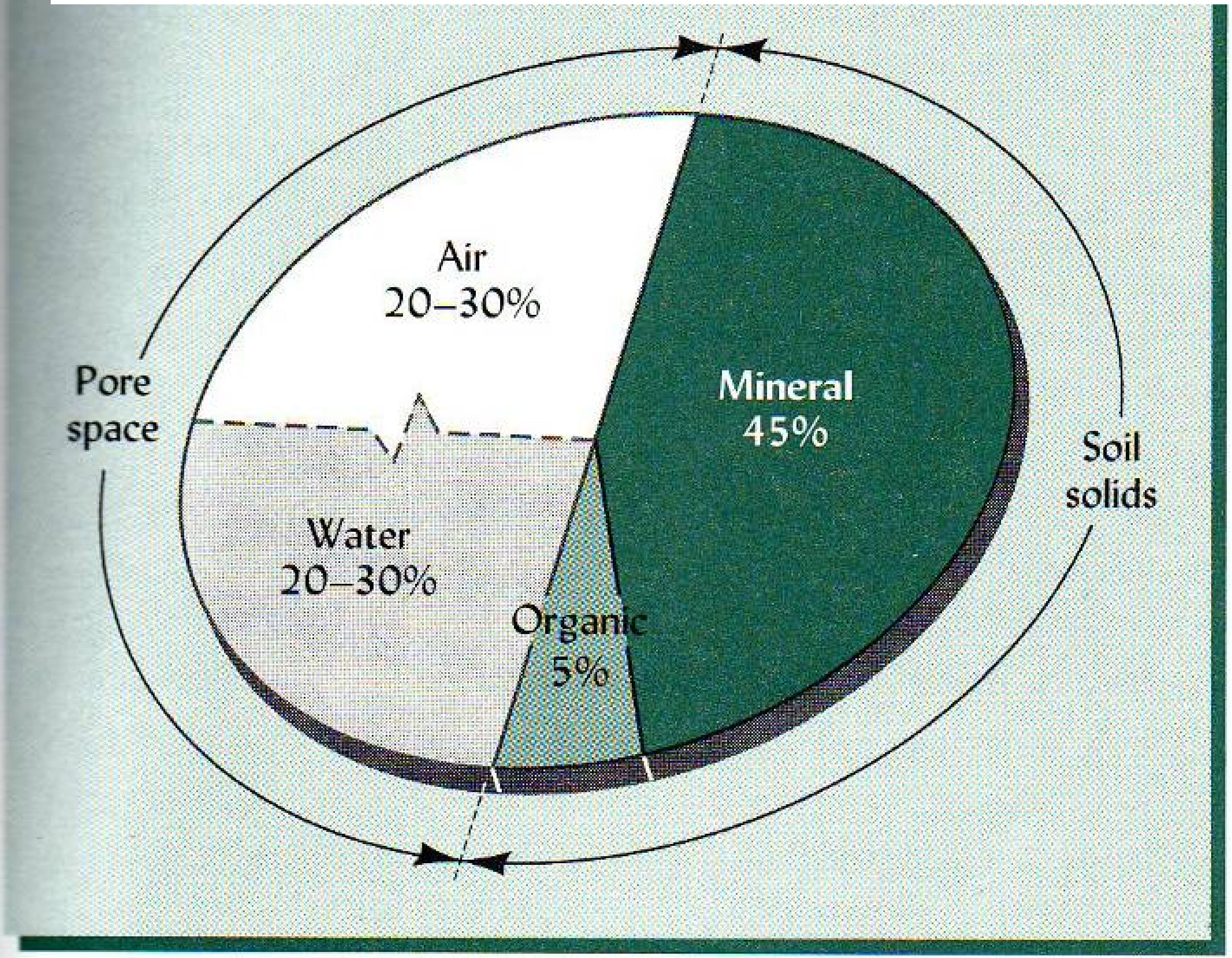

FIGURE 1.17
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Nonetheless, a
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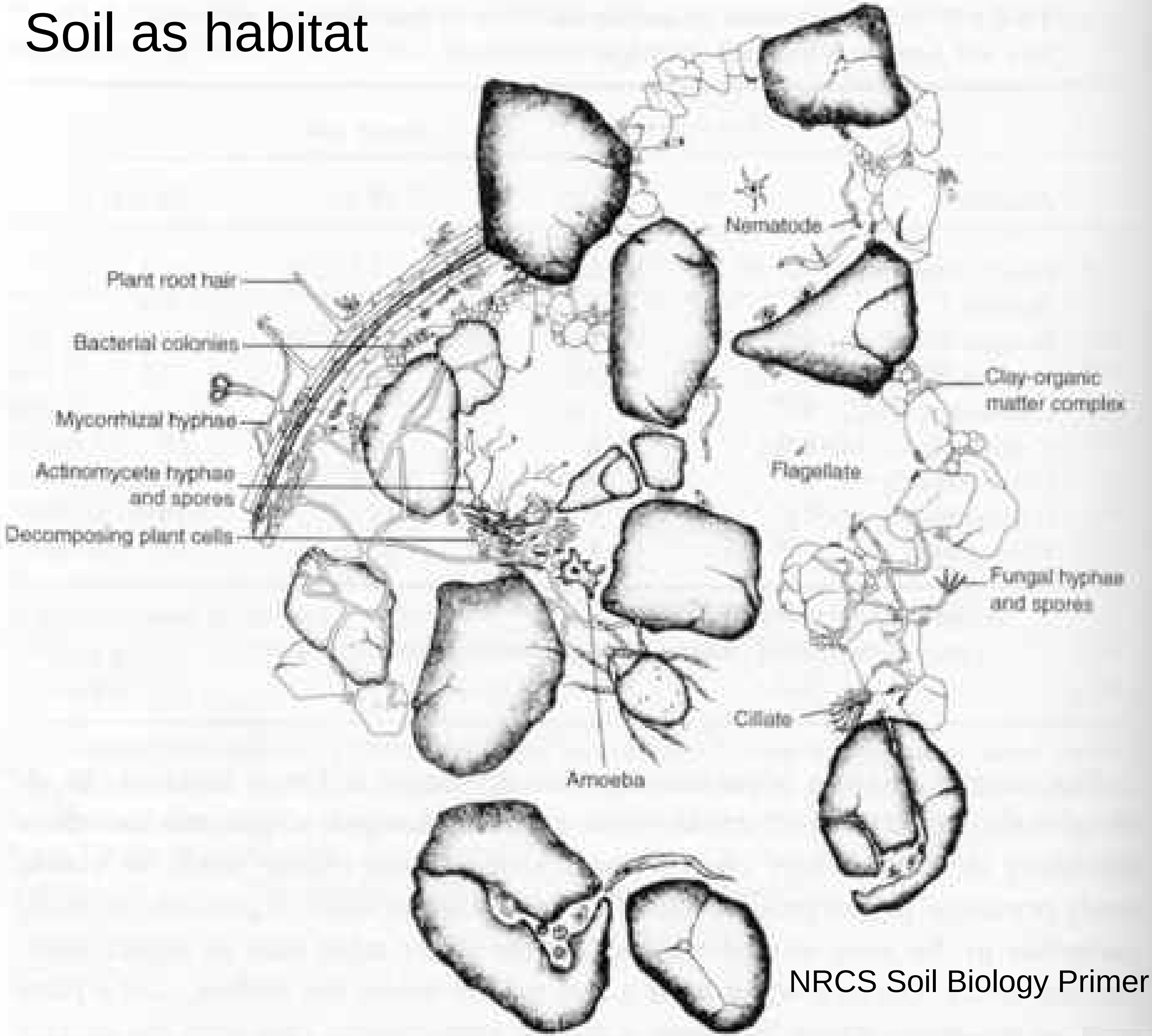
Percent by Volume

Soil as habitat



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Soil color is an indicator of Oxidation – Reduction (Redox) conditions

PLATE 29 Oxidized (red) root zones in the A and E horizons indicate a hydric soil. They result from oxygen diffusion out from roots of wetland plants having aerenchyma tissues (air passages).

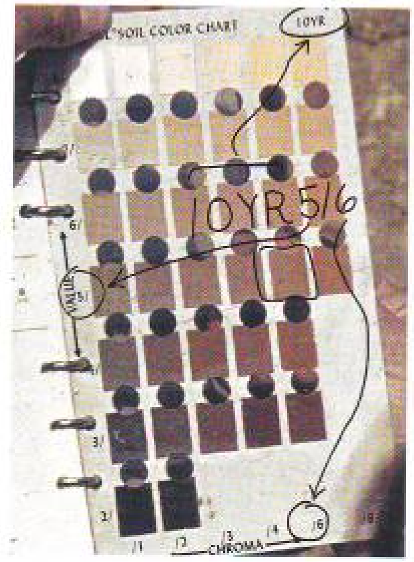

PLATE 22 The 10YR hue page of a Munsell color book. The standard notation is handwritten for the color with hue 10YR, value 5, and chroma 6.

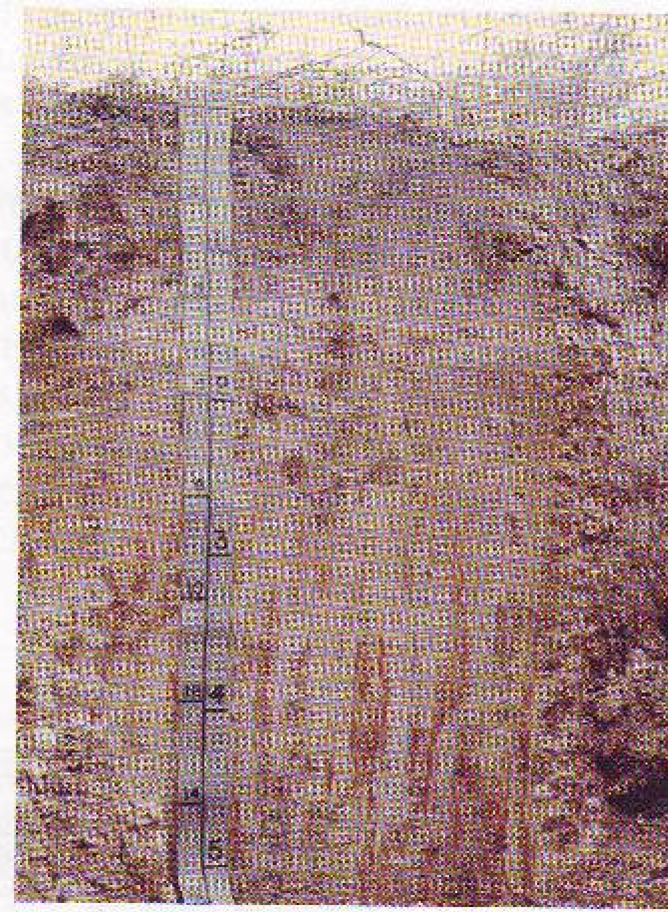

PLATE 21 Effect of poor drainage on soil color. Gray colors and red redox concentrations in the B horizons of a Plinthaquic Paleudalf.

Soil Texture – size distribution of mineral particles in the soil

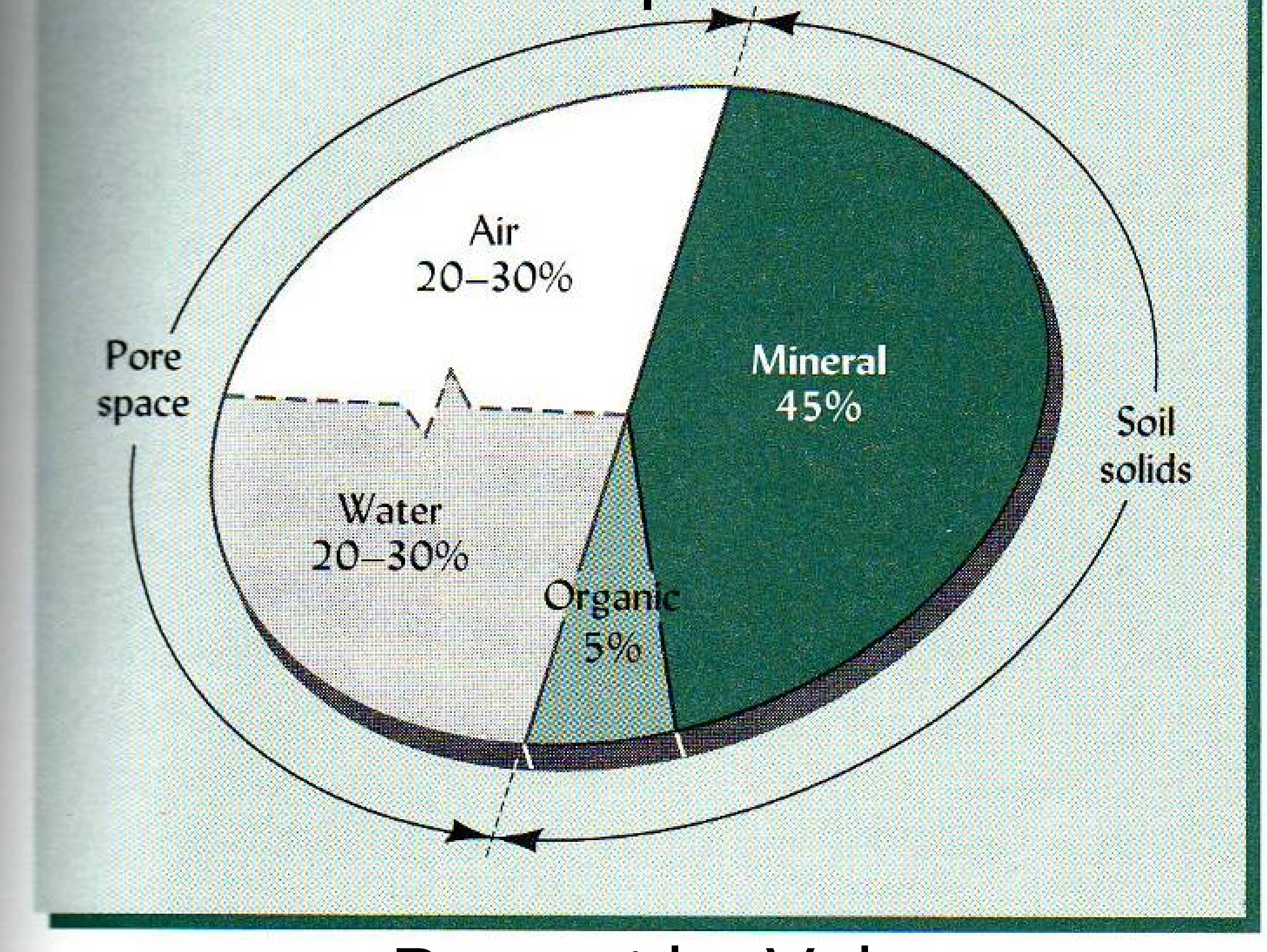

FIGURE 1.17
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between water
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Percent by Volume

Soil Texture
“You play the hand you are dealt”

- Managing field soil doesn’t modify texture

- In contrast, manufactured soils and potting mix are designed and texture can be chosen
  - Landscape architecture projects spec soil
  - Plant propagation e.g. rooting in sand
  - Potting mix
  - Green roofs

Soil Texture – proportion of sand, silt, and clay

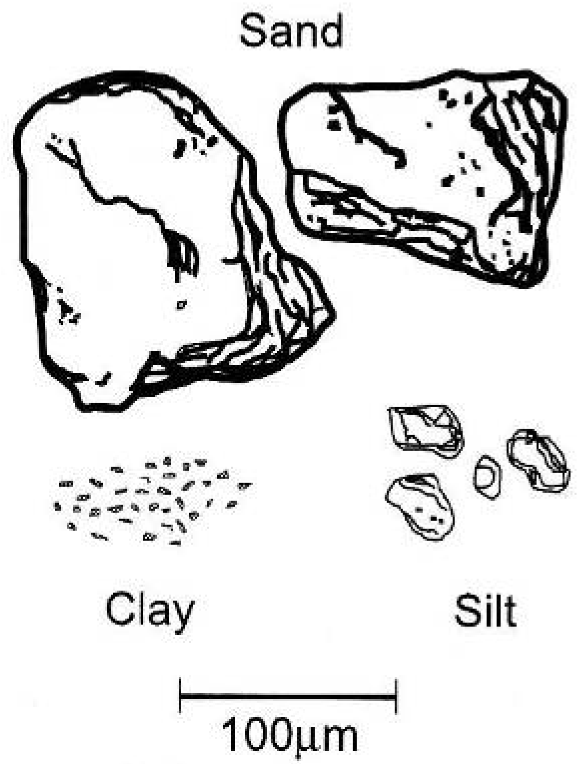


Fig. 3.2. A visual representation of the comparative sizes of sand, silt, and clay particles.

Environmental Soil Physics. 1998. Daniel Hiller

Soil particle classification systems – particle size

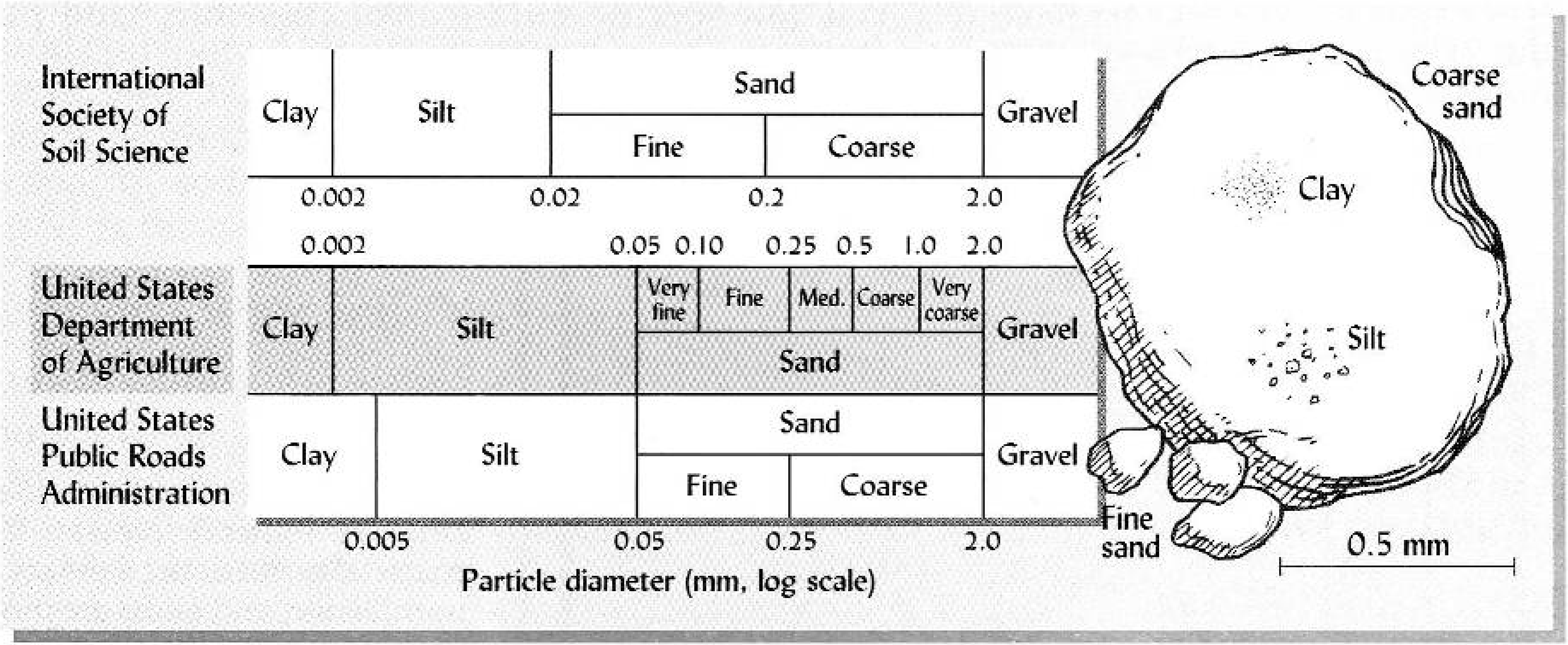


FIGURE 4.1 Classification of soil particles according to their size. The shaded scale in the center and the names on the drawings of particles follow the United States Department of Agriculture system, which is widely used throughout the world. The USDA system is also used in this book. The other two systems shown are also widely used by soil scientists and by highway construction engineers. The drawing illustrates the size of soil separates (note scale).

Particle-size distribution across soil textures

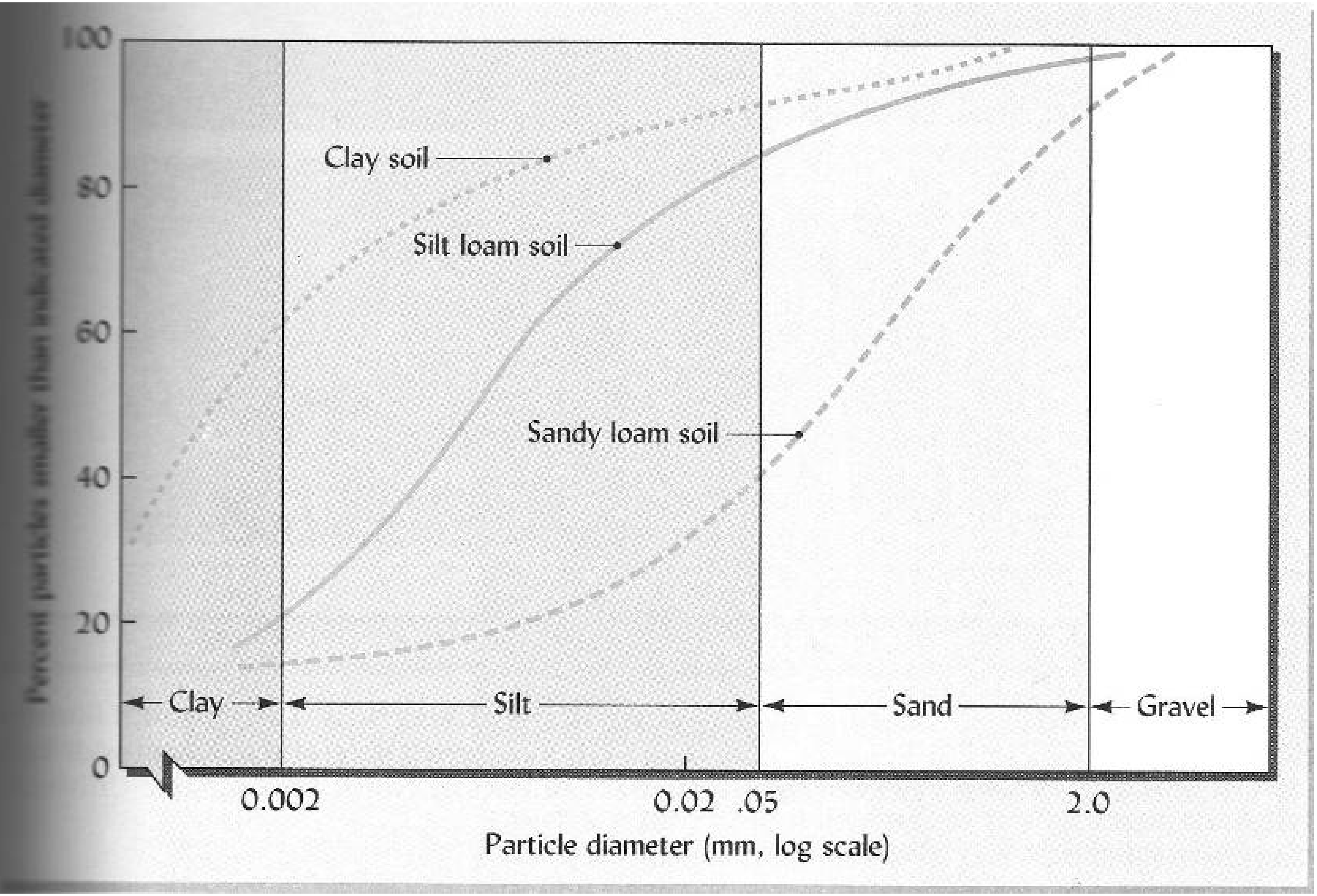
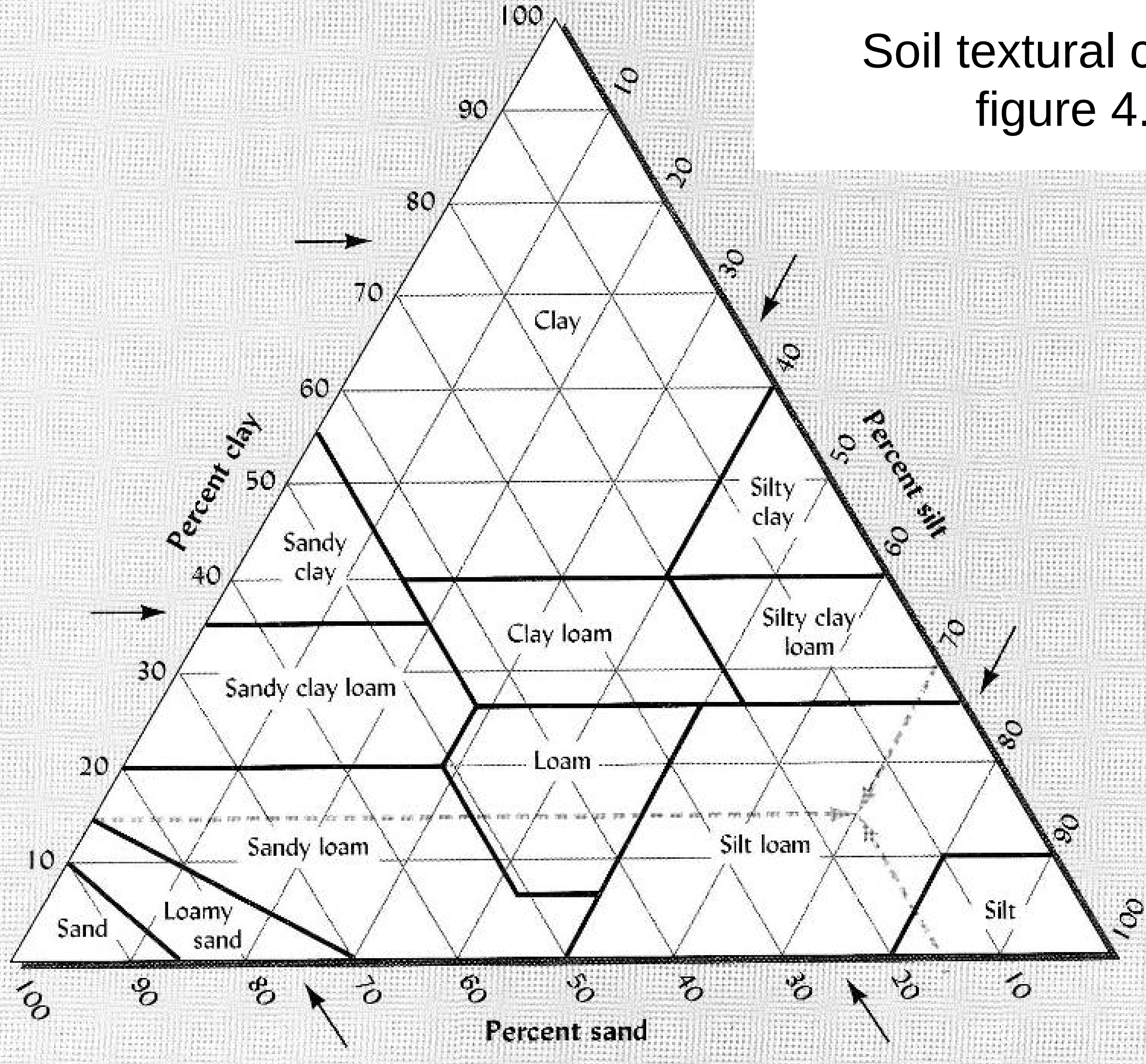


Figure 4.9

Soil textural classes
figure 4.6



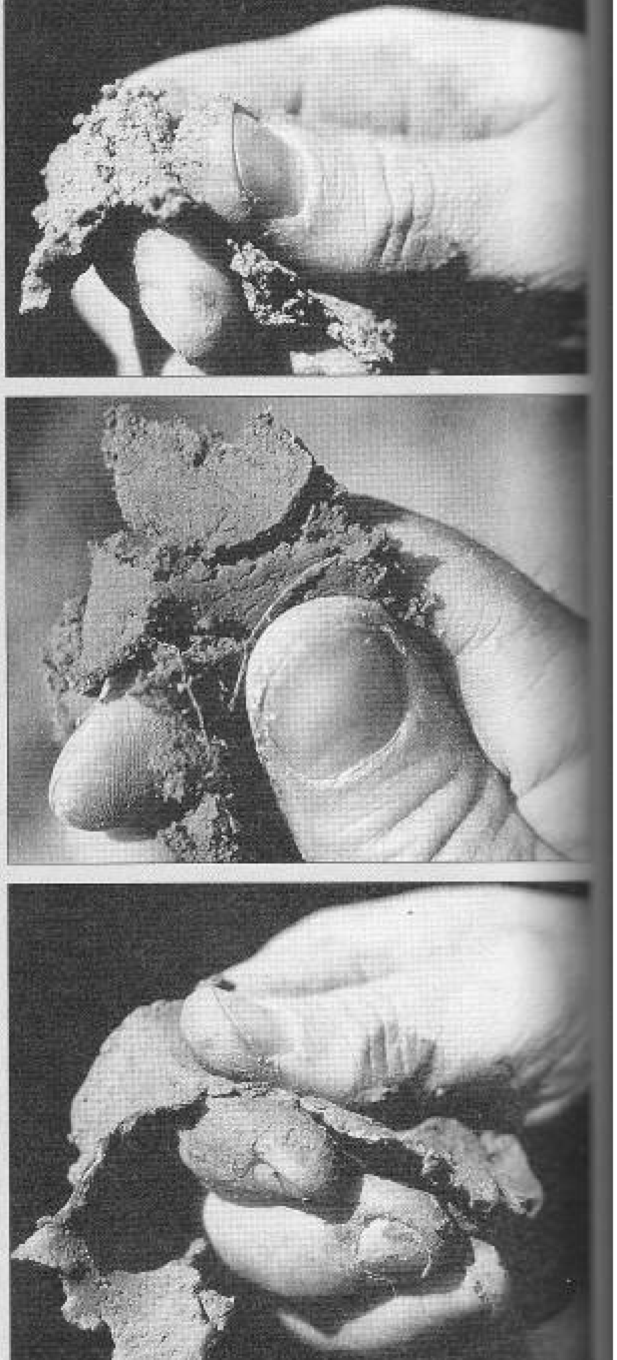
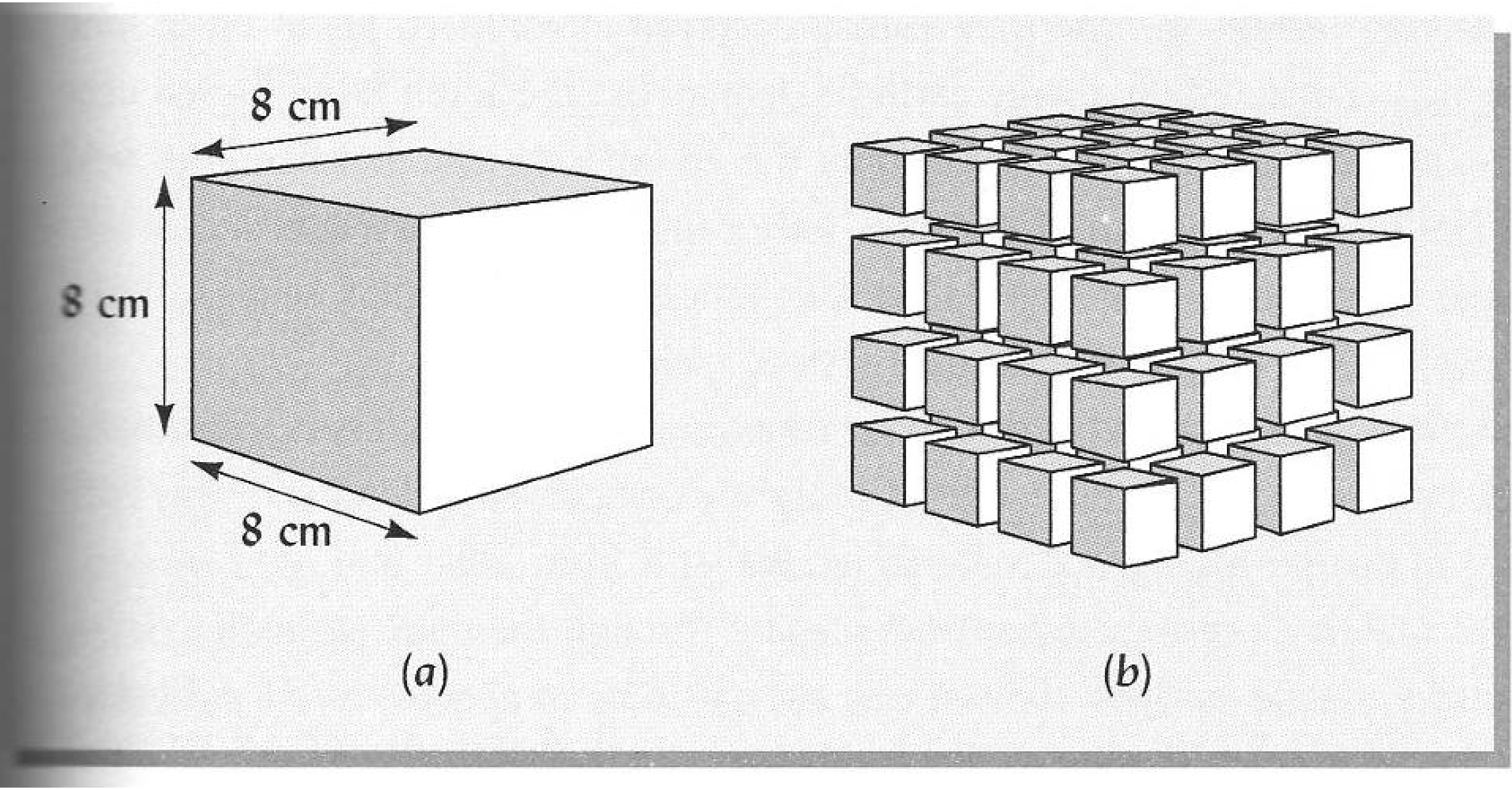


FIGURE 4.7 The “feel” method for determinin
soil textural class. A moist soil sample is rubb

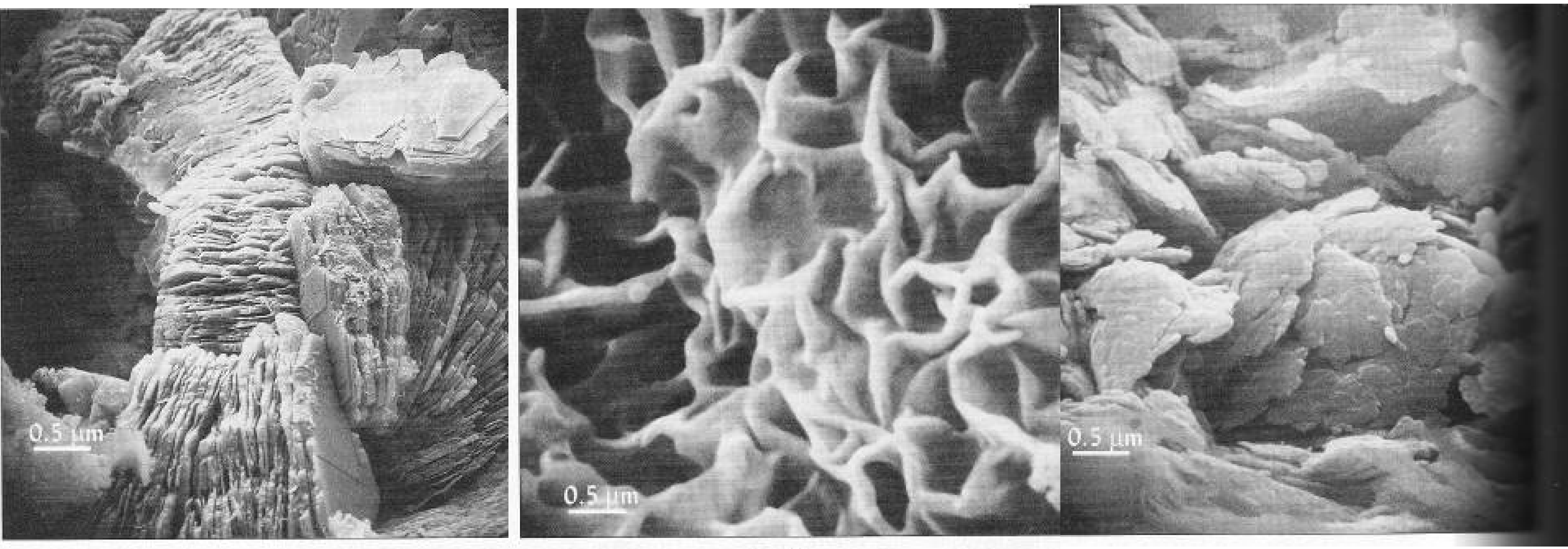
Soil texture by feel

Physical properties of soil particles – surface area to mass ratio. Clays have much more reactive surface area than sand



Clay Physical Properties

Internal spaces, negative electrical charge, colloid formation



Kaolinite   Montmorillonite   Mica

Figure 8.3

Soil macropores between soil particles (sandy soil) and soil aggregates (clayey soil)

Also micropores within clayey aggregates

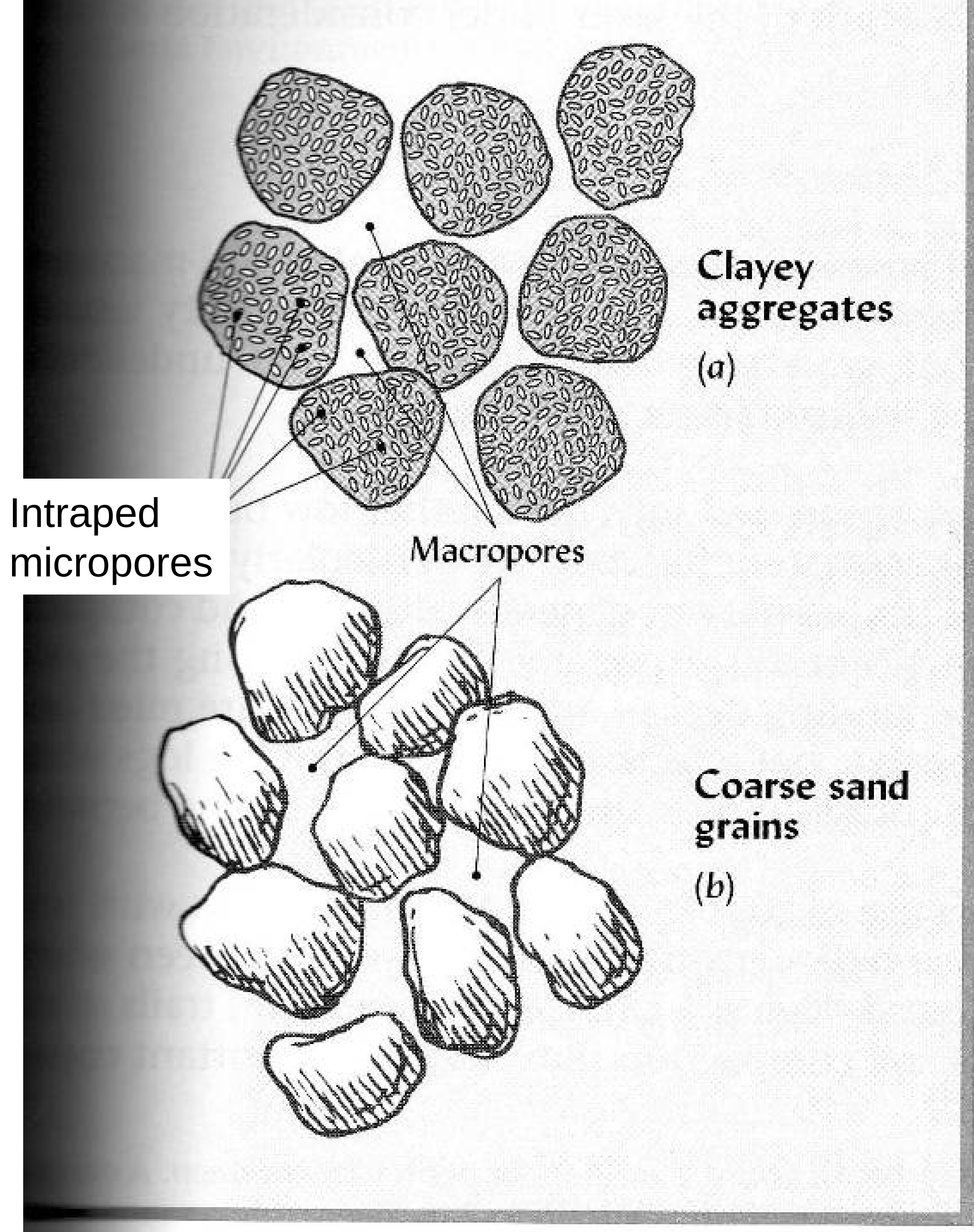


FIGURE 4.15
the relative ar
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aggregate (a),
aggregates, are
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Soil Texture vs. Soil Structure

- <u>Texture</u>
- Termed soil particles or separates
- Sand
- Silt
- Clay

- <u>Structure</u>
- Termed aggregates or peds
- Arrangements of soil particles
- Described based on shape and size of aggregates/peds

Soil Structure – arrangement of pores and particles – how they fit together

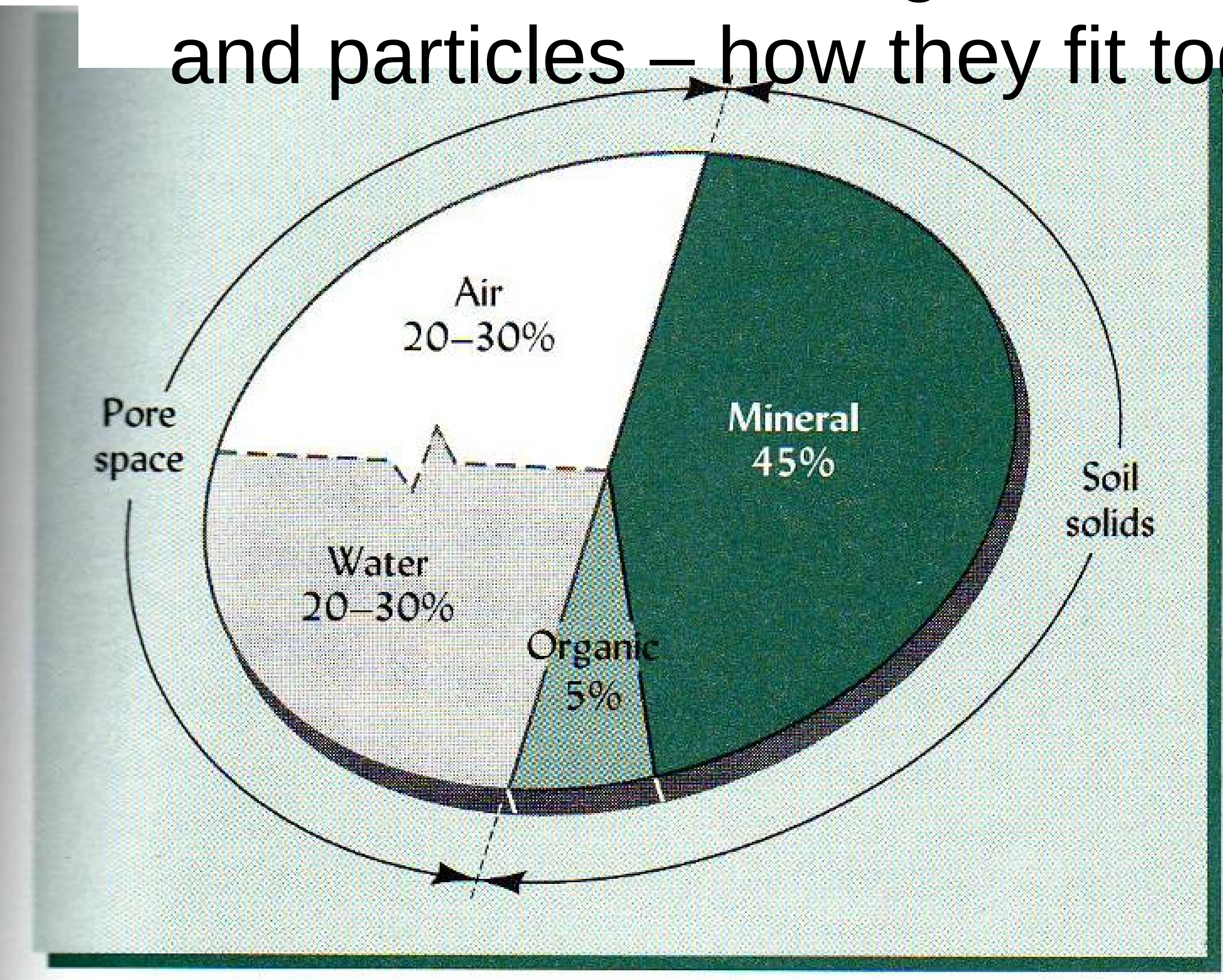

FIGURE 1.17
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Nonetheless, a
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Percent by Volume

Soil pore network (2 mm soil block)

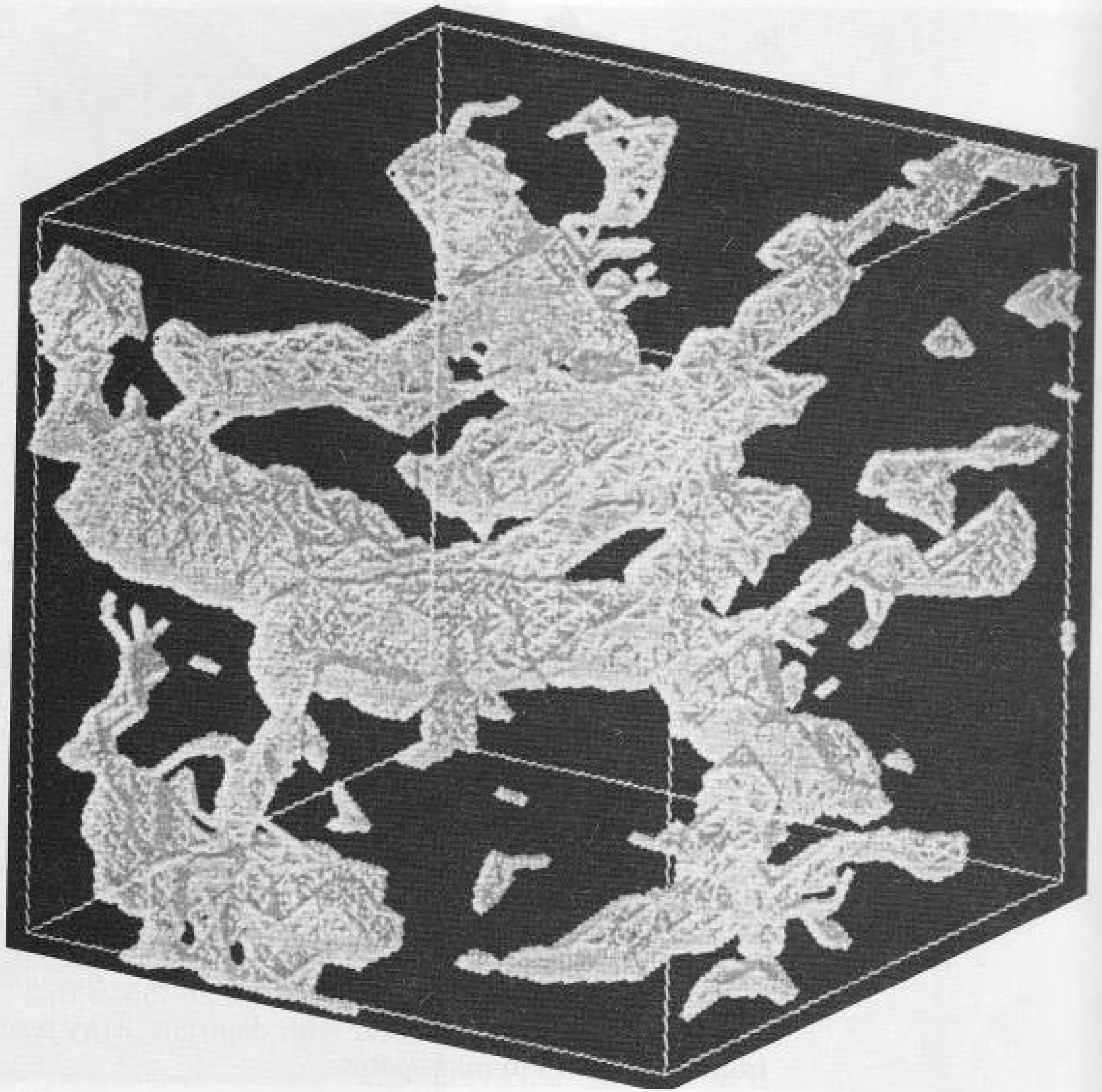


FIGURE 4.24 A three-dimensional representation of the network of pores in a small block of undisturbed soil in France (edges about 2 mm in length). The pores (light in color) exhibit great

Soil pore types – packing pores, interped pores, and biopores

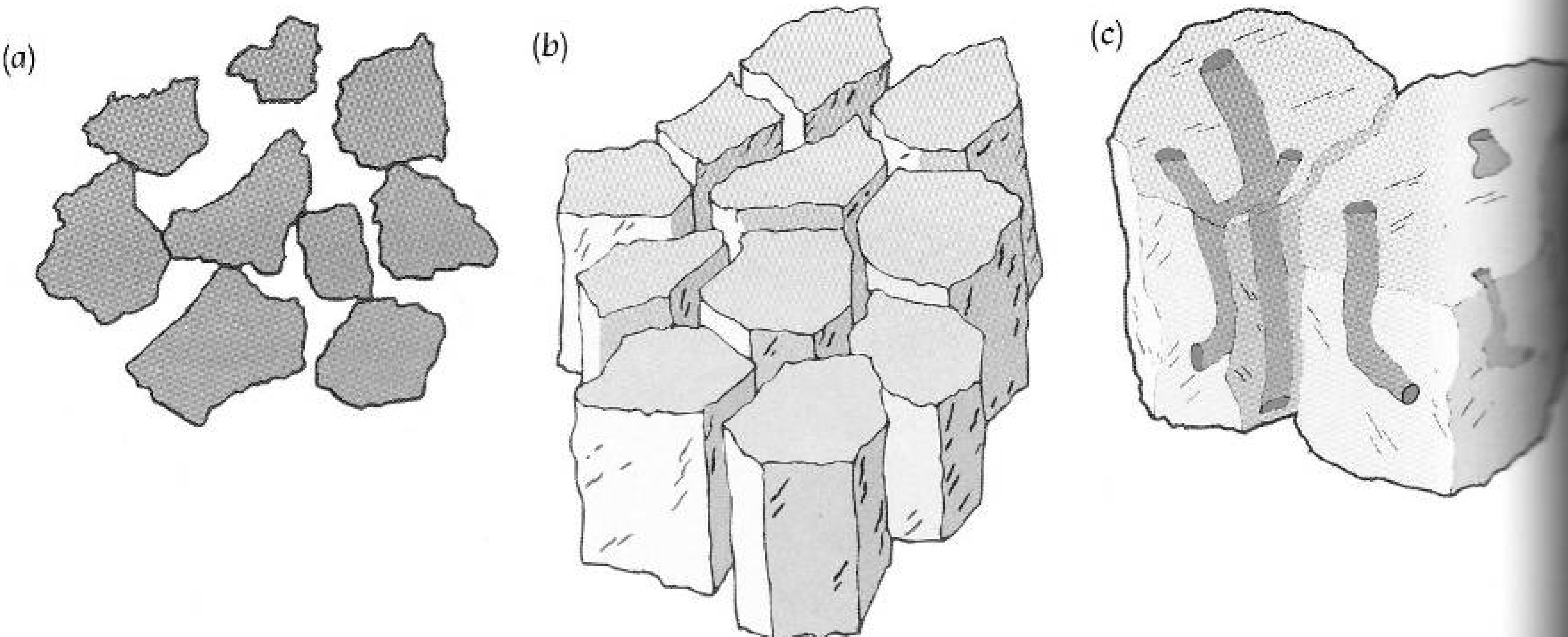
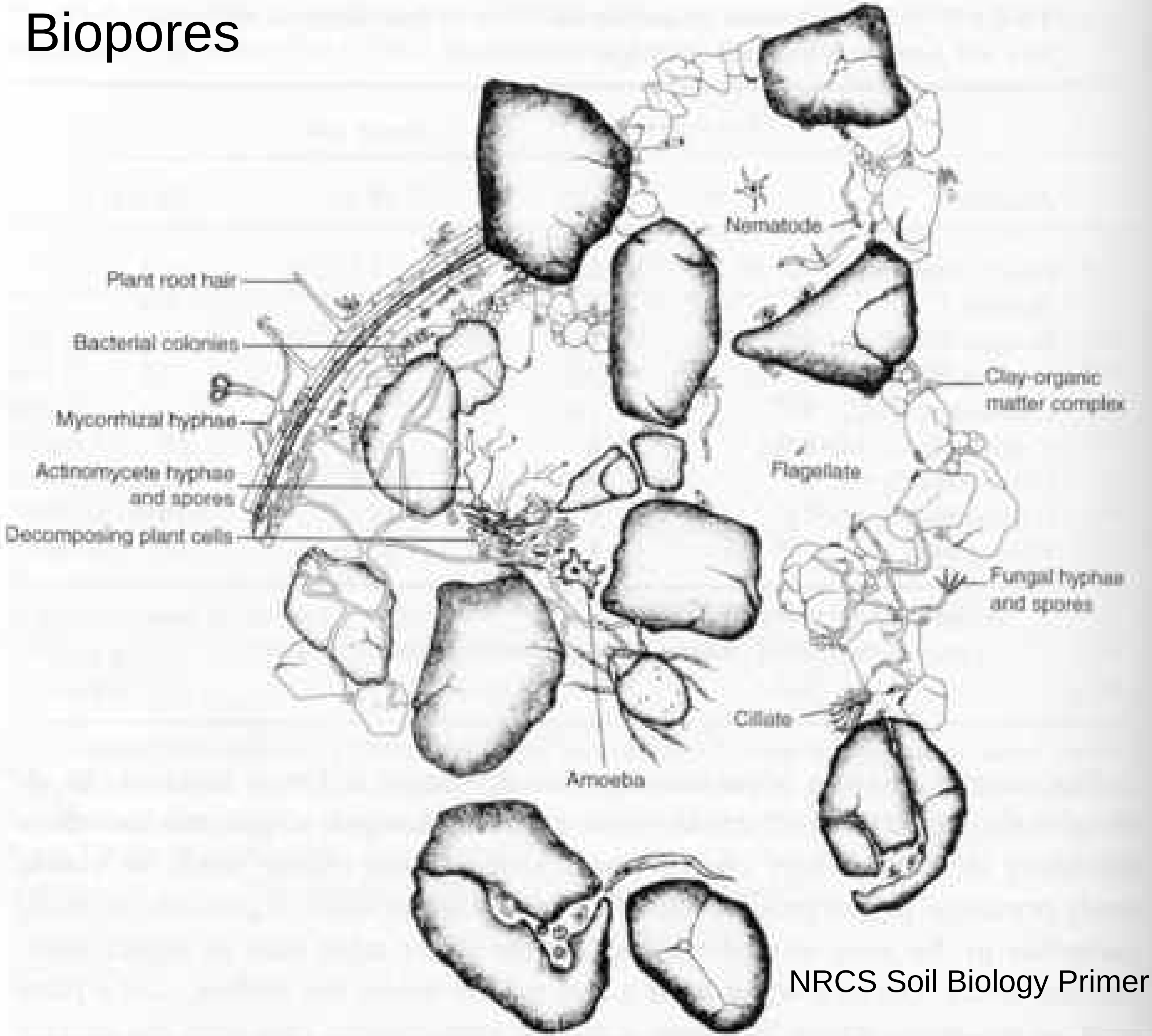


FIGURE 4.25 Various types of soil pores. (*a*) Many soil pores occur as *packing pores,* spaces left betw primary soil particles. The size and shape of these spaces is largely dependent on the size and sha primary sand, silt, and clay particles and their packing arrangement. (*b*) In soils with structural p the spaces between the peds form *interped pores*. These may be rather planar in shape, as with the cra between prismatic peds, or they may be more irregular, like those between loosely packed gra aggregates. (*c*) *Biopores* are formed by organisms such as earthworms, insects, and plant roots. Mo these are long, sometimes branched channels, but some are round cavities left by insect nests and like.

Biopores



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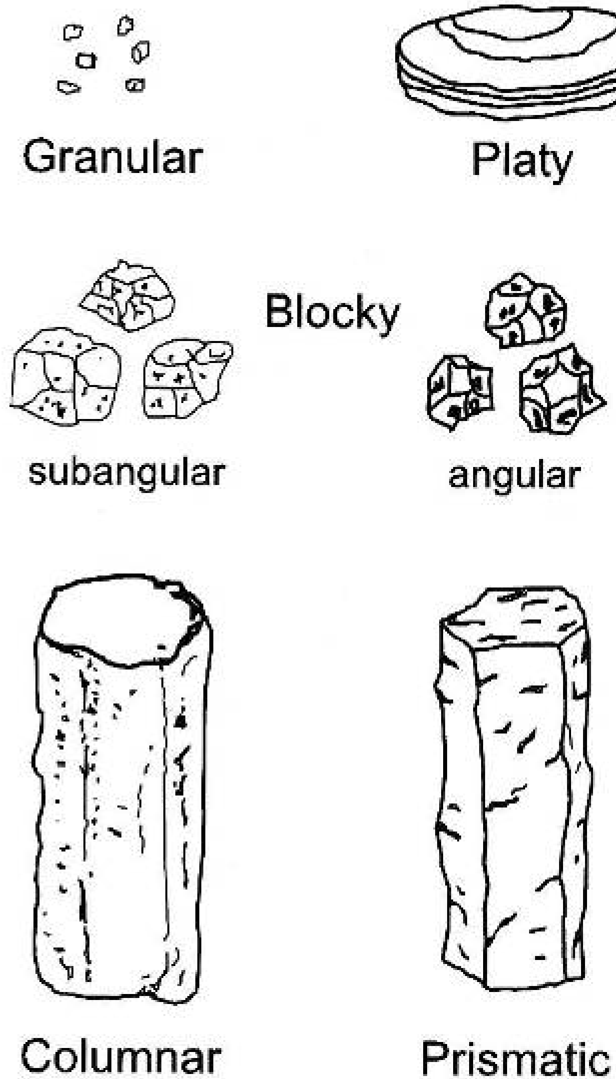


Fig. 5.5. Observable forms of soil aggregation.

Soil aggregates or peds

Environmental Soil Physics. 1998. Daniel Hiller

Soil Structure – Aggregate Formation

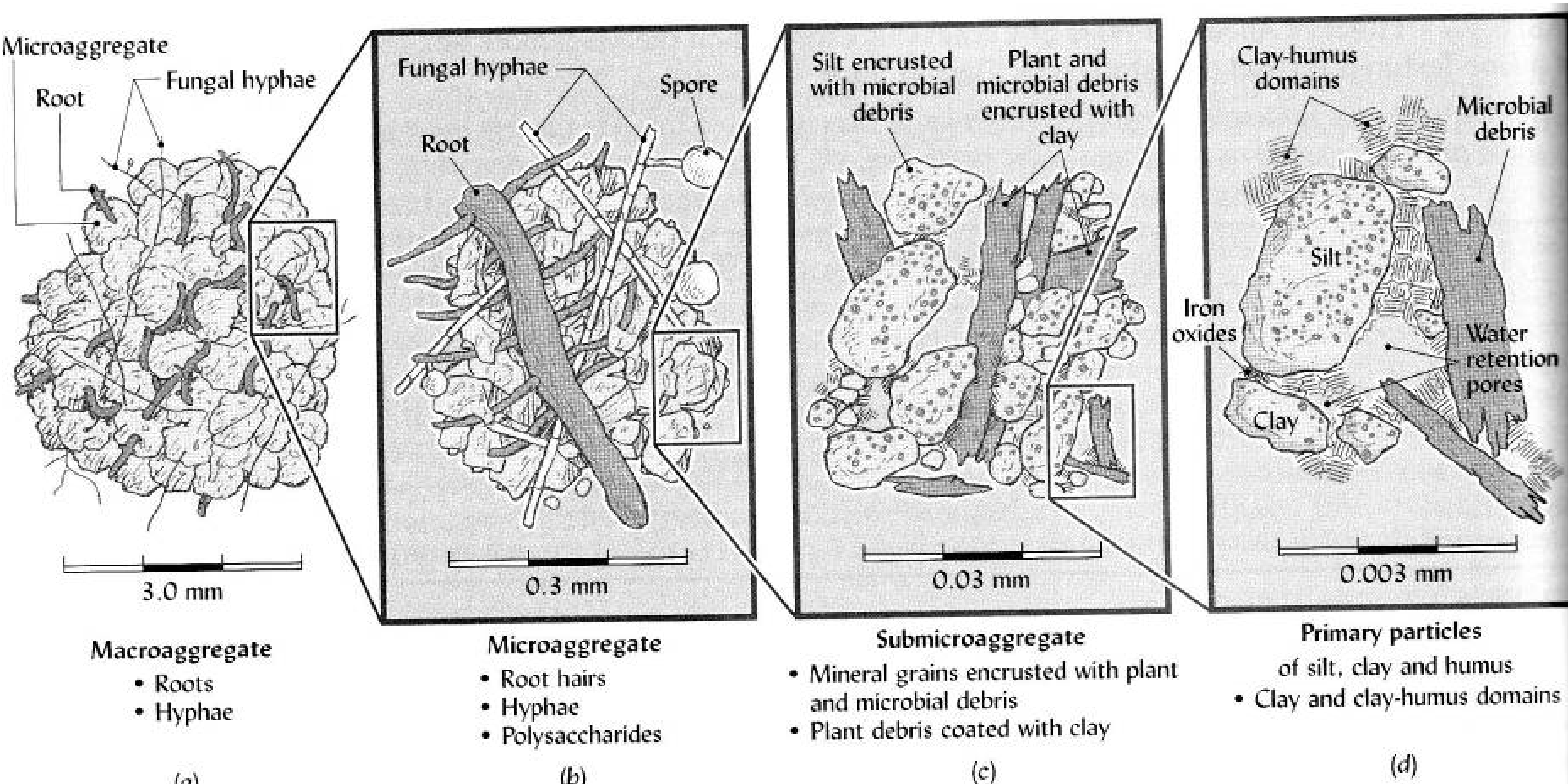


FIGURE 4.28 Larger aggregates are often composed of an agglomeration of smaller aggregates. This illustration shows four levels in th hierarchy of soil aggregates. The different factors important for aggregation at each level are indicated. (*a*) A *macroaggregate* composed

Soil aggregates - Humus structure

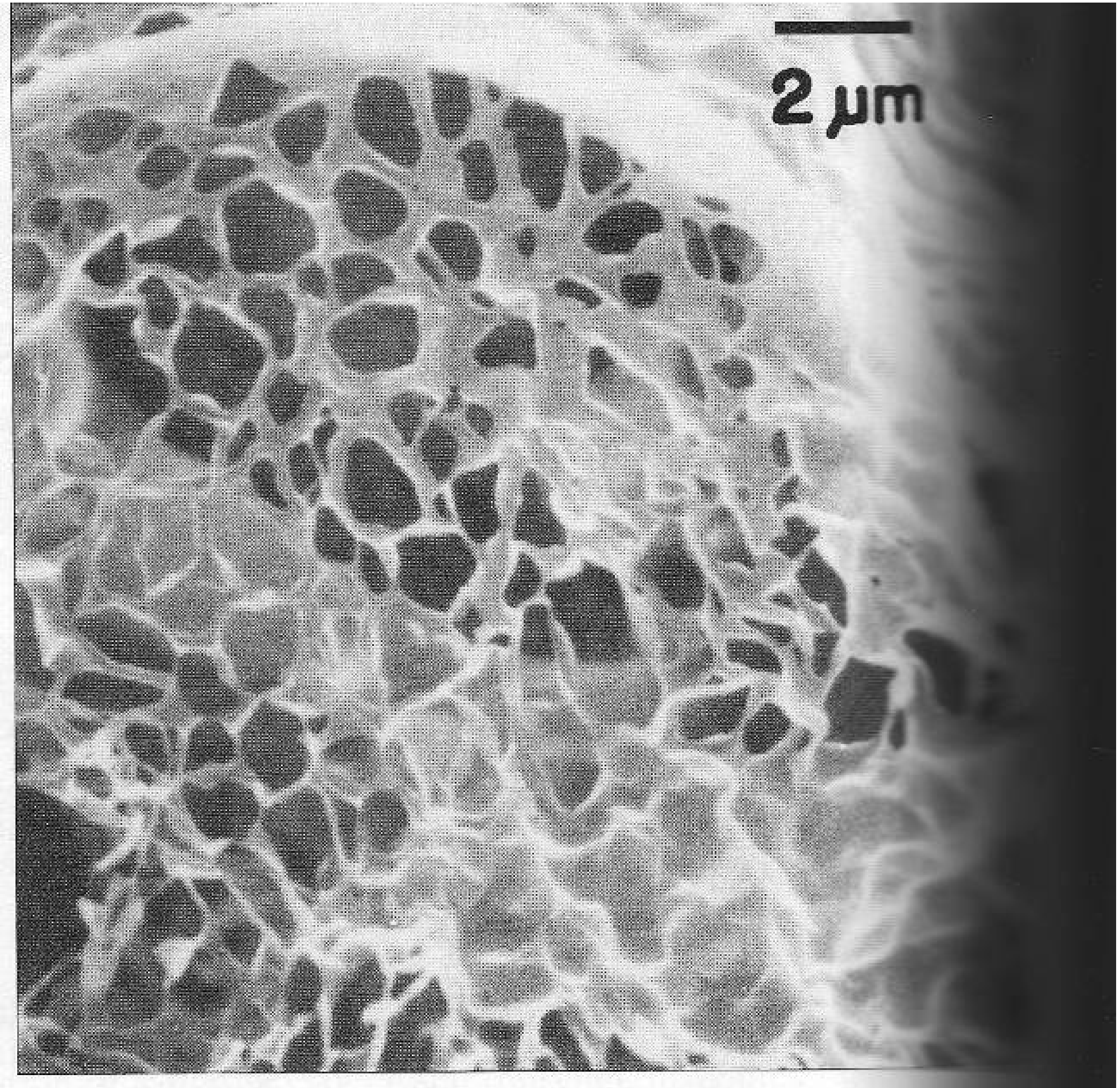


Figure 8.3

Aggregate Formation – role of humus colloids and cation bridging

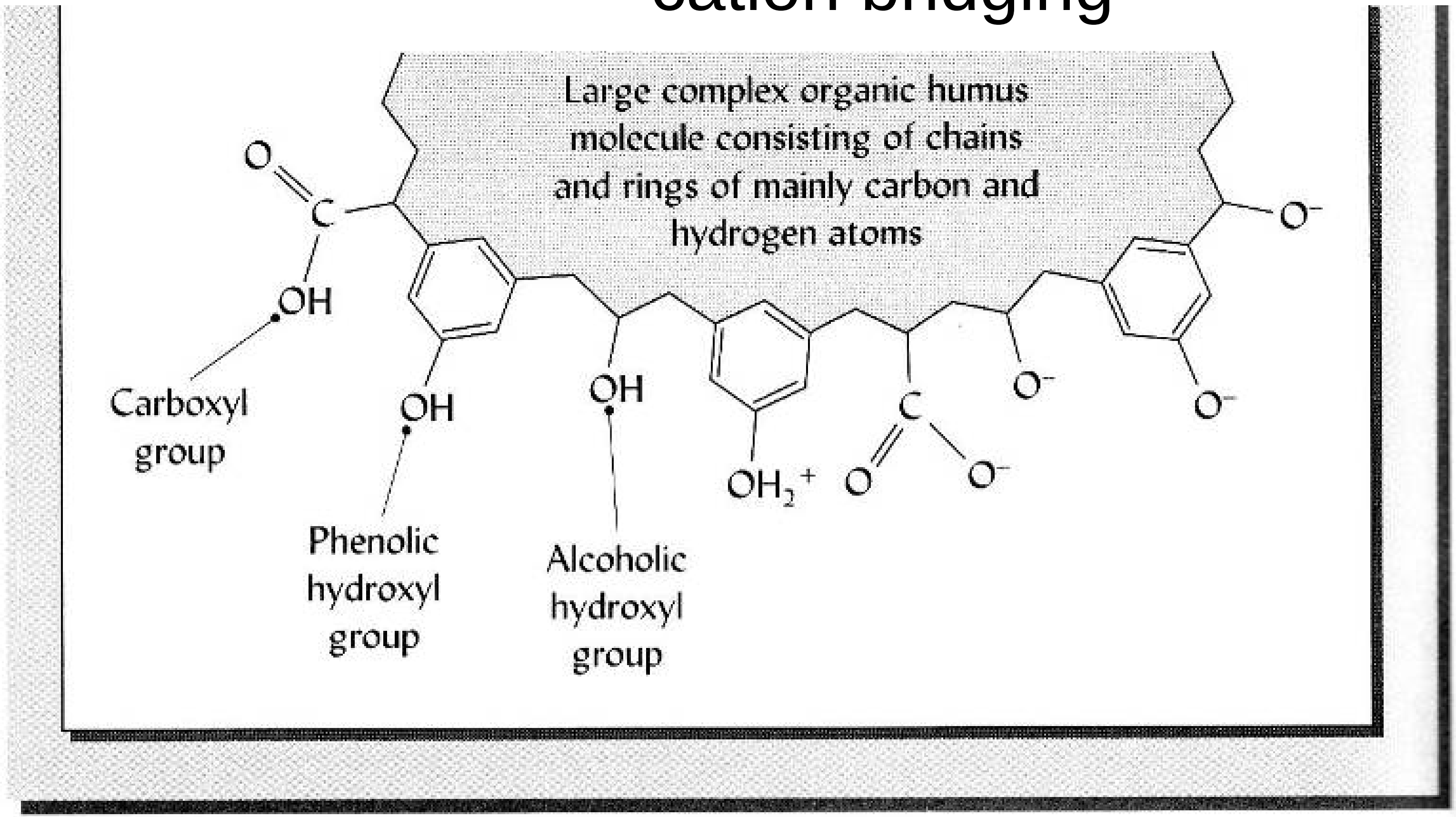


FIGURE 8.13 A simplified diagram showing the principal chemical groups responsible for the high amount of negative charge on humus colloids. The three groups highlighted all include –OH that can lose its hydrogen ion by dissociation and thus become negatively charged. Note that the **alcoholic**, **phenolic**, and **carboxylic** groups on the right side of the diagram are shown in their disassociated state, while those on the left side still have their associated hydrogen ions. Note also that association with a second hydrogen ion causes a site to exhibit a net positive charge.

Aggregate stability – Native prairie compared to cultivated soil

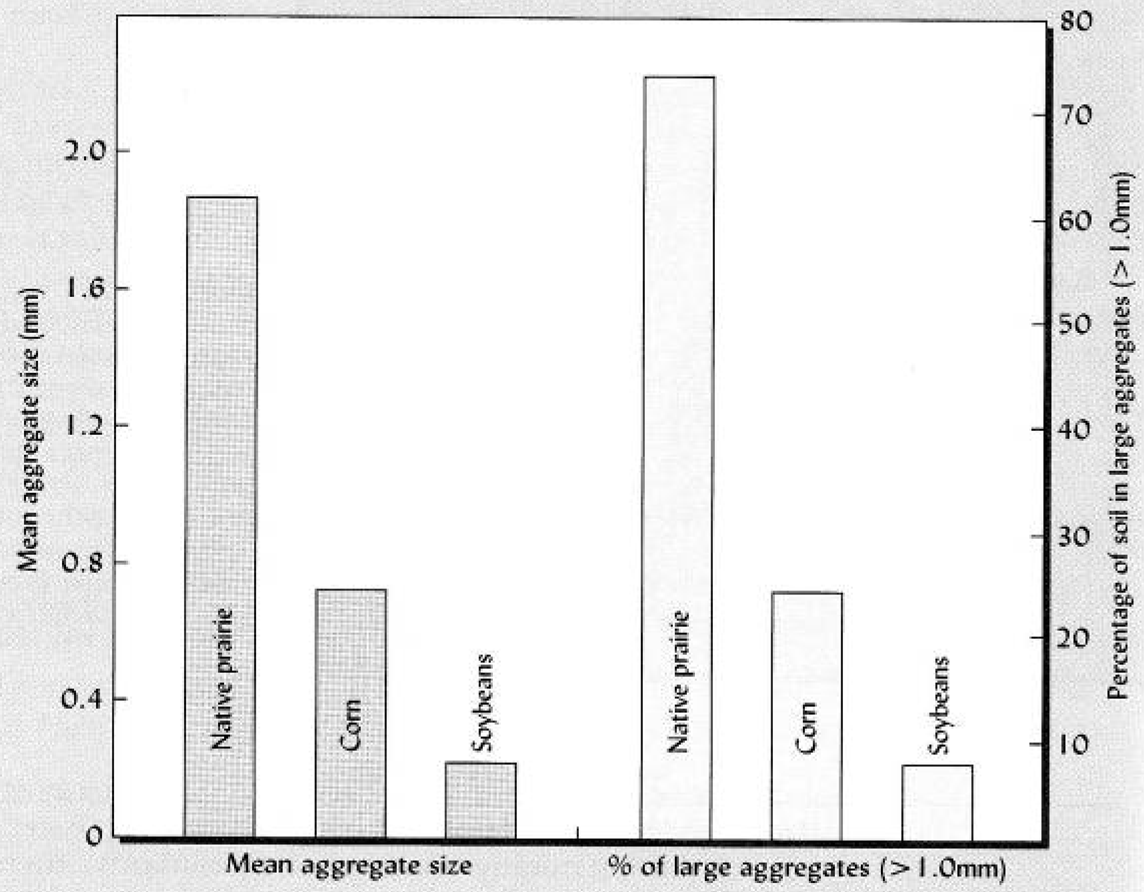


FIGURE 4.27 Soil aggregates in a Mollisol in Iowa are larger and more stable under native prairie vegetation than where cultivated crops had been grown for some 90 years. In this study, soil samples were taken from a prairie area and from two nearby fields, where either corn or soybeans had been grown the previous year. Differences in past management may in part account for differences between the corn and soybean fields, but the soil in both of these fields shows distinct aggregate breakdown compared to the native grassland area. [Drawn from data in Martens (2000)]

Aggregate stability – organic polysaccharides (P) excreted by microbes

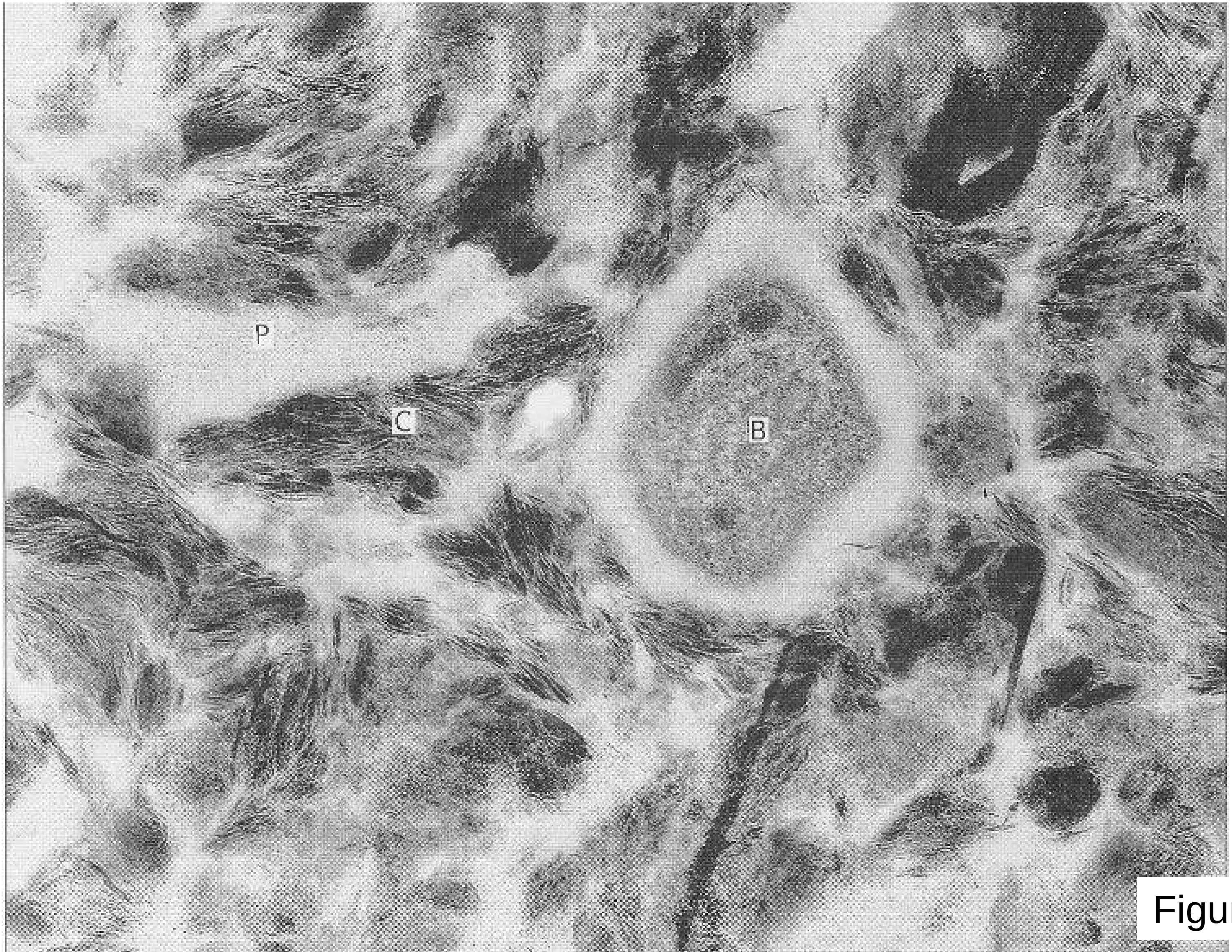


Figure 4.31

Aggregate stability – fungal hyphae, in this case mycorrhizae

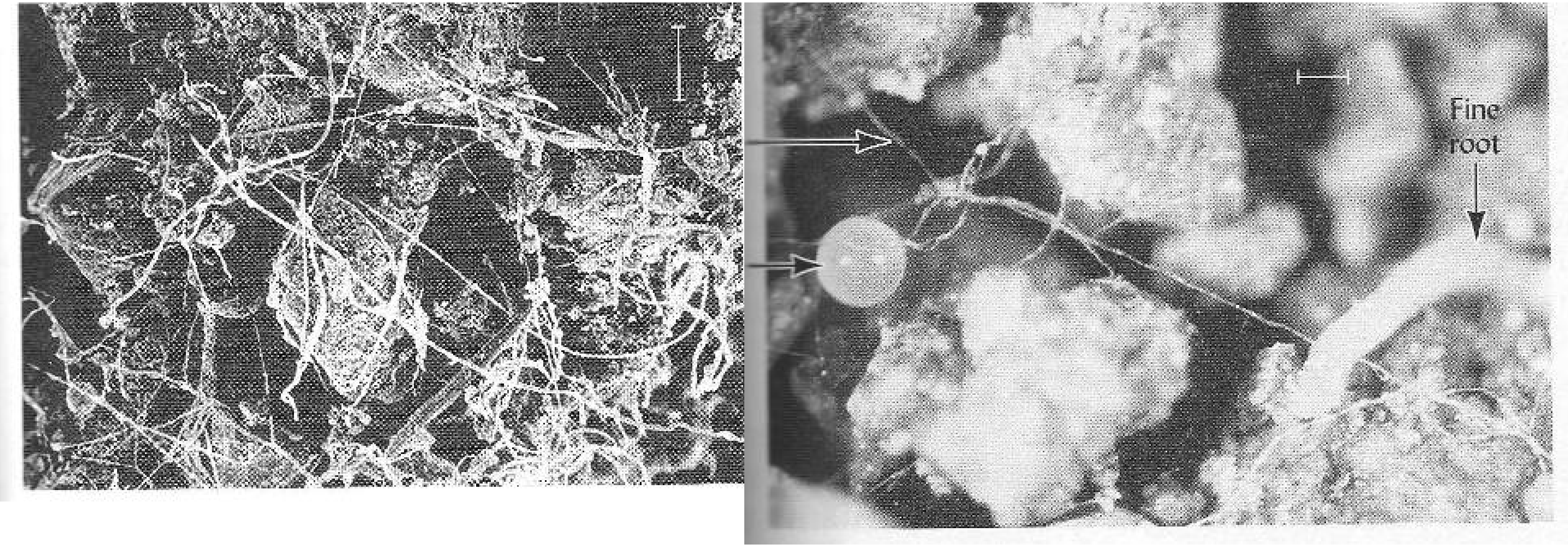
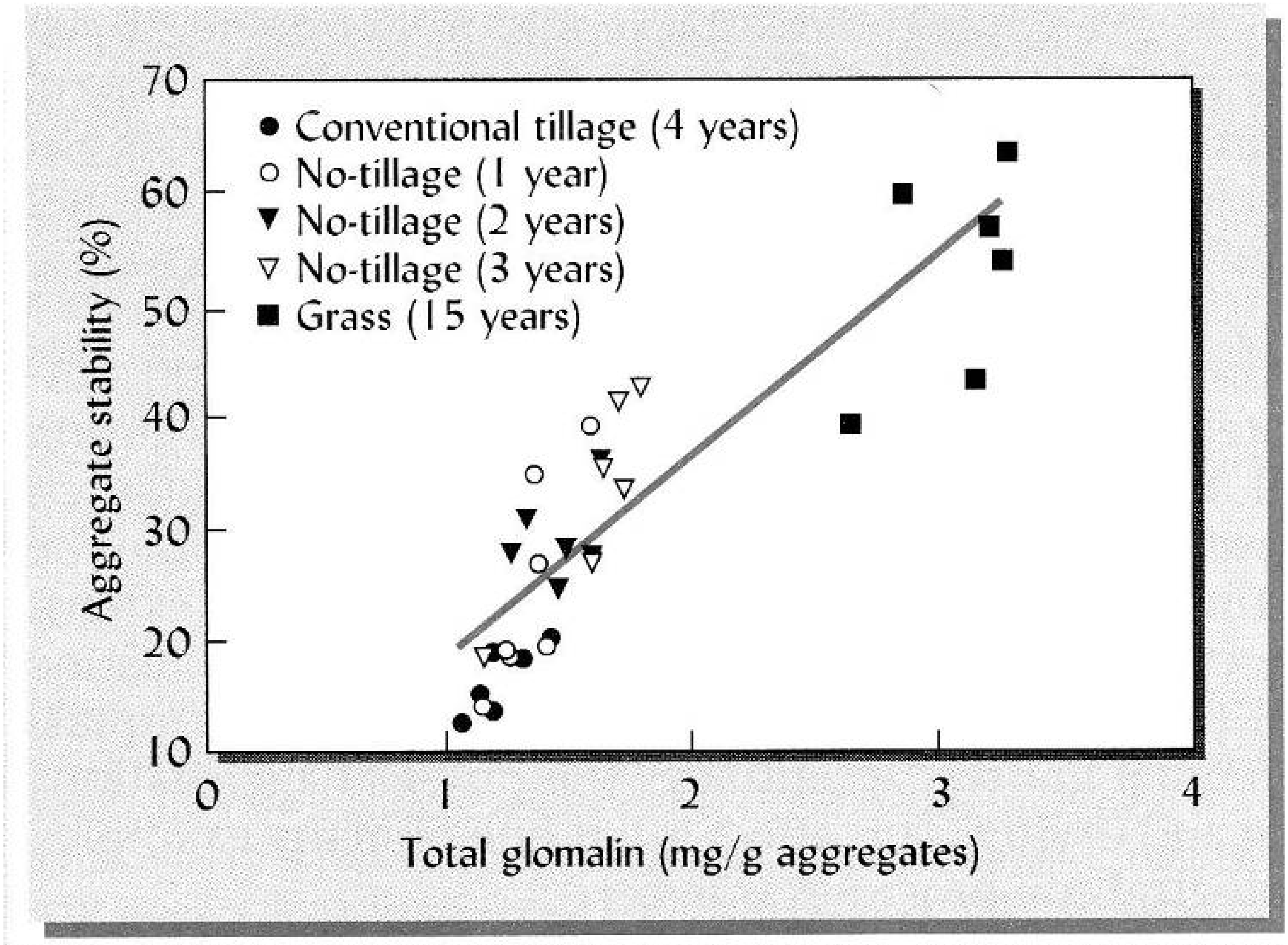


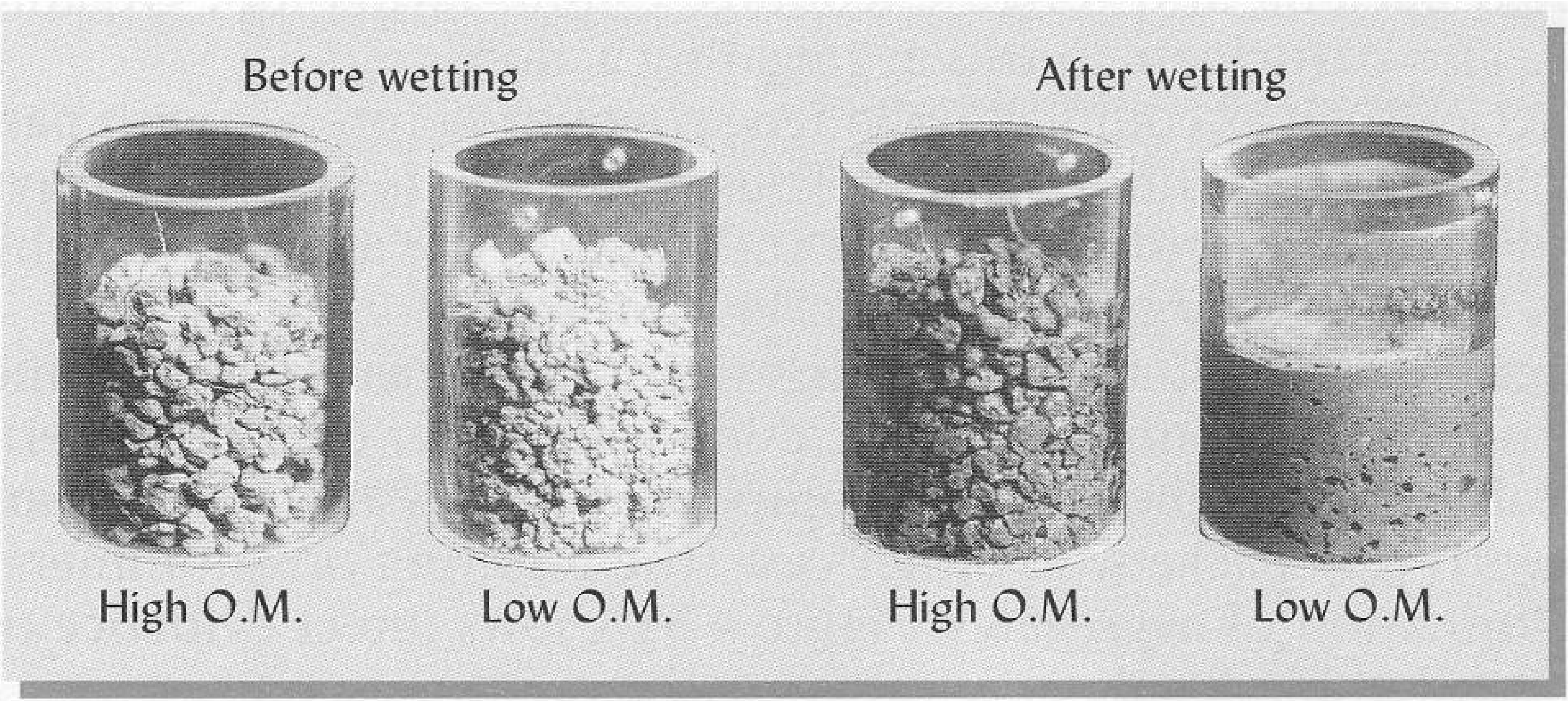
Figure 4.30

Aggregate stability – fungal hyphae and glomalin from mycorrhizae



Box 4.6

Aggregate stability – effect of soil organic matter content



Soil Compaction – affects texture or structure?

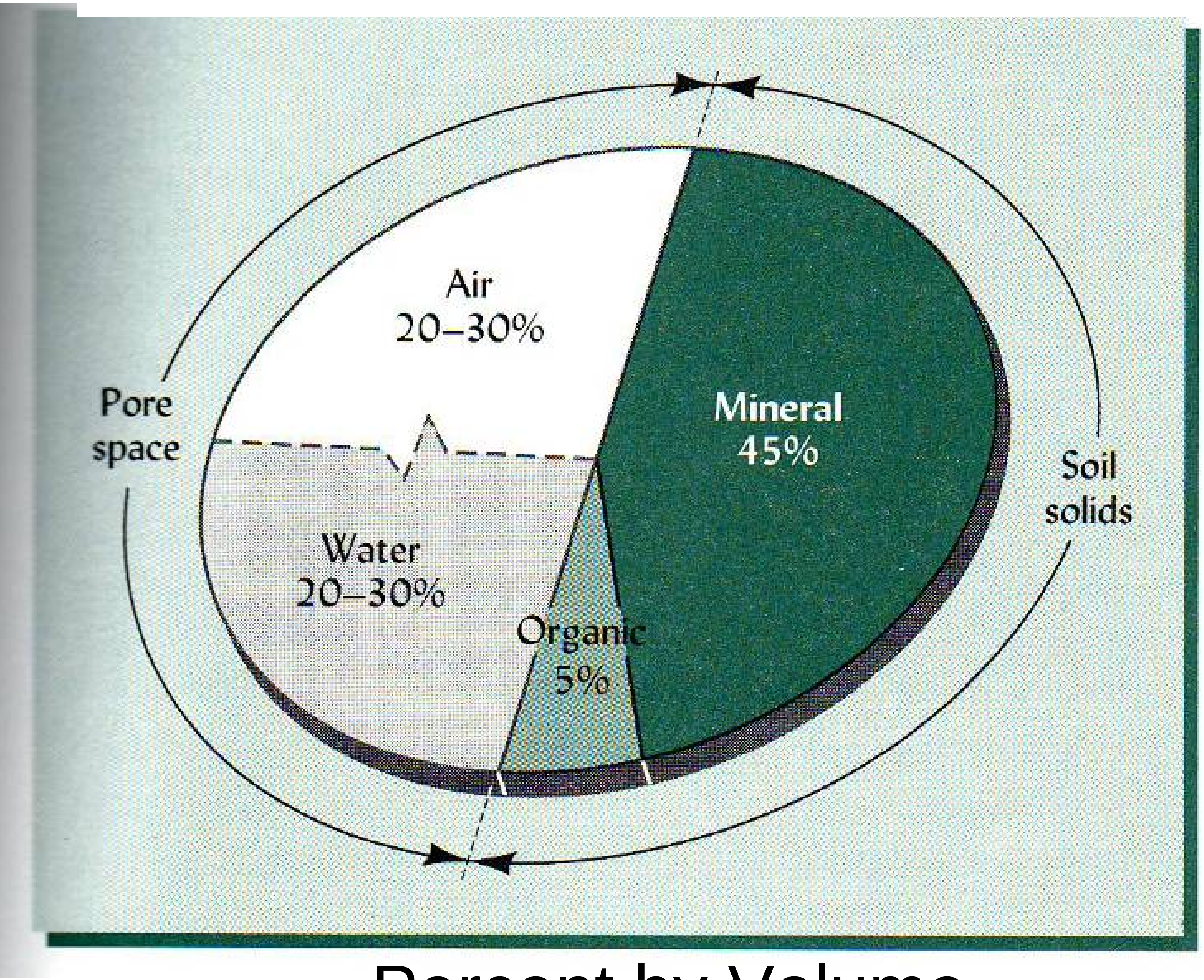


FIGURE 1.17
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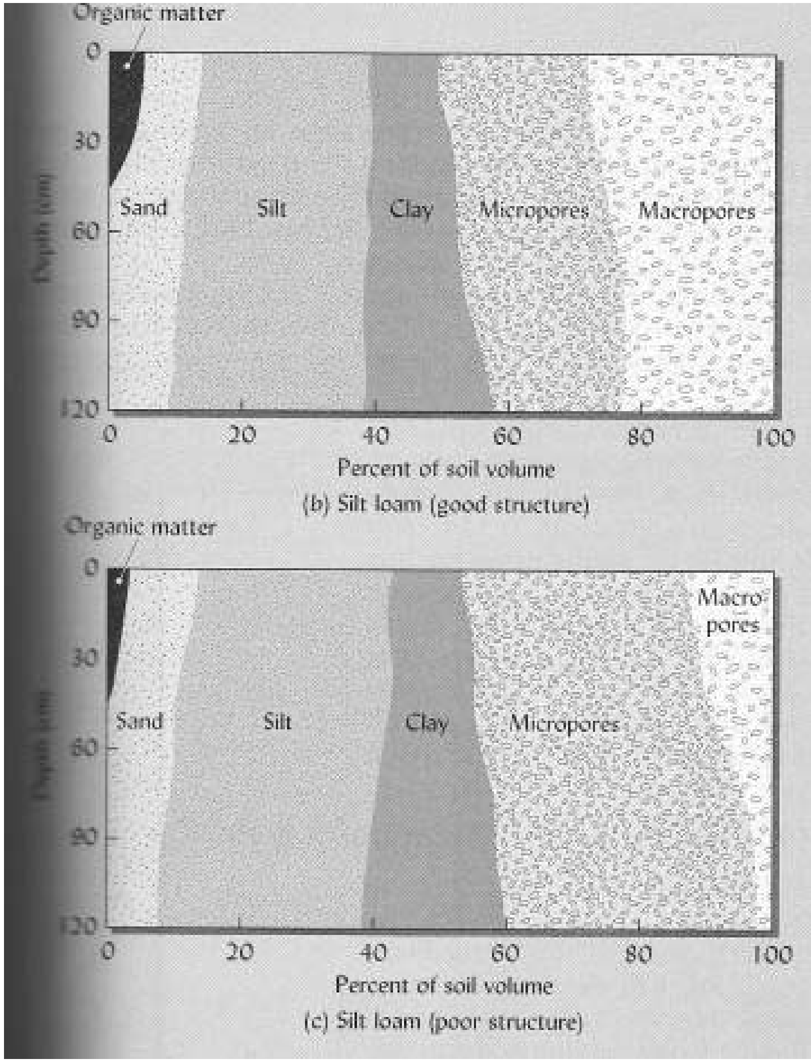
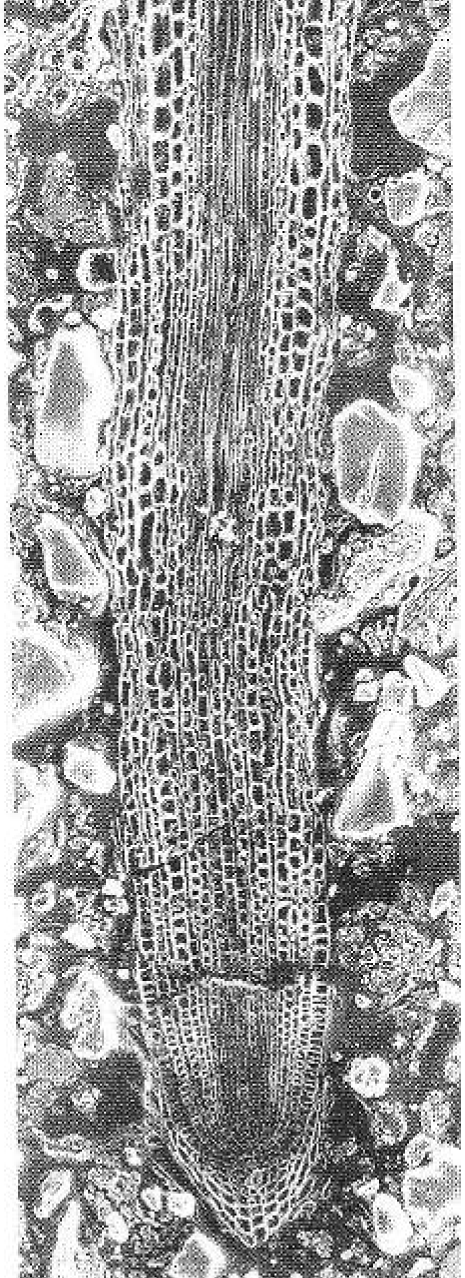


Compaction decreases macropores (figure 4.26)

Hardpan limits rooting depth

Fig. 11.9. Root system of a pigweed (*Amaranthus retroflexus*) that grew on soil with a horizontal soil pan of excessive strength. (Reprinted by permission from H. M. Taylor and E. Burnett, *Soil Sci.* 98: 174–80, © 1964, The Williams & Wilkins Co., Baltimore, Md. 21202, U.S.A.)

Root elongation in compacted soil



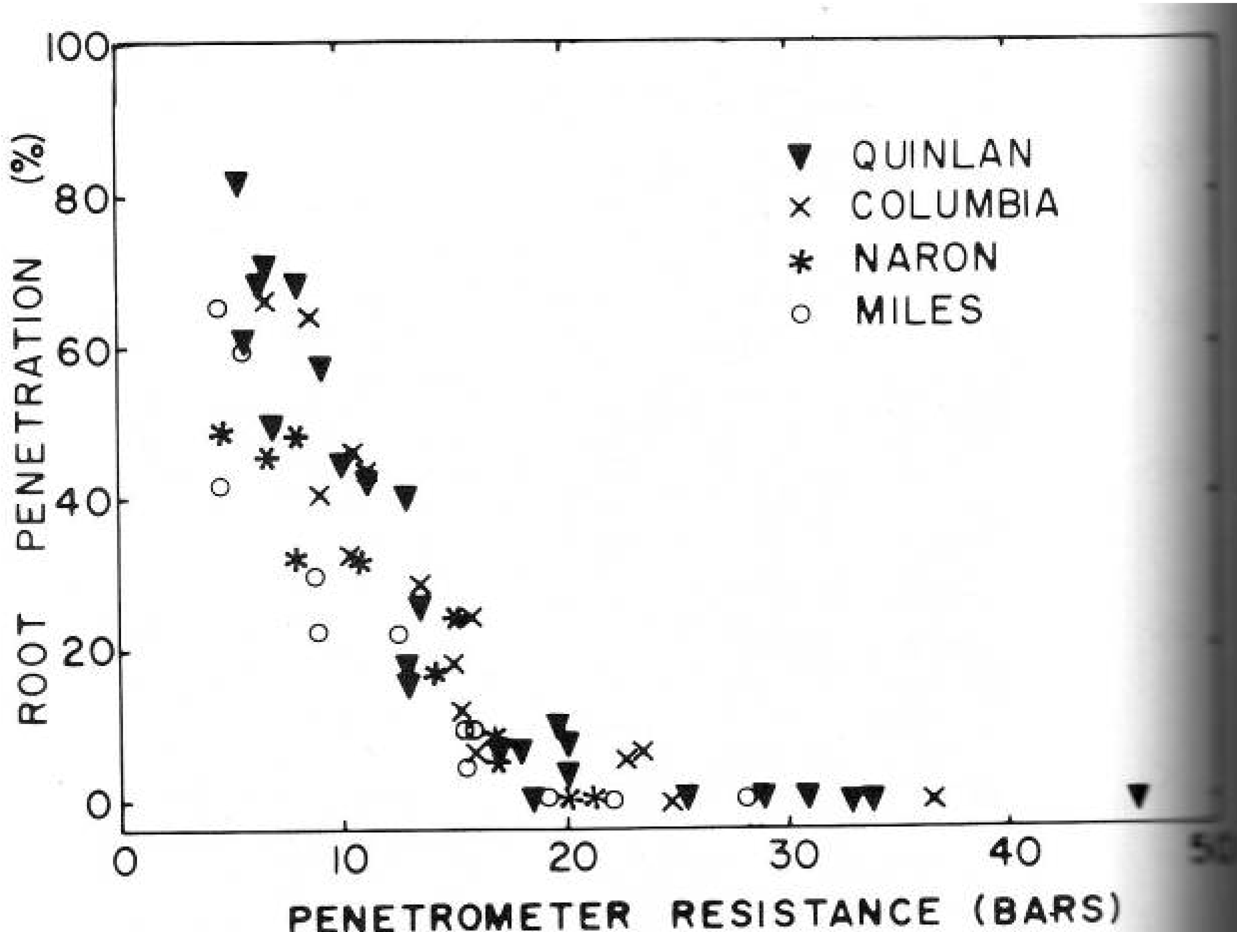


Fig. 11.5. Relations among root penetration and the penetrometer resistance of fou[illegible] materials. (Reprinted by permission from H. M. Taylor, G. M. Roberson, and J. J. Pa[illegible] Jr., *Soil Sci*. 102: 18–22, © 1966, The Williams & Wilkins Co., Baltimore, Md. 2[illegible] U.S.A.)

The Plant Root and Its Environment. 1974. E.W. Carson

Soil compaction – 110 years after wagon trail abandoned in Minnesota

Soil Characteristic	Values found	
	Wheel ruts	Outside the trail
Bulk density (Mg/m3)	1.13	1.03
Water infiltration (mm/s)	0.53	0.92
Air permeability (mm2)	0.11	0.37

Compaction - Increasing Bulk Density

Box 4.4

Plow pan - Moldboard plow

FIGURE 4.35 While the action of the moldboard plow lifts, turns, and loosens the upper 15 to 20 cm of soil (the furrow slice), the counterbalancing downward force compacts the next lower layer of soil. This compacted zone can develop into a *plowpan*. Compactive action can be understood by imagining that you are lifting a heavy weight—as you lift the weight your feet press down on the floor below. (Photo courtesy of R. Weil)

Soil compaction – wheel traffic and plow pan. Note soil bulk density values

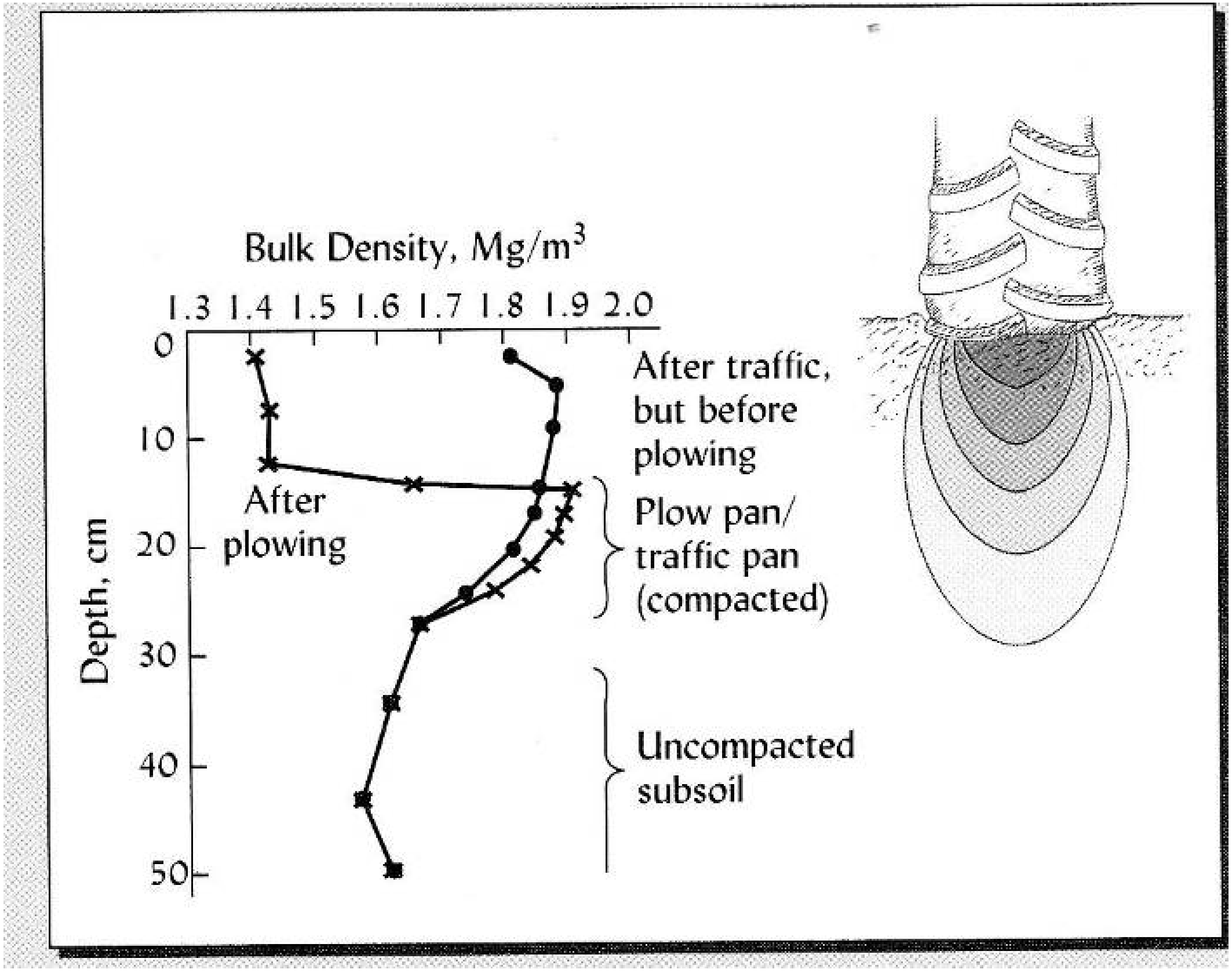


Figure 4.19

Soil compaction and plant rooting

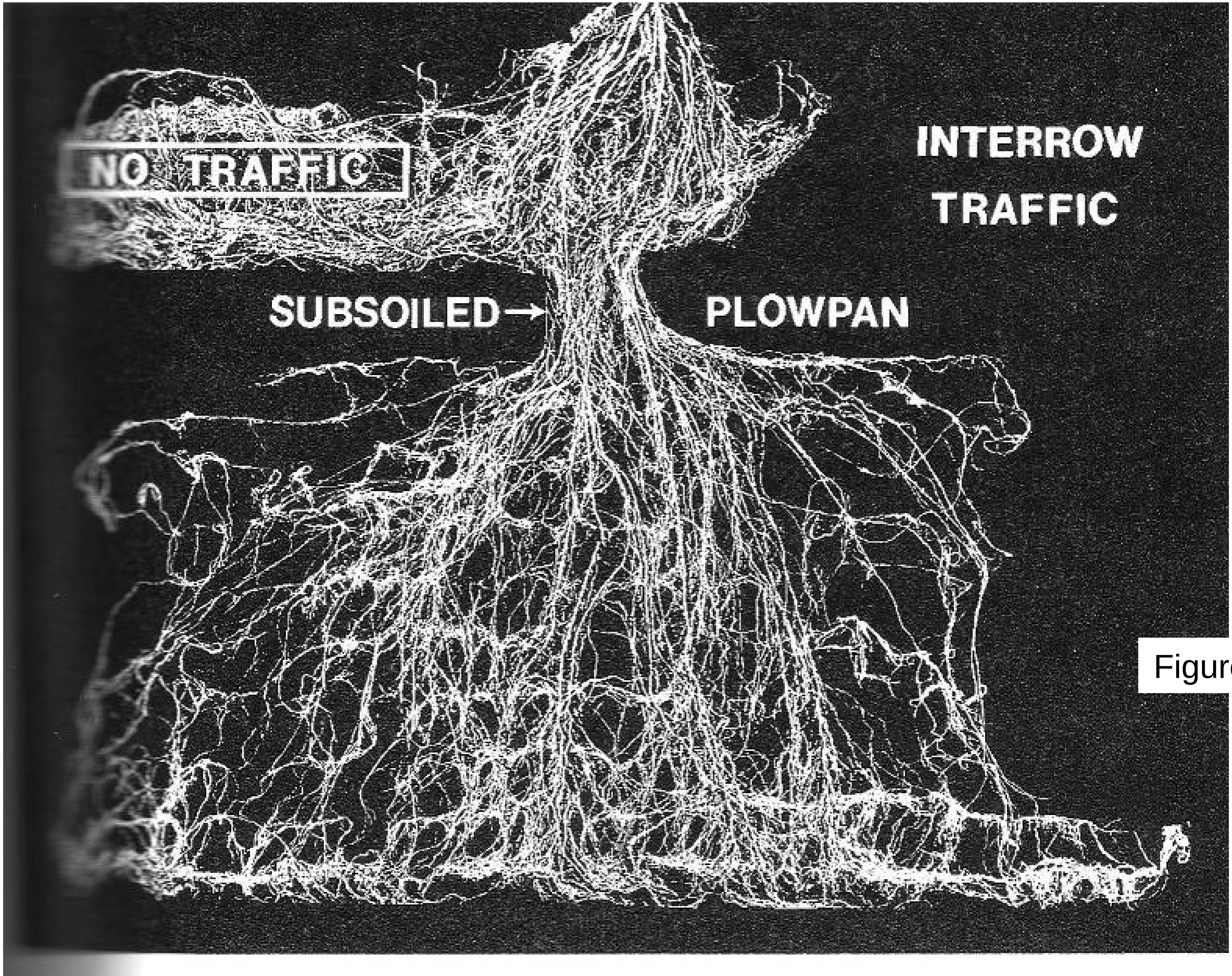


Figure 4.21

Subsoiling to reduce soil compaction

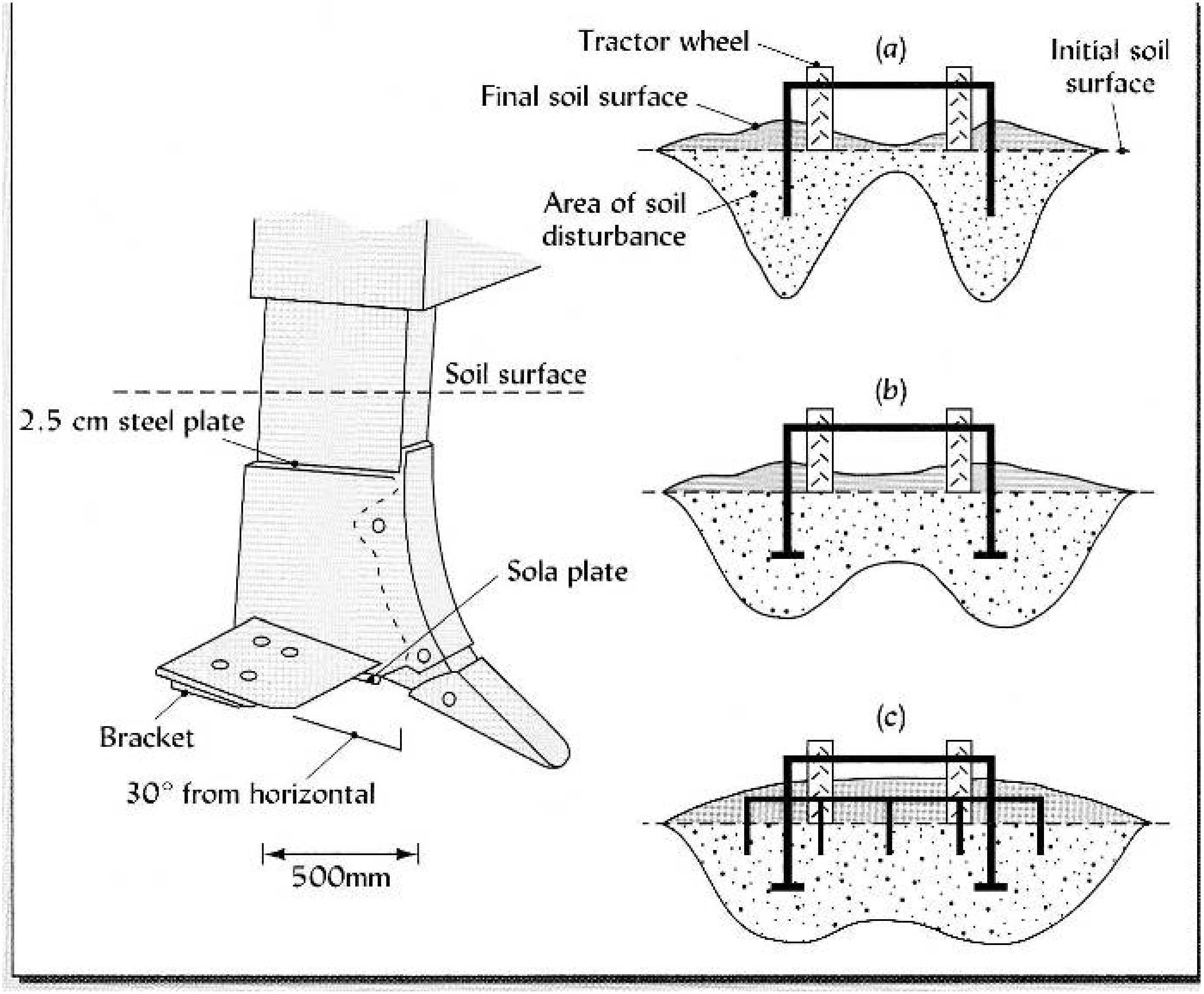
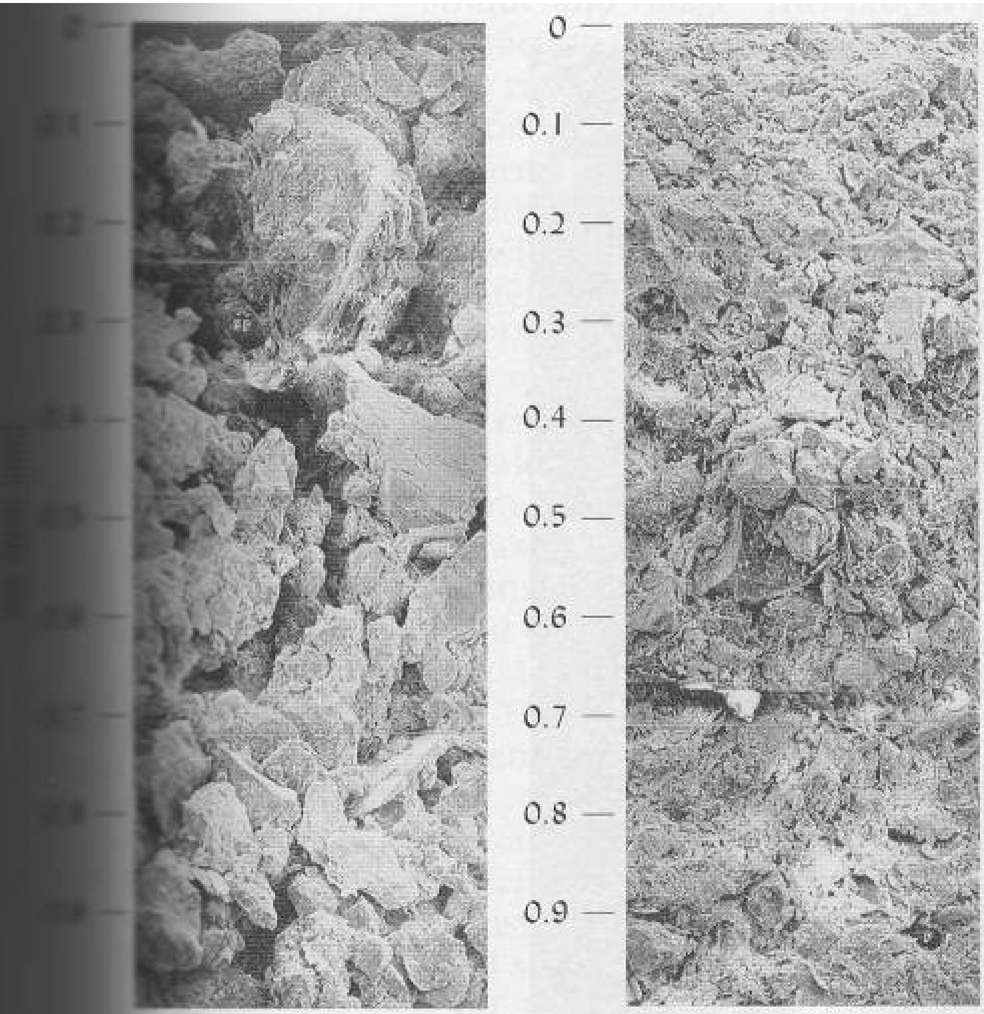


Figure 4.20

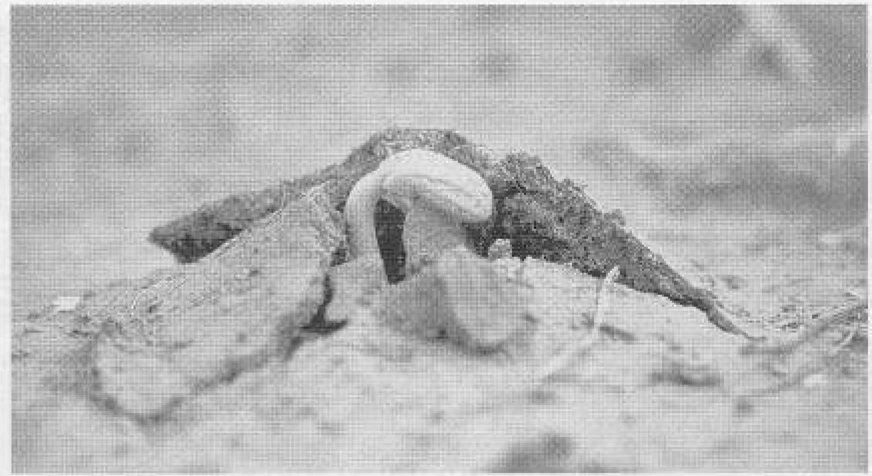
Soil crusting and seedling germination

(Capon, 2005)

Soil Crusting



(*a*) (*b*)



(*c*)

FIGURE 4.37 Scanning electron micrographs of the upper 1 mm of a soil with stable aggregation (*a*) compared to one with unstable aggregates (*b*). Note that the aggregates in the immediate surface have been destroyed and a surface crust has formed. The bean seedling (*c*) must break the soil crust as it emerges from the seedbed. [Photos (*a*) and (*b*) from O'Nofiok and Singer (1984), used with permission of Soil Science Society of America; photo (*c*) courtesy of R. Weil]

Flocculation and Dispersion of soil clays – effect of Calcium verses Sodium

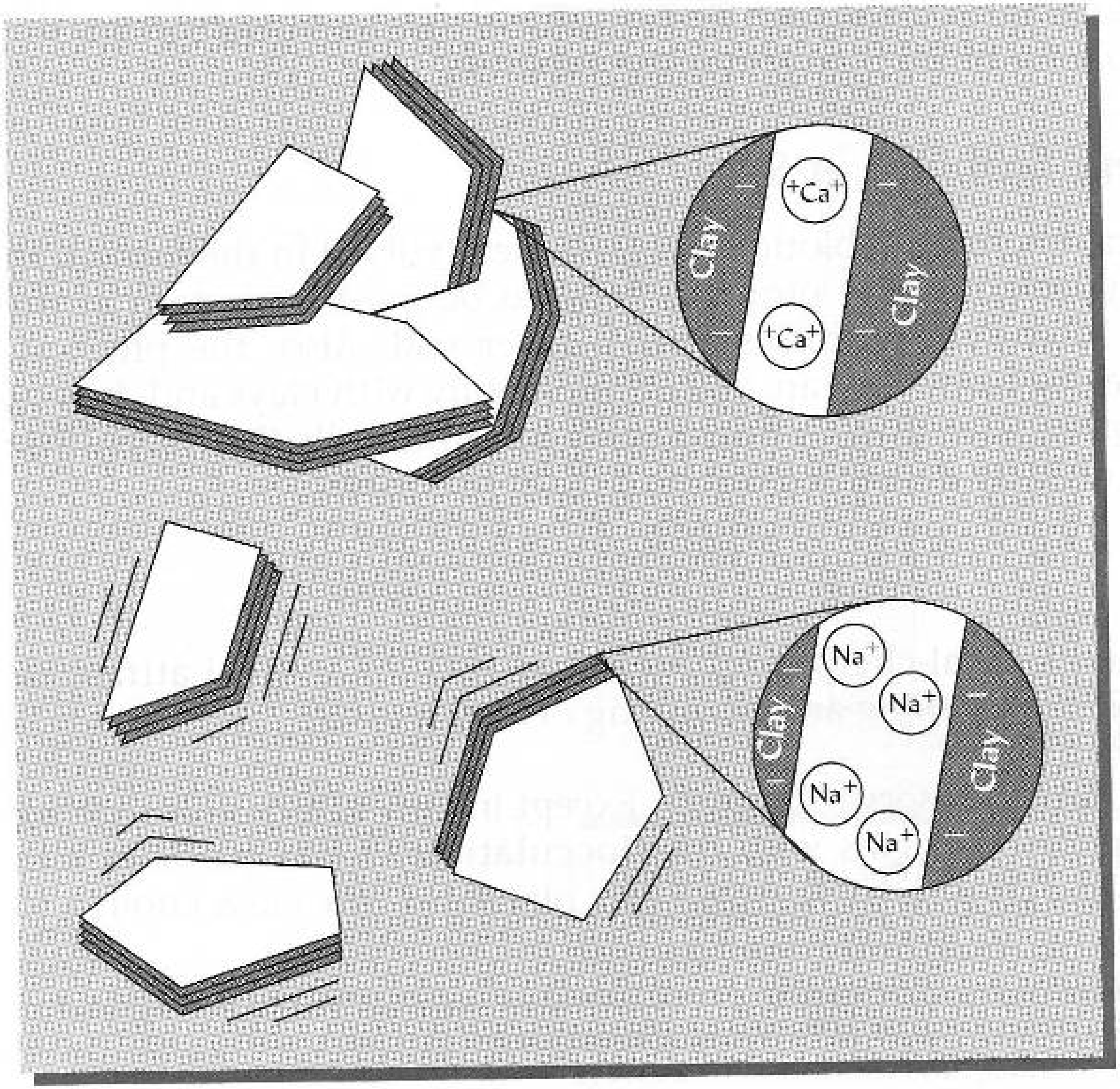


FIGURE 4.29
clays. The di- a
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surface charge
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cause clay parti
condition. Two
hydrated sodiu
effectively neu
charge on sodi
clay particles.

Soil Conditioners

- Polysaccharides
  - PAH
  - Yuccah plant extract
- Gypsum
  - Calcium sulfate

Expanding soils – clay drying and wetting

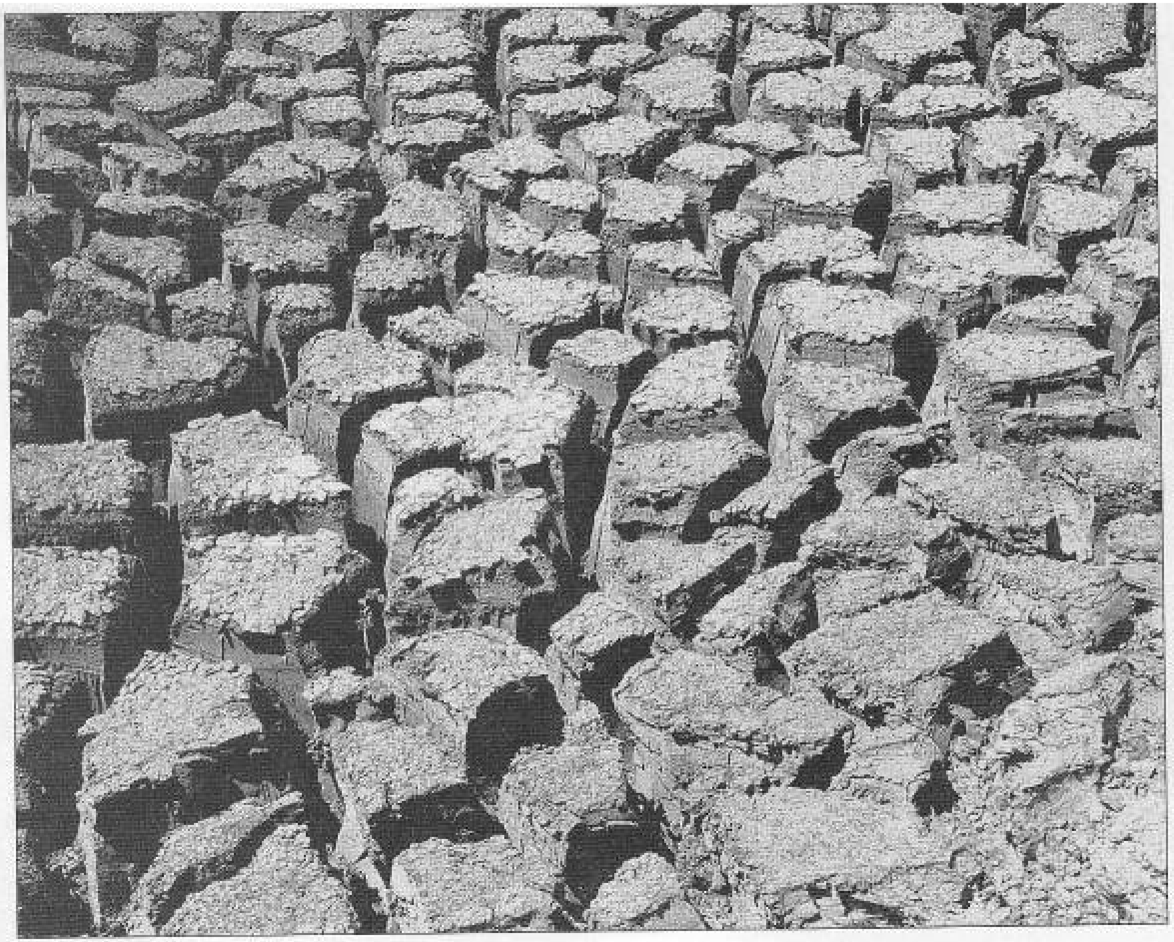

FIGURE 4.43 Certain types of clays, especially the smectites, undergo significant volume changes in conjunction with changes in water content. Here, an expansive soil rich in smectitic clay has shrunk during a dry period, causing a network of large cracks to open up in the soil surface. (Courtesy of USDA Natural Resources Conservation Service)

Swelling soils – type of clay and sodium (Na)

CHAPTER 4 NATURE AND BEHAVIOR OF CLAY

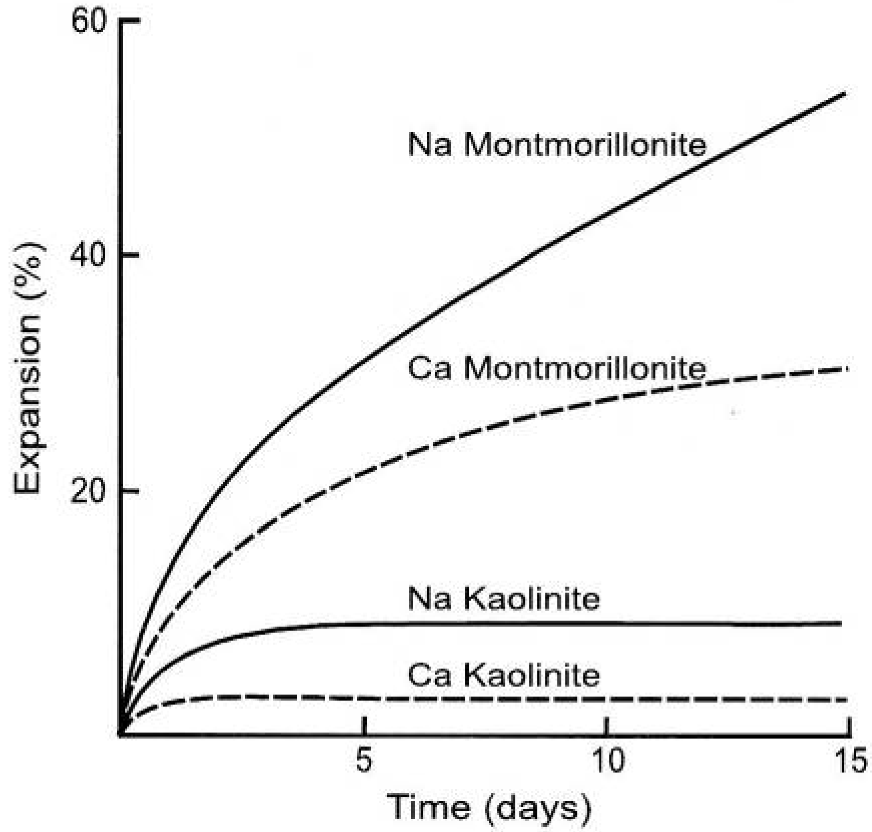

Fig. 4.11. Volume changes of montmorillonite and kaolinite clays during hydration.

Environmental Soil Physics. 1998. Daniel Hiller

Roots follow vertical shrinking crack in clay

Fig. 11.6. Plant roots located in a vertical shrinkage crack of Houston Black clay. Note that the roots apparently were unable to readily penetrate the vertical face of the crack. (Photograph courtesy of E. Burnett)

The Plant Root and Its Environment. 1974. E.W. Carson

Swelling soils – effect on soil structure over time

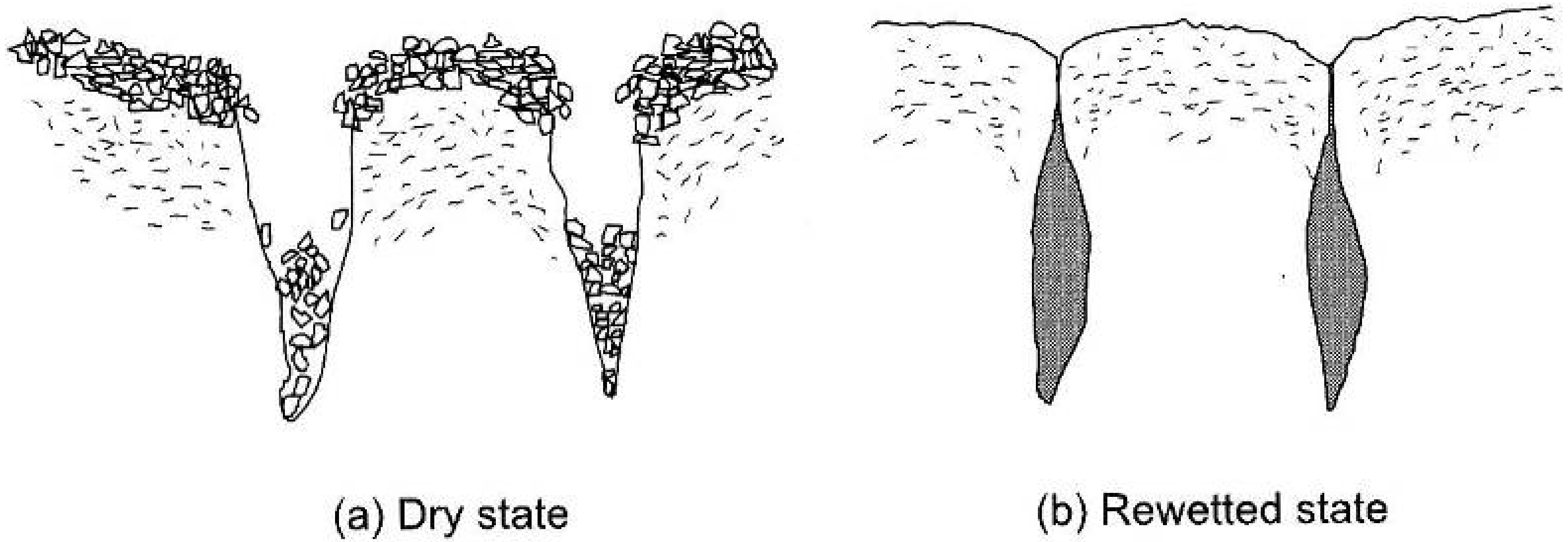

Fig. B4.1 Self-mixing in a vertisol.

Example of managing soil for increased structure with tillage systems
UC Santa Cruz Farm and Gardens

Key is organic matter additions

Greatly modified soil structure

Increased Soil Organic Matter Levels
Compost and Cover Crops

Increased Soil Organic Matter Levels
Compost and Cover Crops

Study questions Brady and Weil

- Chapter 4. Questions 2-5, 7-8