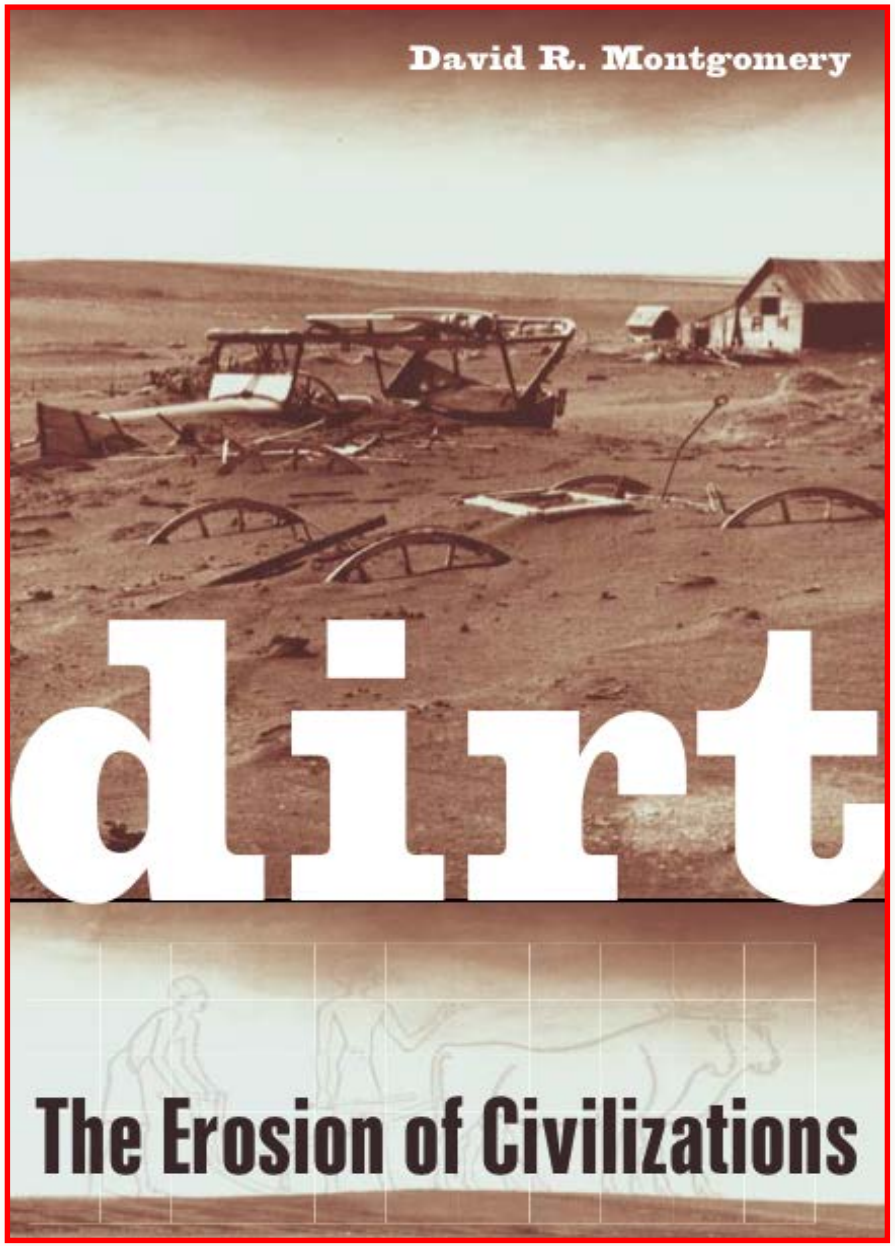
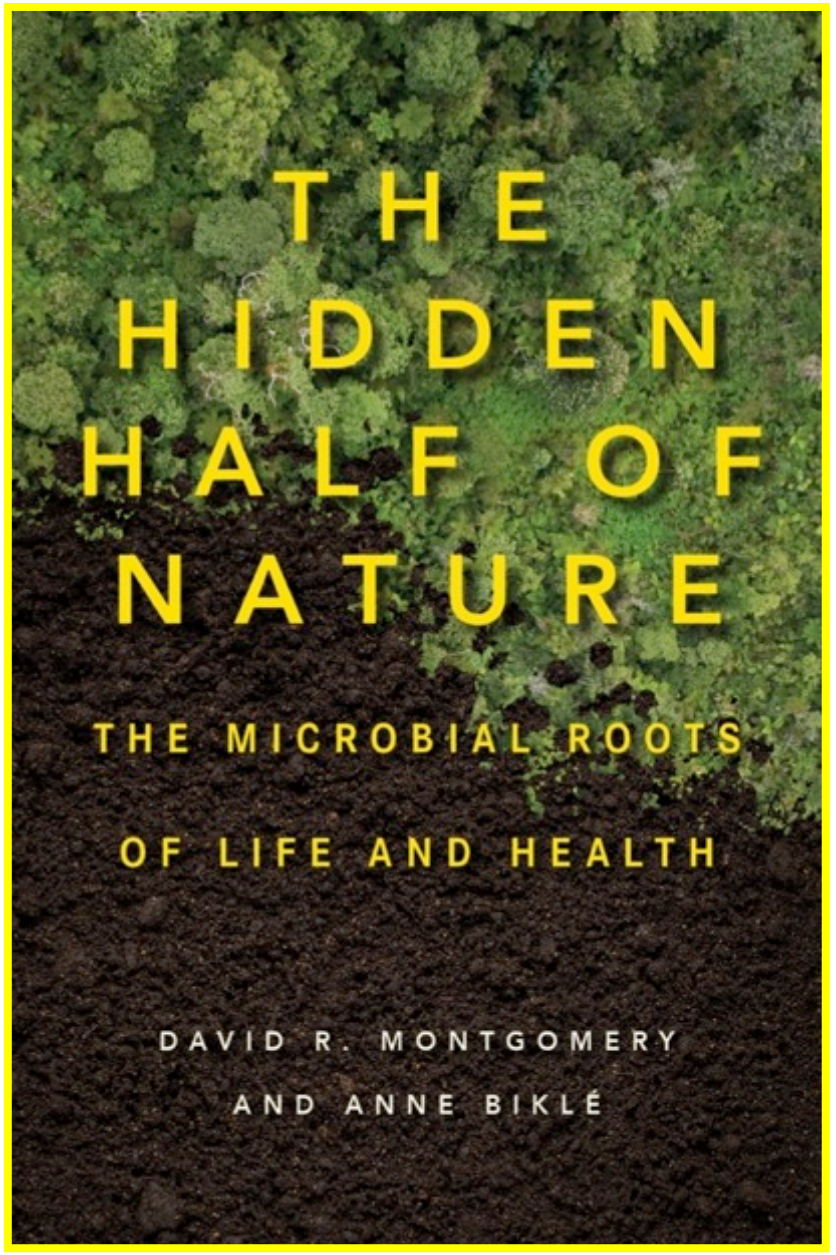




Twitter: @dig2grow

430 million ha of arable land lost to soil degradation, an area equivalent to about one third of all present cropland.

- Pimental et al., 1995

The world's agricultural soils have already lost 66 to 90 billion tons of carbon, mostly due to tillage.

- Lal, 1999

Soil erosion resulting from deforestation has been proposed to explain the demise of civilizations around the world.

Mesopotamia
Minoans
Greece
Rome

Indus
Angkor Watt

Olmec
Maya
Inca

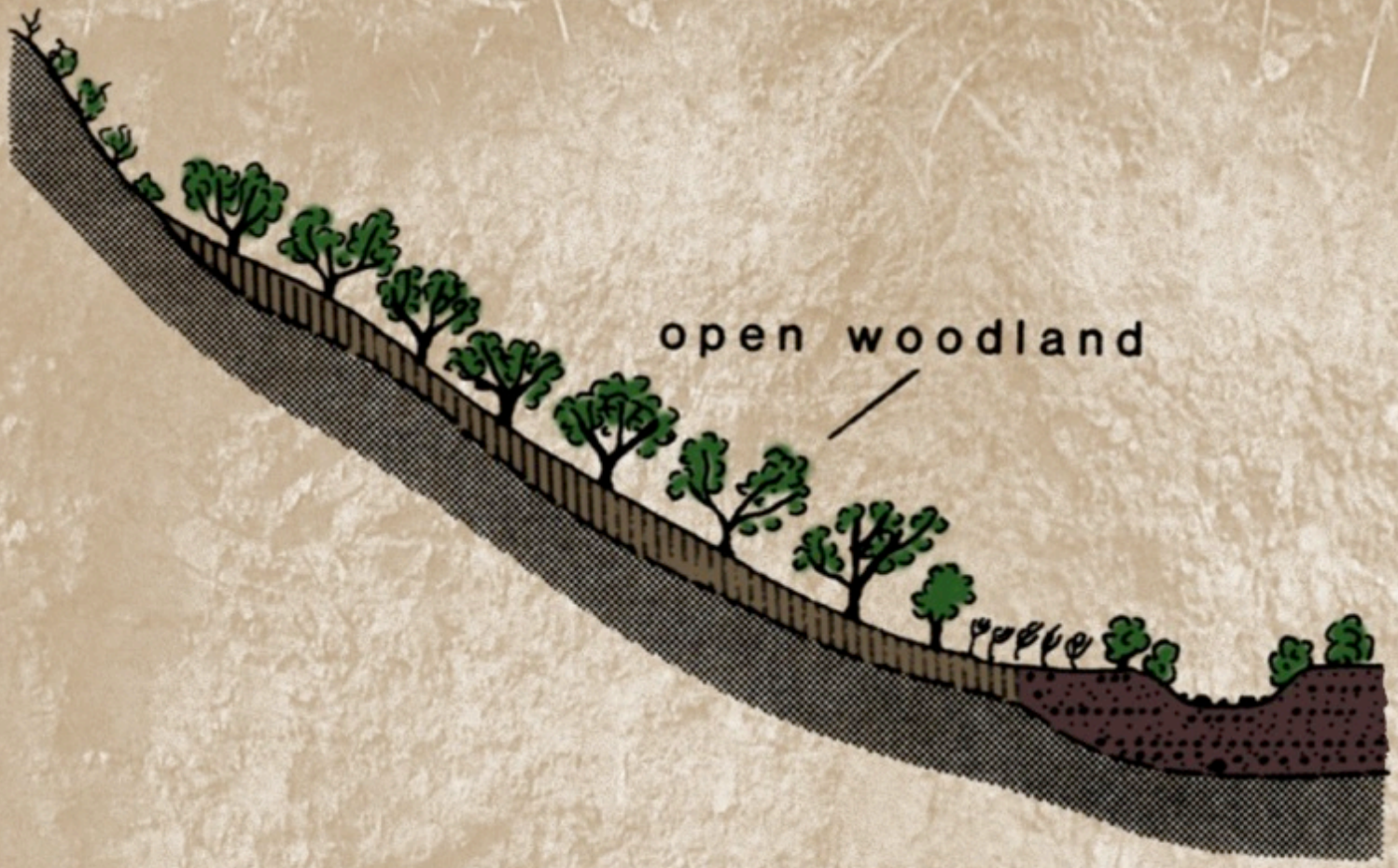
But in many regions trees can grow back before soil disappears…

Could agricultural soil erosion and degradation limit the life span of civilizations?

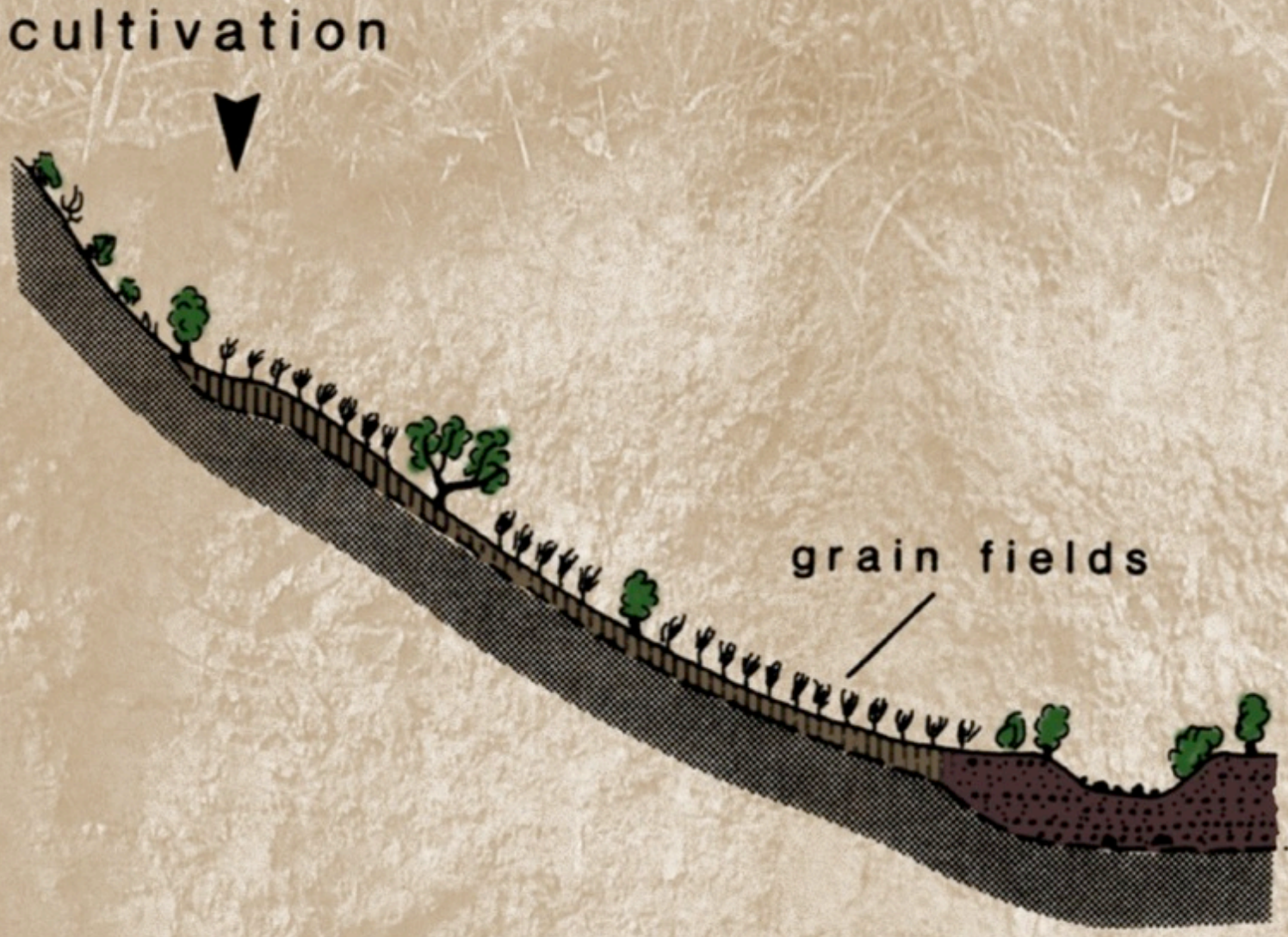
Recent archaeological studies showed that soil erosion played a role in the demise of ancient civilizations of Neolithic Europe, Classical Greece, Rome, the Southern United States, and Central America.

Invention of the plow fundamentally altered the balance between soil production and soil erosion, dramatically increasing soil erosion…

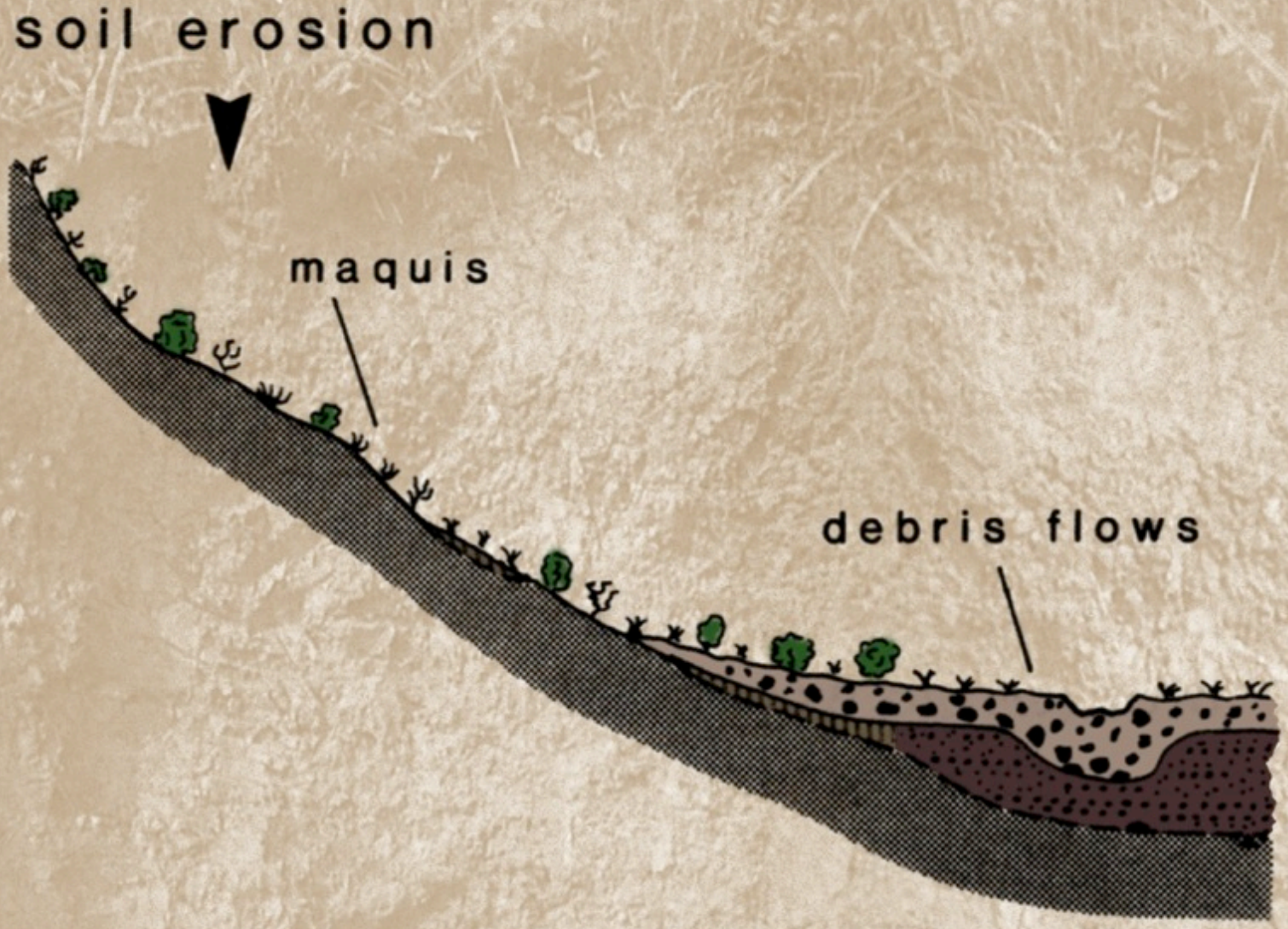
Cycles of erosion and soil formation in ancient Greece began with Bronze Age erosion after introduction of plow-based agriculture.



Van Andel and Runnels (1987)

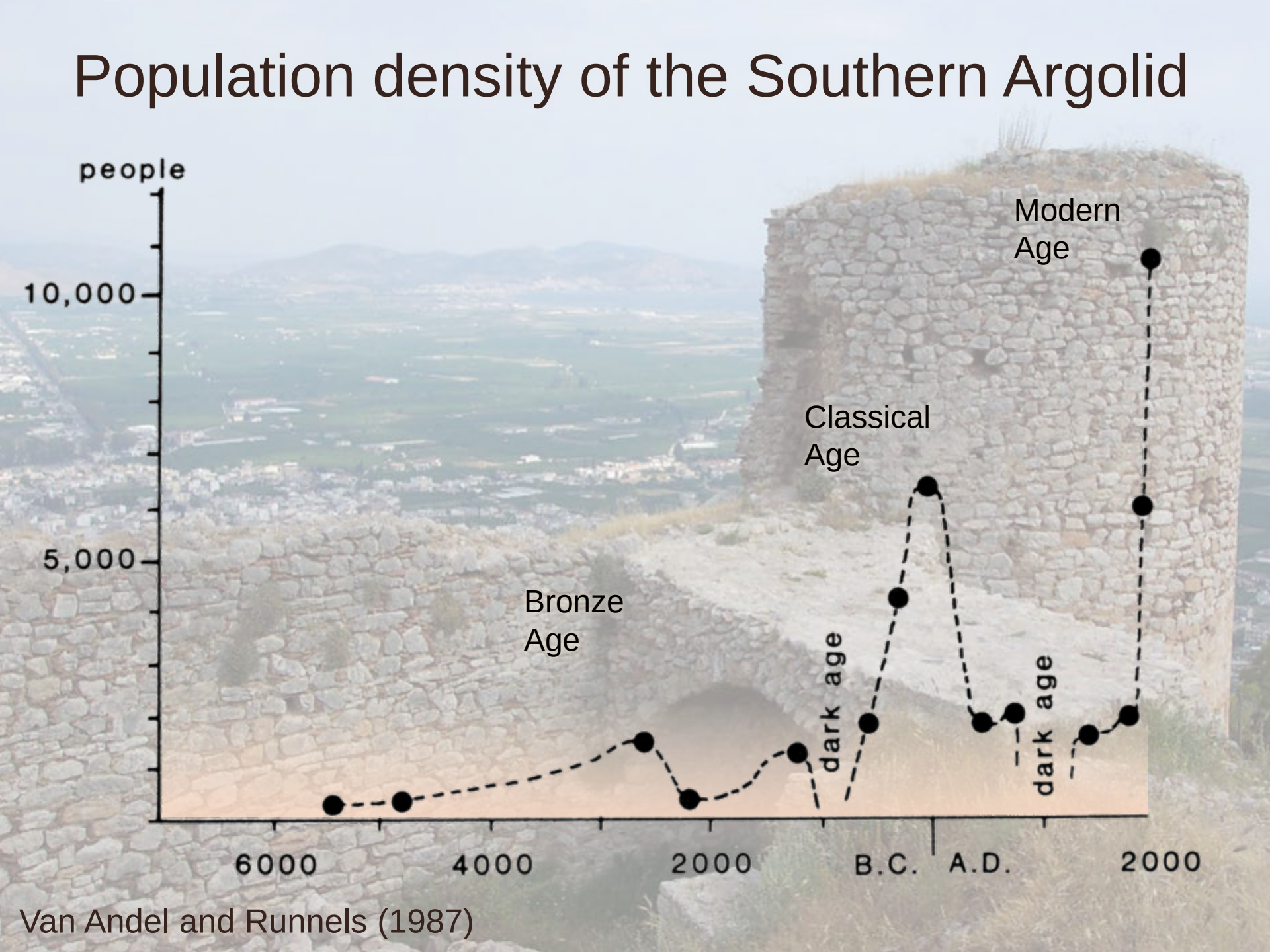


Van Andel and Runnels (1987)



Van Andel and Runnels (1987)

Population density of the Southern Argolid

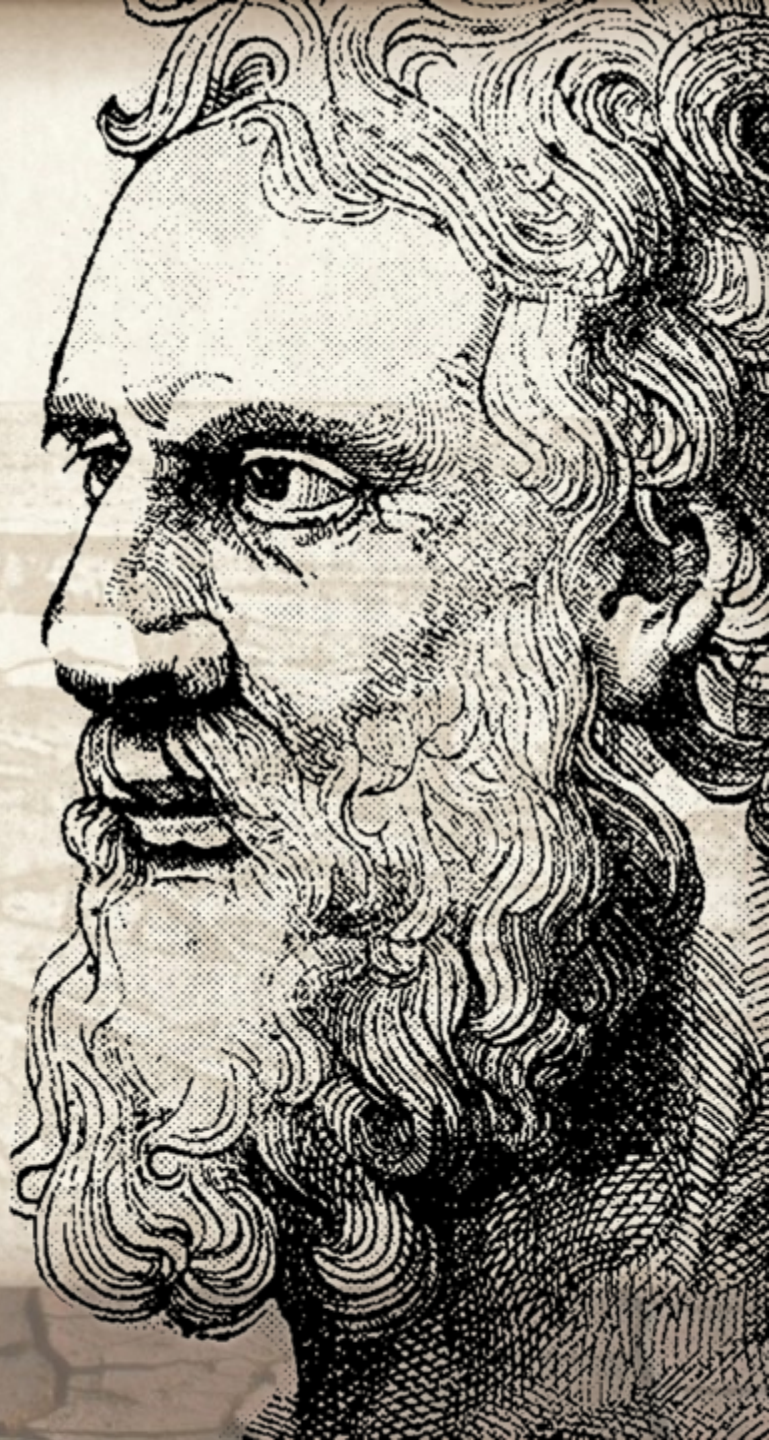


Van Andel and Runnels (1987)

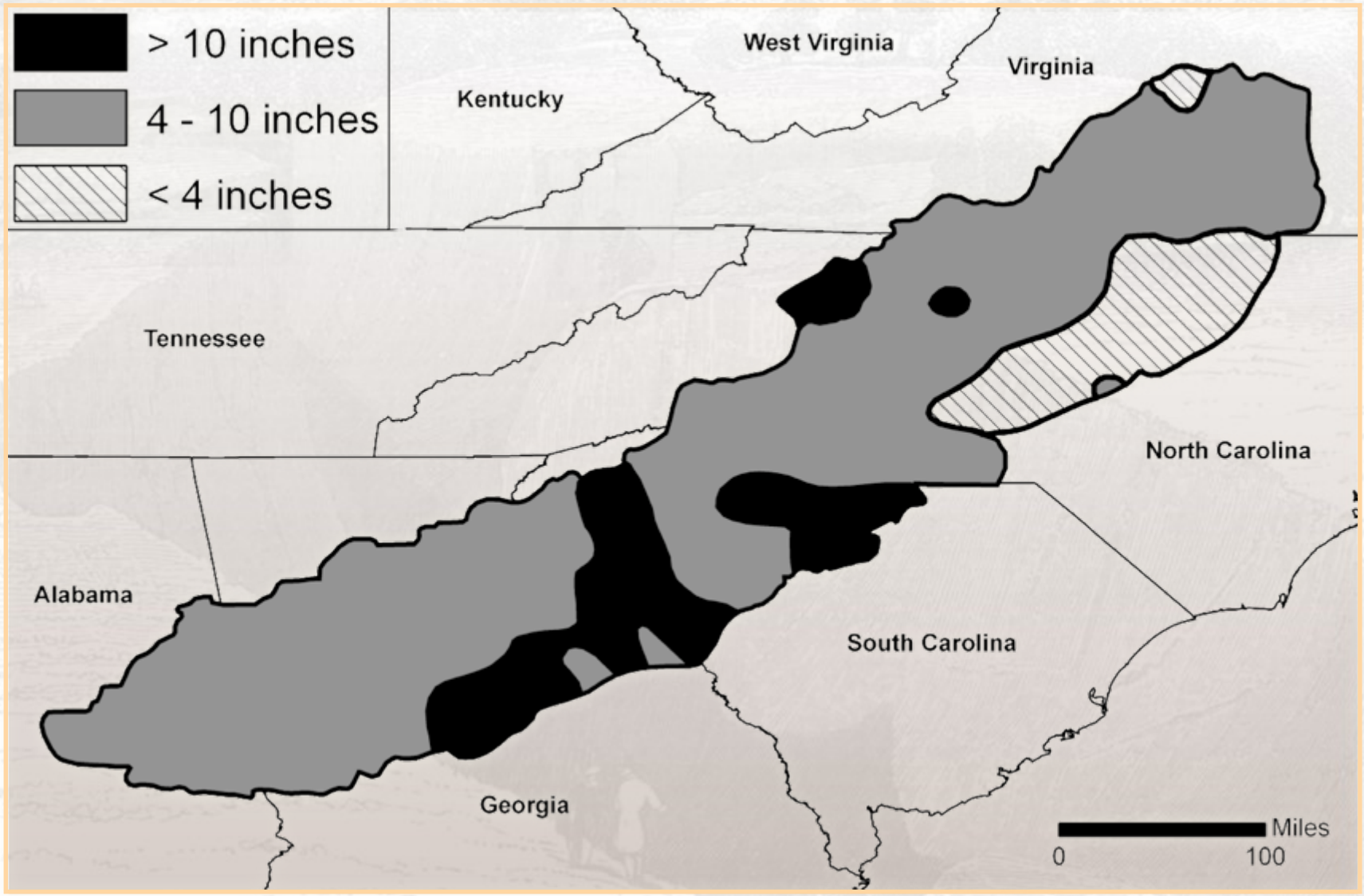
Plato

427-347 B.C.

The rich, soft soil has all run away leaving the land nothing but skin and bone. But in those days the damage had not taken place, the hills had high crests, the rocky plain of Phelleus was covered with rich soil, and the mountains were covered by thick woods, of which there are some traces today.



Historical soil erosion in the Piedmont region



after Trimble and Meade

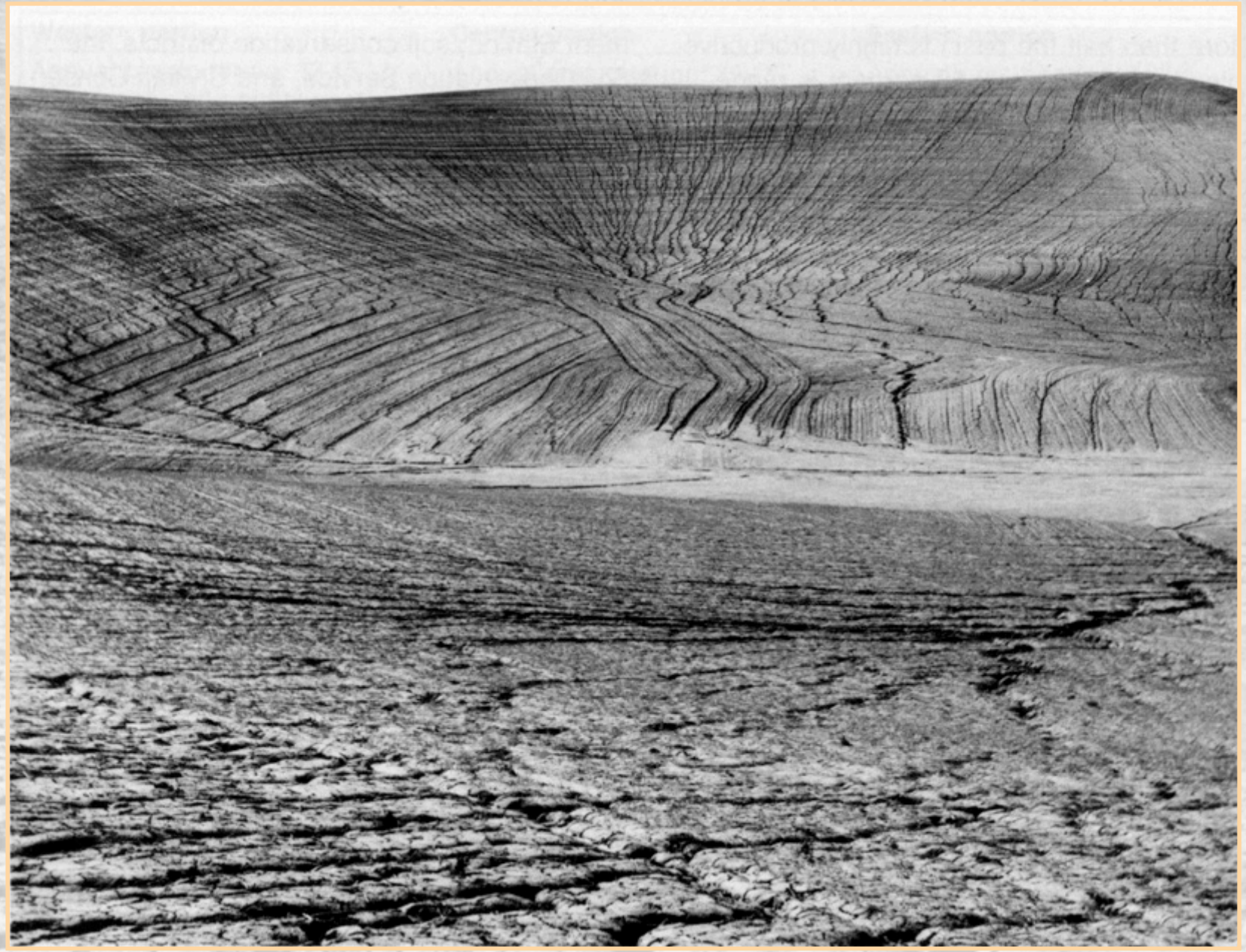
In a 1796 letter to Alexander Hamilton…

A few years more of increased sterility will drive the Inhabitants of the Atlantic States westward for support; whereas if they were taught how to improve the old, instead of going in pursuit of new and productive soils, they would make these acres which now scarcely yield them any thing, turn out beneficial to themselves.

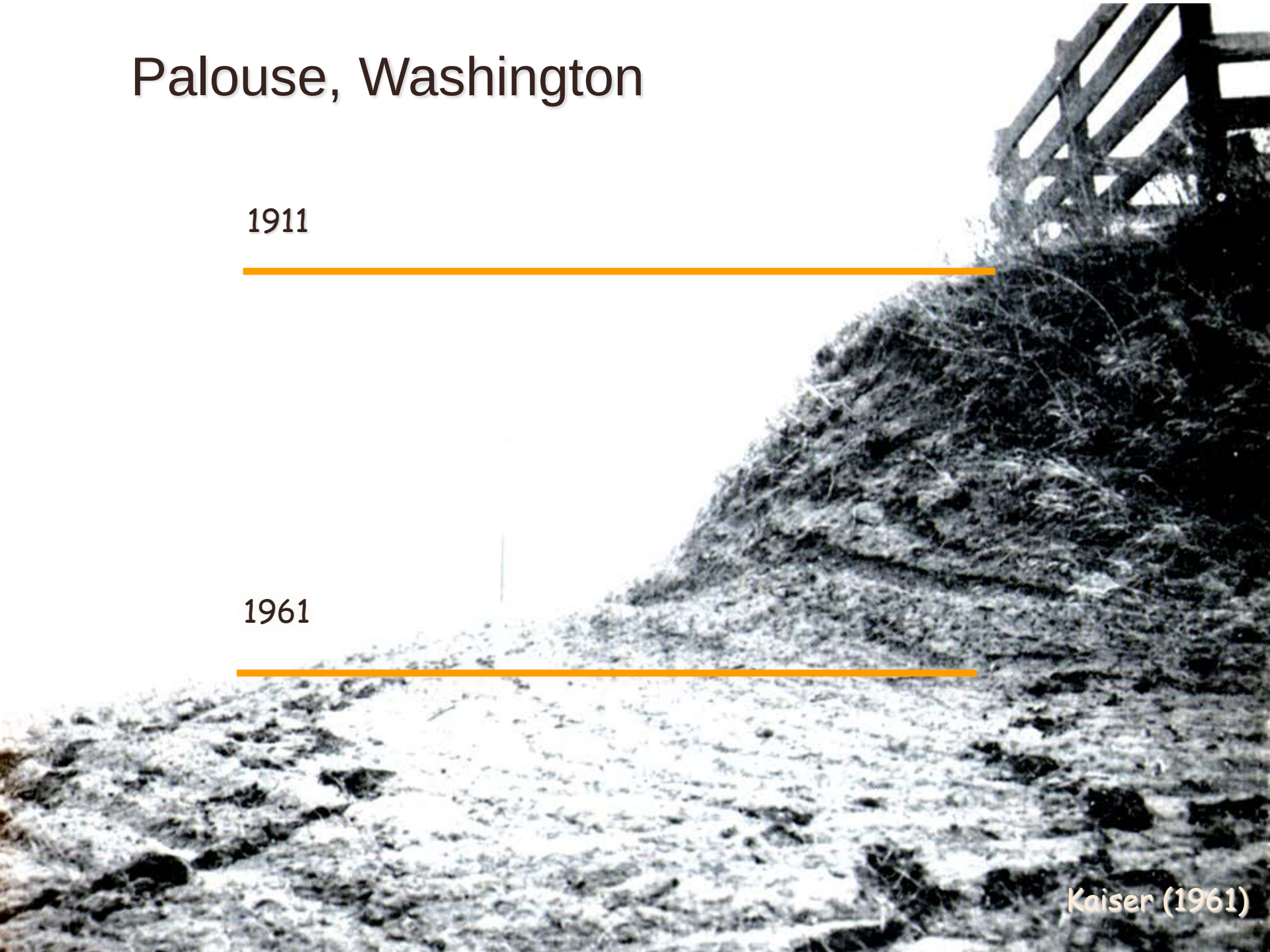
- [G. Washington, 1892, v. XIII, p. 328-329]

Palouse, Washington

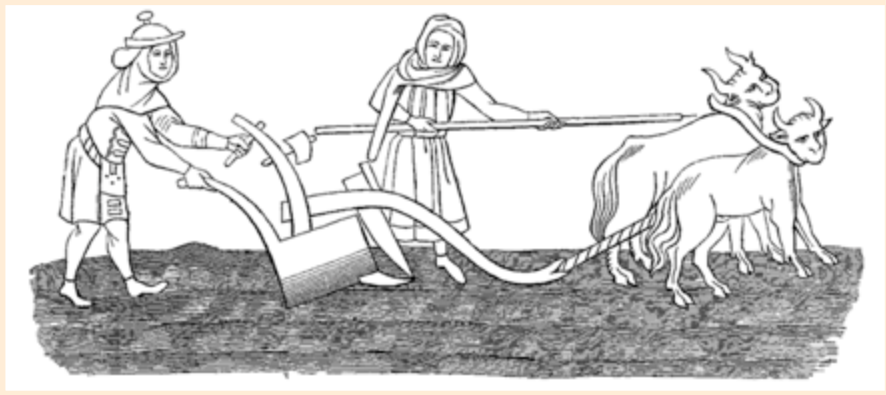
1970



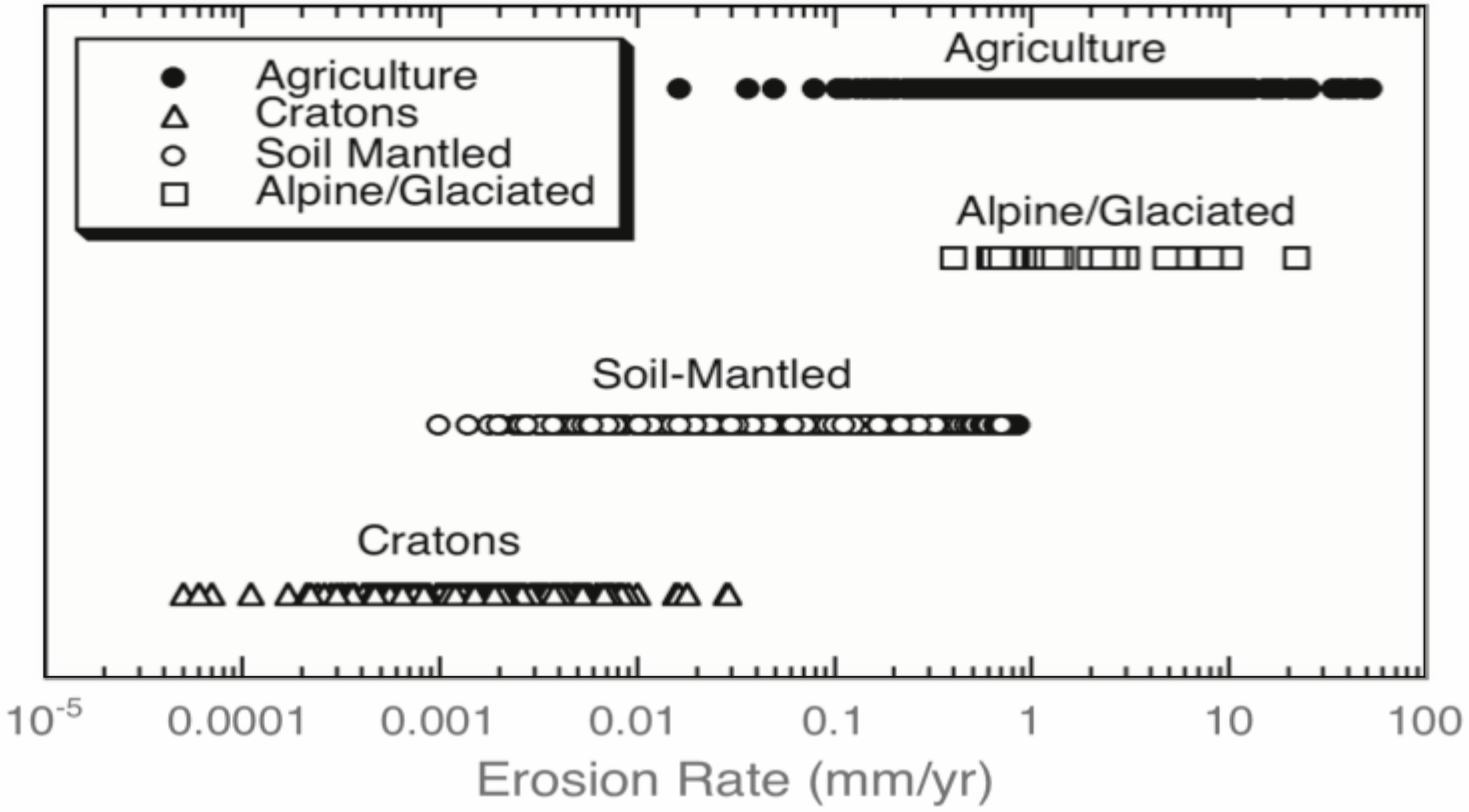
Palouse, Washington



In researching the book, I began compiling additional data on both contemporary and long-term (geological) erosion rates—and agricultural erosion rates in particular…



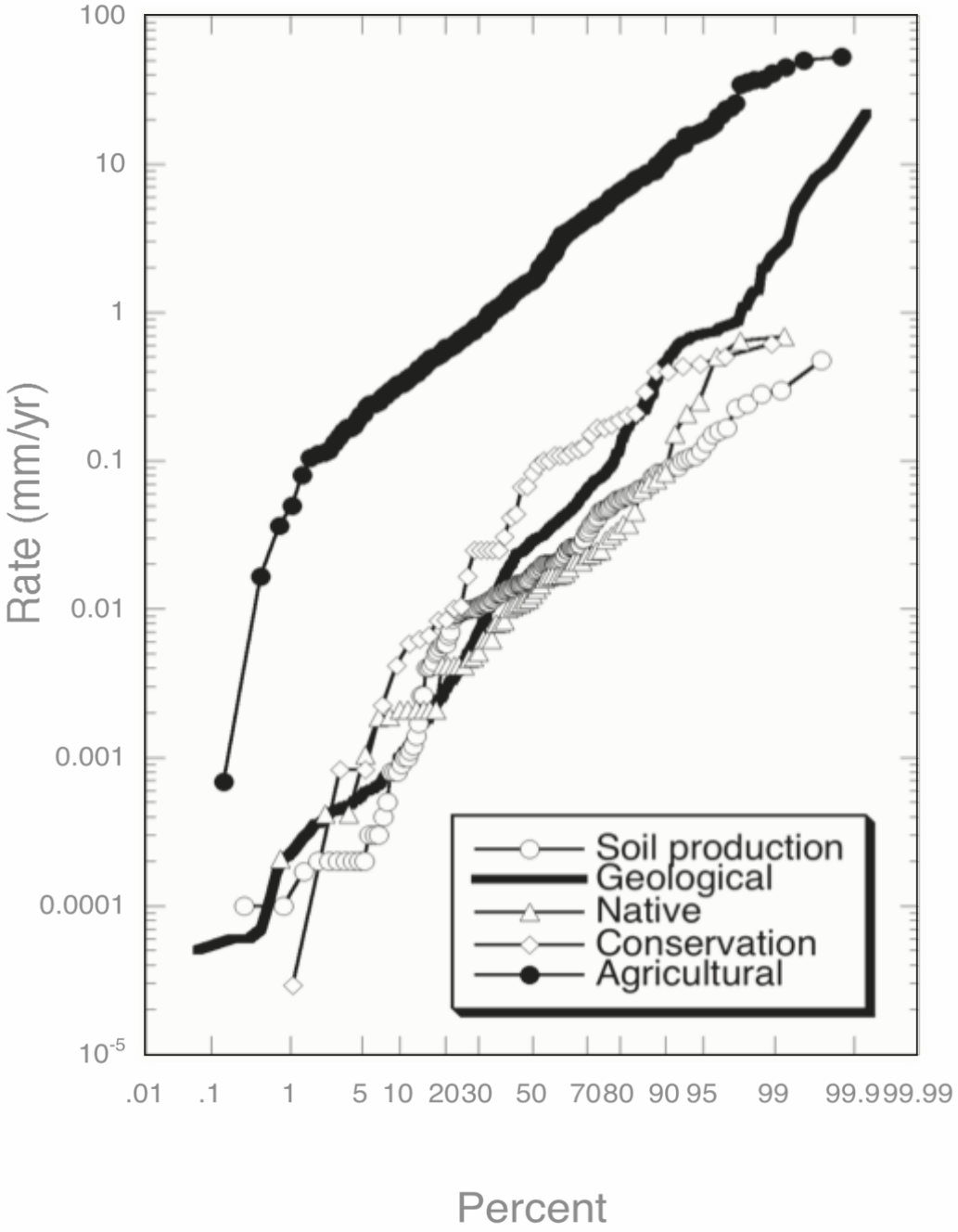
1402 measurements of agricultural and geological erosion rates



Did not include USLE-based model studies

Probability distributions for geological erosion rates, erosion under native vegetation, and by no-till agriculture are all comparable.

Agricultural soil loss is not because humanity farms but arises from how we farm.



Erosion Rates

Measurement type (sample size)	Median (mm/yr)	Mean (mm/yr)
Conventional (448)	1.537	3.939
Conservation (No-till) (47)	0.082	0.124
Native Vegetation (65)	0.013	0.053
Soil Production (188)	0.017	0.036
Geological (925)	0.029	0.173

Net soil loss of ≈ 1 mm/yr implies that erosion of a typical 0.5 to 1 m thick hillslope soil could occur in roughly 500 to 1000 years.

This is approximately the lifespan of most major civilizations outside of major river floodplains…

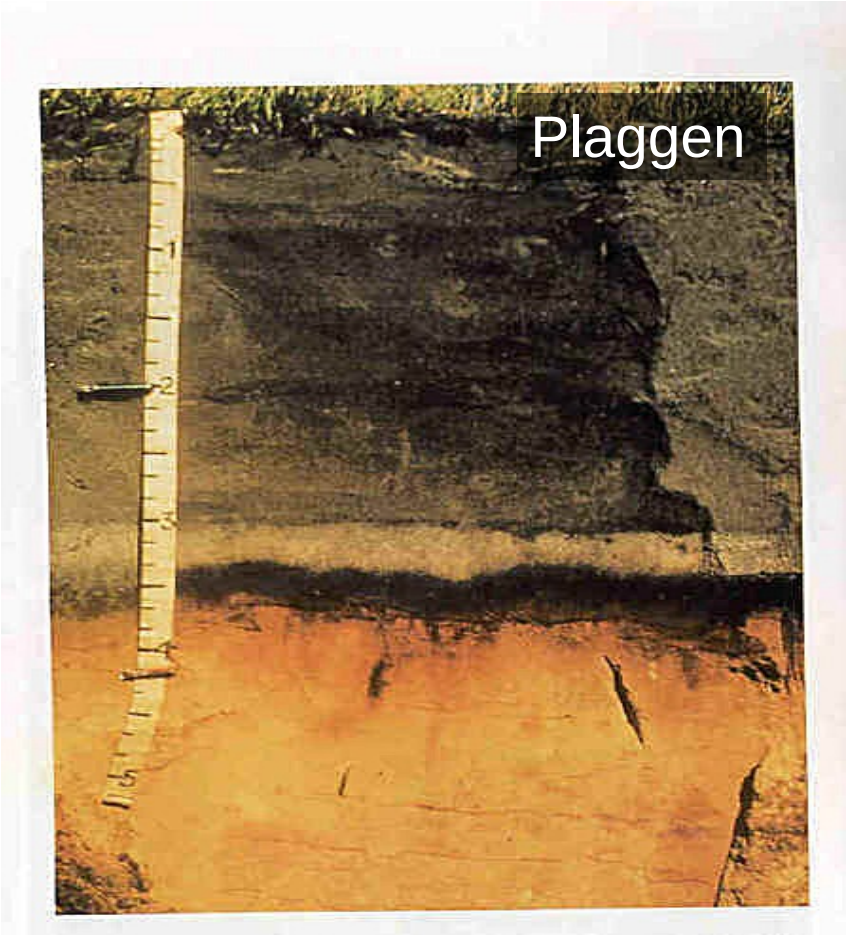
A nation that destroys its soils, destroys itself.
– President Franklin D. Roosevelt, Feb. 26, 1937.

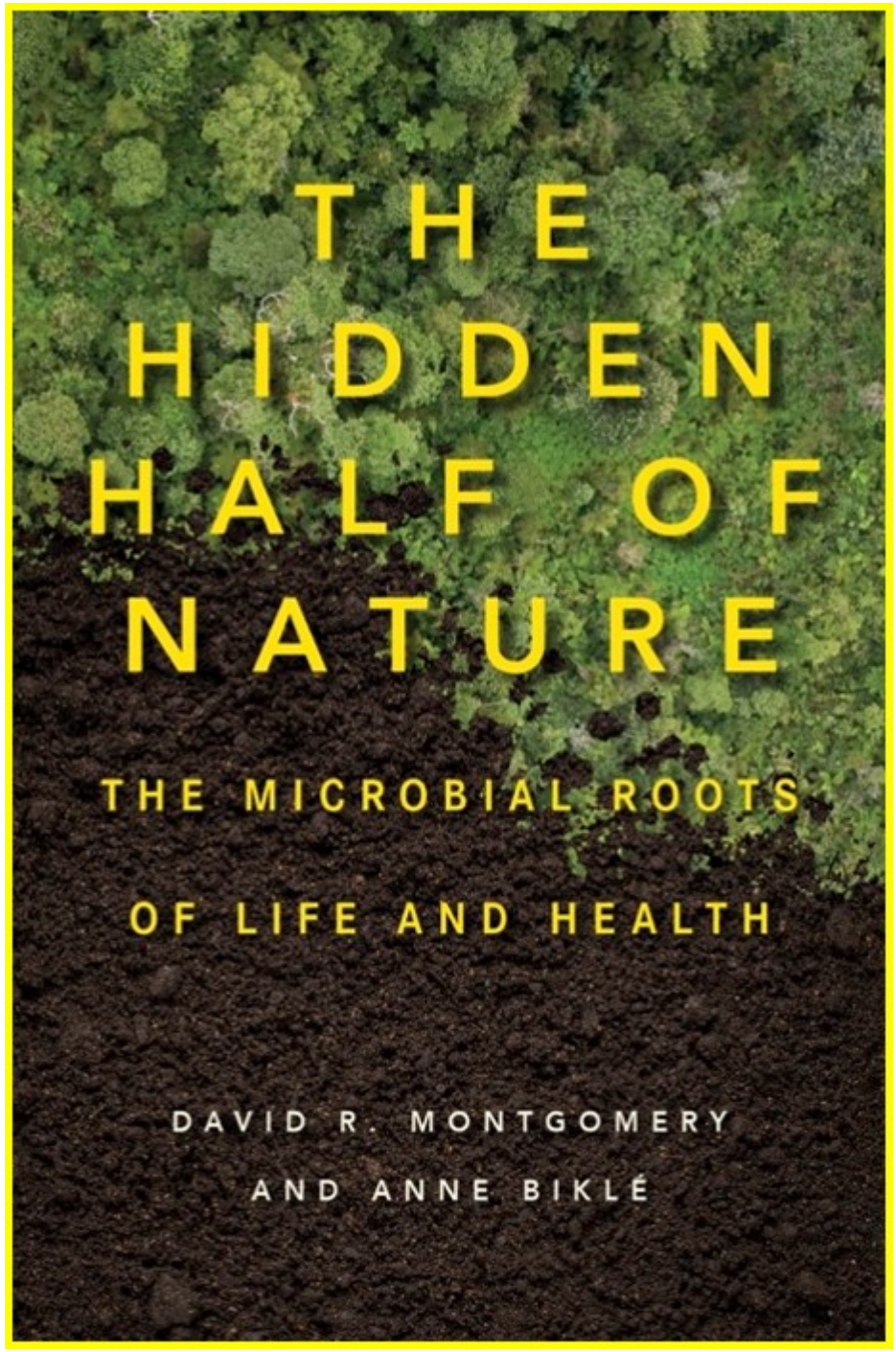
National Archives: 114 SC 5089

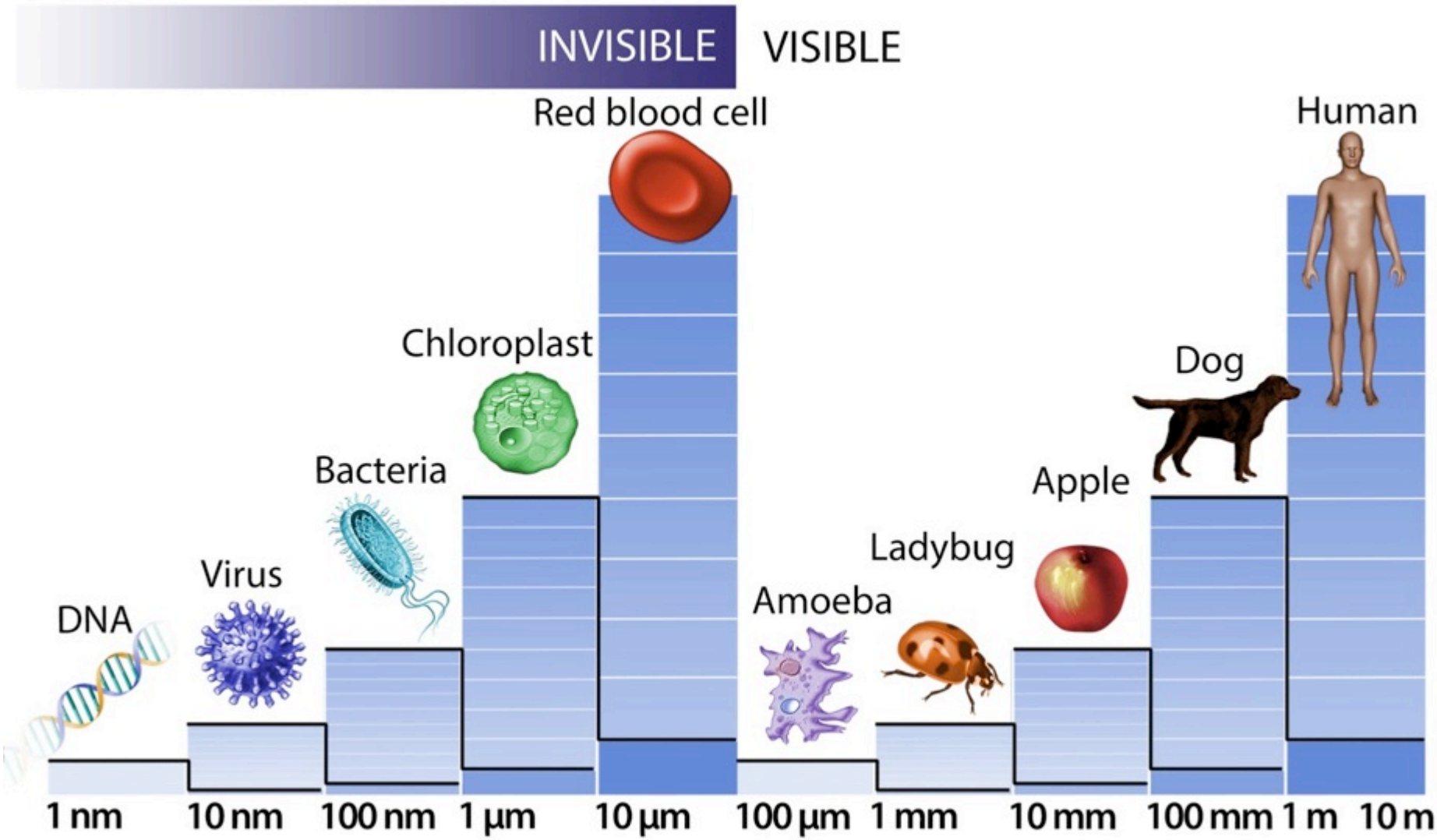
Is Soil Restoration Possible?

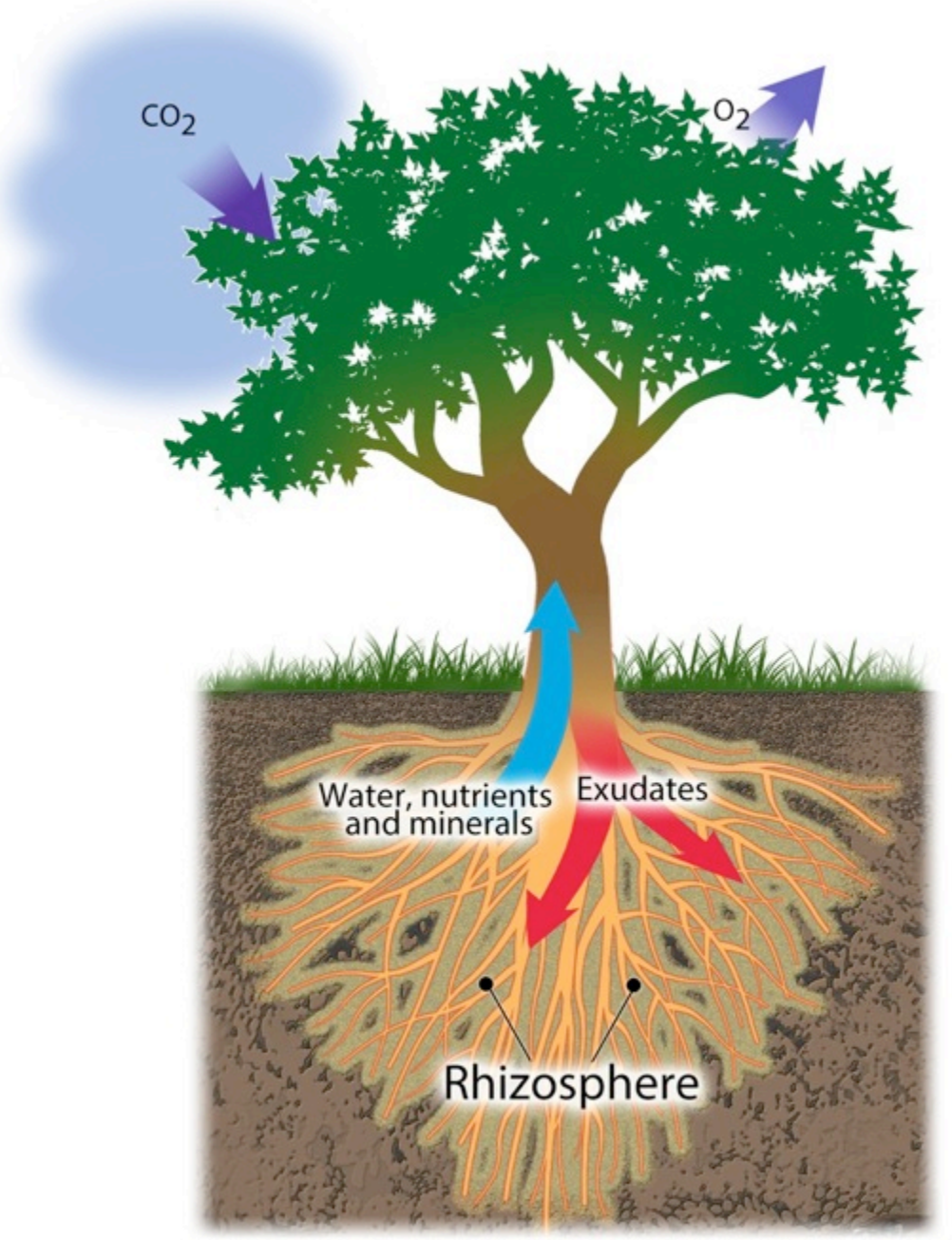
Can we reverse the historical pattern?

Fertile carbon-rich soils built by anthropogenic activity in the Amazon and reclaimed sea beds in northern Europe.



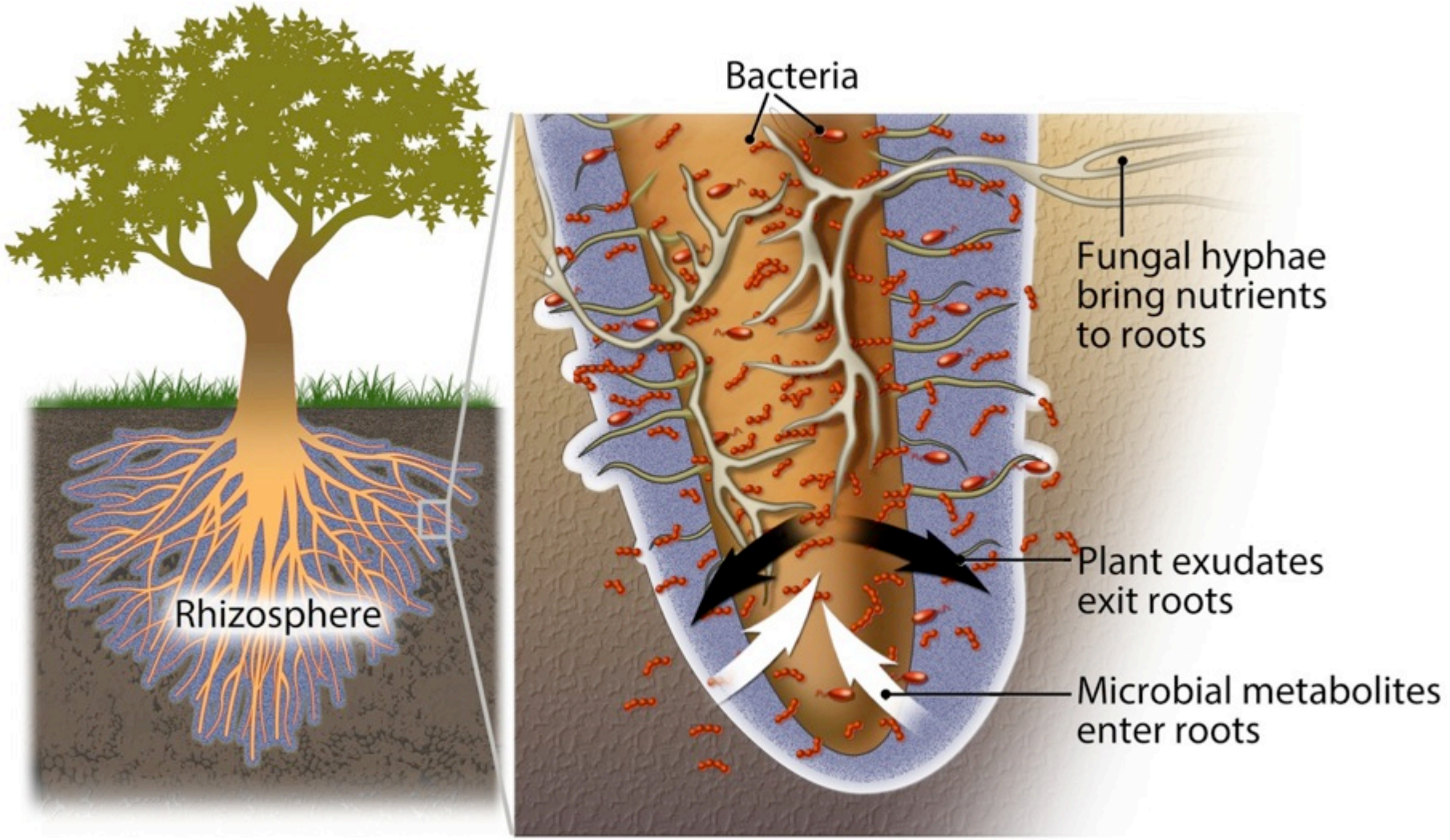

THE HIDDEN HALF OF NATURE
THE MICROBIAL ROOTS OF LIFE AND HEALTH
DAVID R. MONTGOMERY AND ANNE BIKLÉ


INVISIBLE
VISIBLE
Red blood cell
Human
Chloroplast
Dog
Bacteria
Apple
Ladybug
Virus
Amoeba
DNA
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
10 mm
100 mm
1 m
10 m

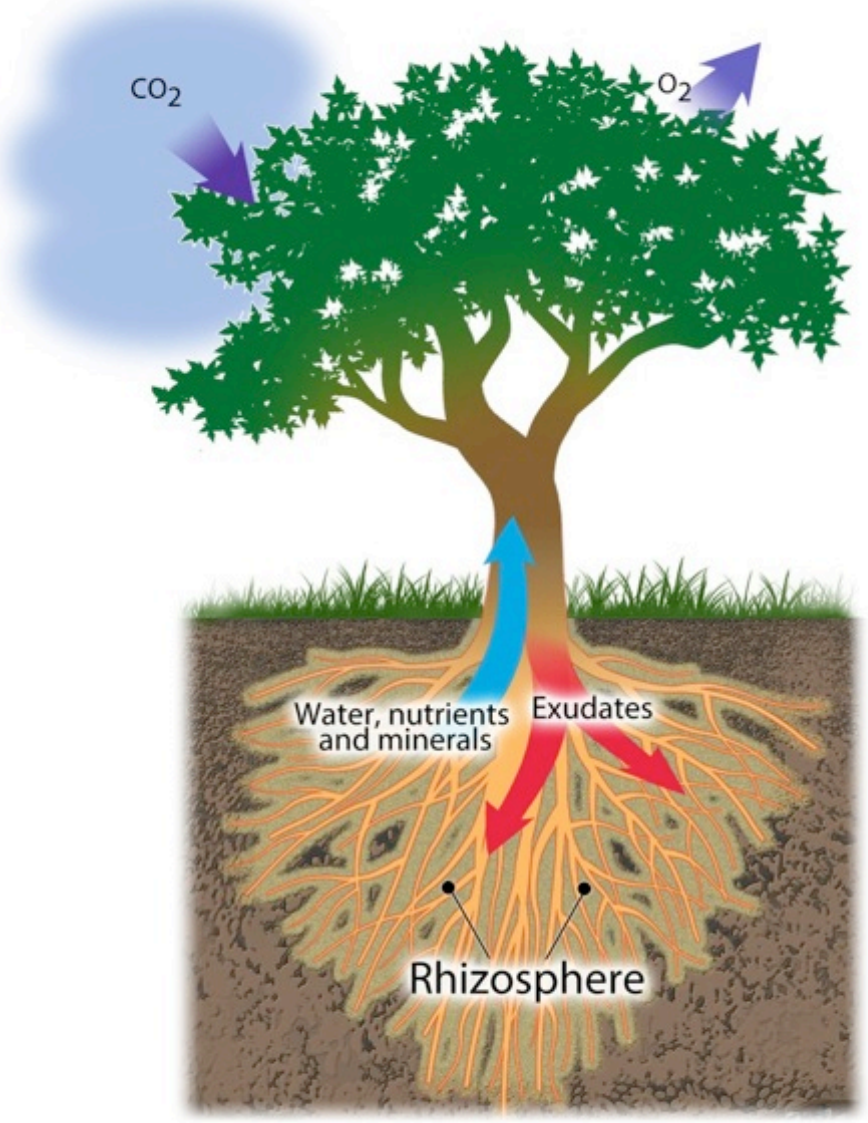


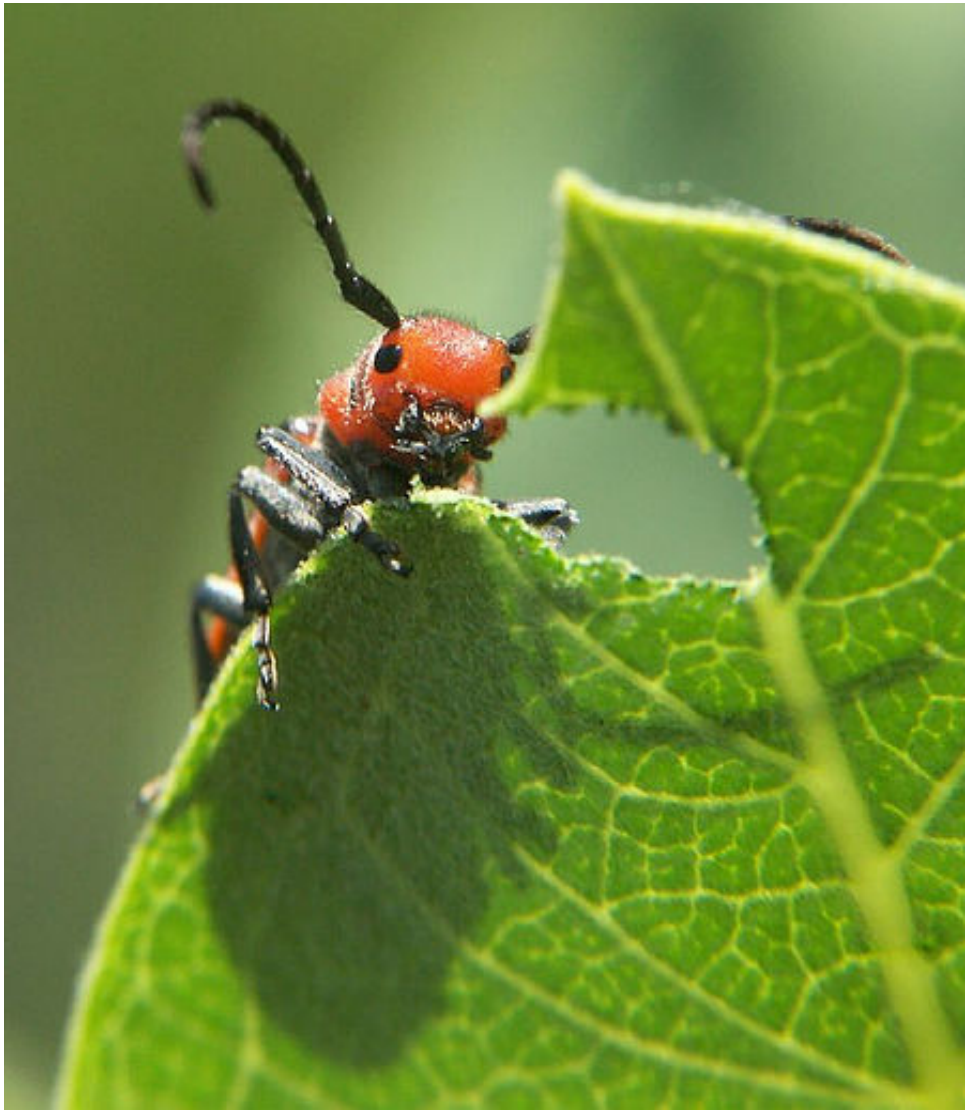
The rhizosphere is a zone rich with microbial life, a living halo that surrounds plant roots

The rhizosphere is a biological bazaar where microbes and plants trade nutrients, metabolites, and exudates

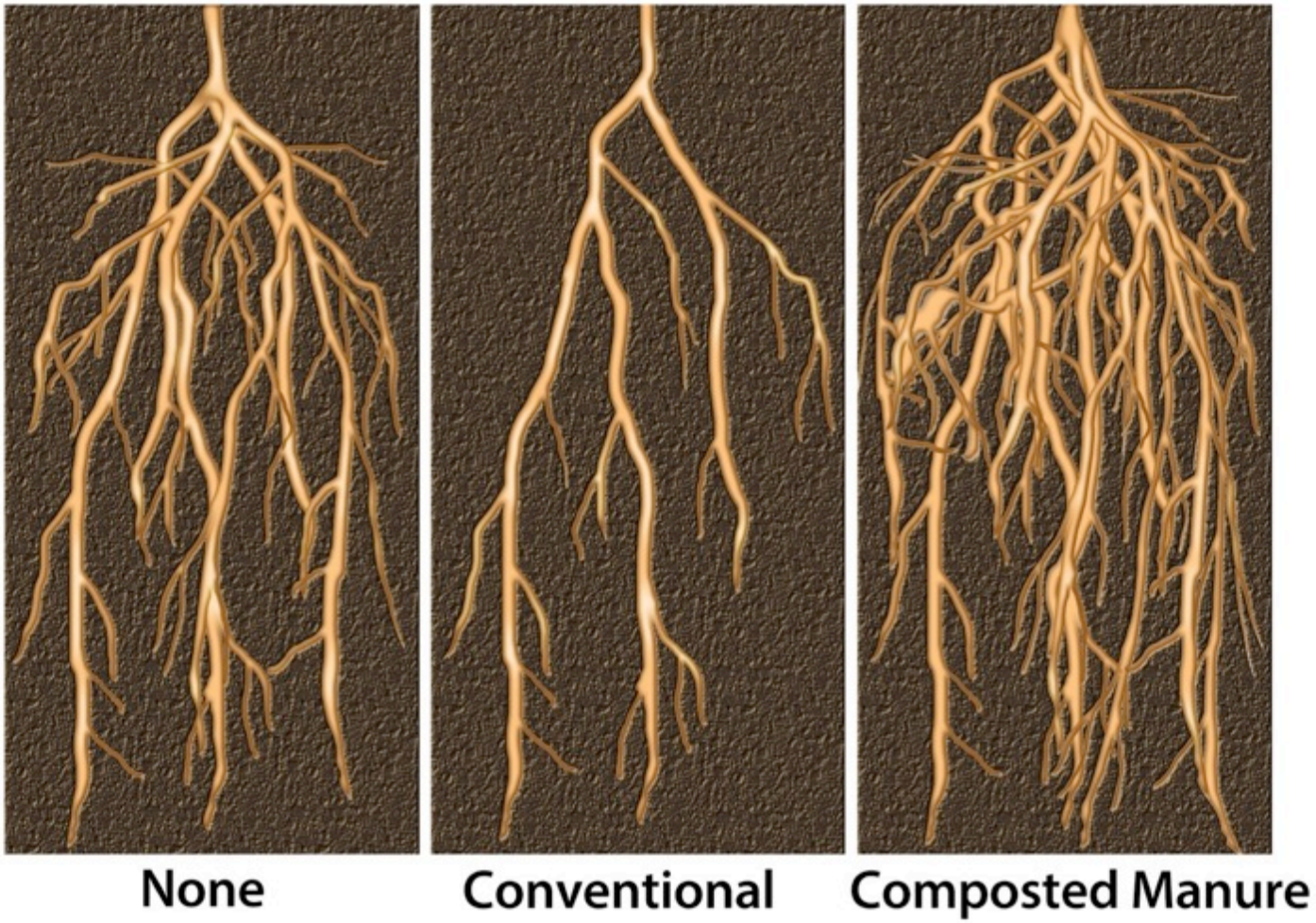


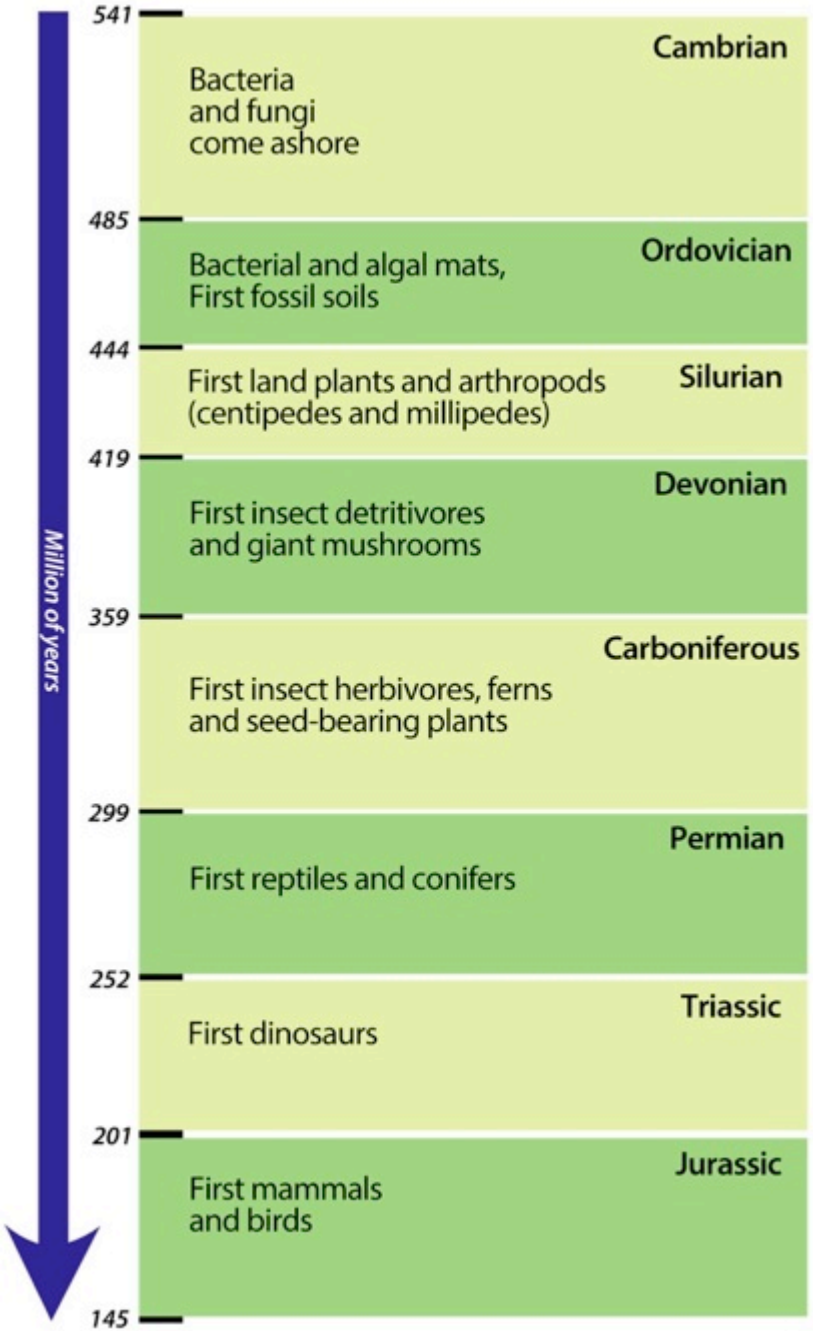
When above-ground pests attack, plants can release chemical signals that stimulate microbes in the rhizosphere to produce compounds that repel the pests



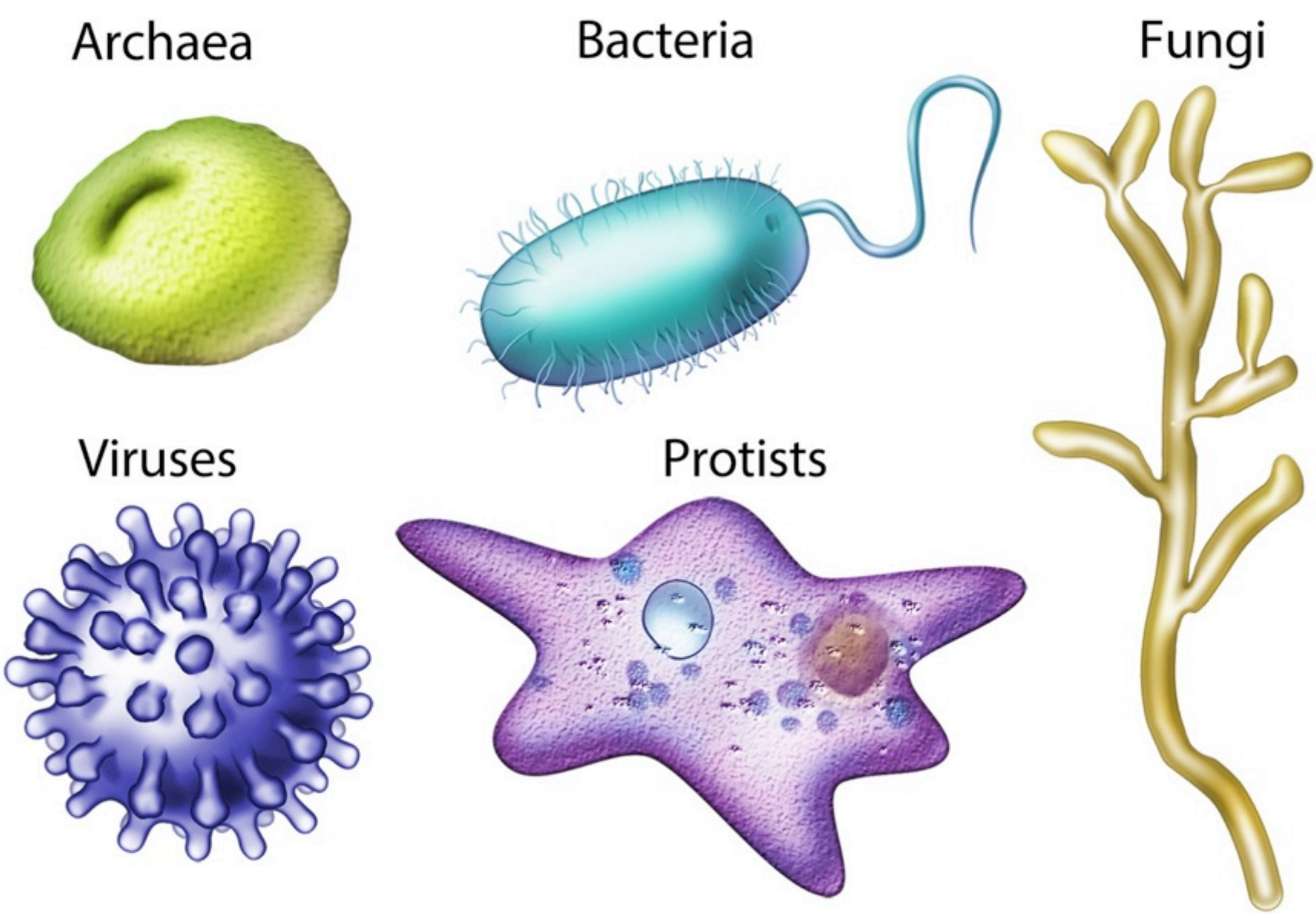


Fertilization can affect root growth and the production of plant exudates, which influences microbial life in the rhizosphere.

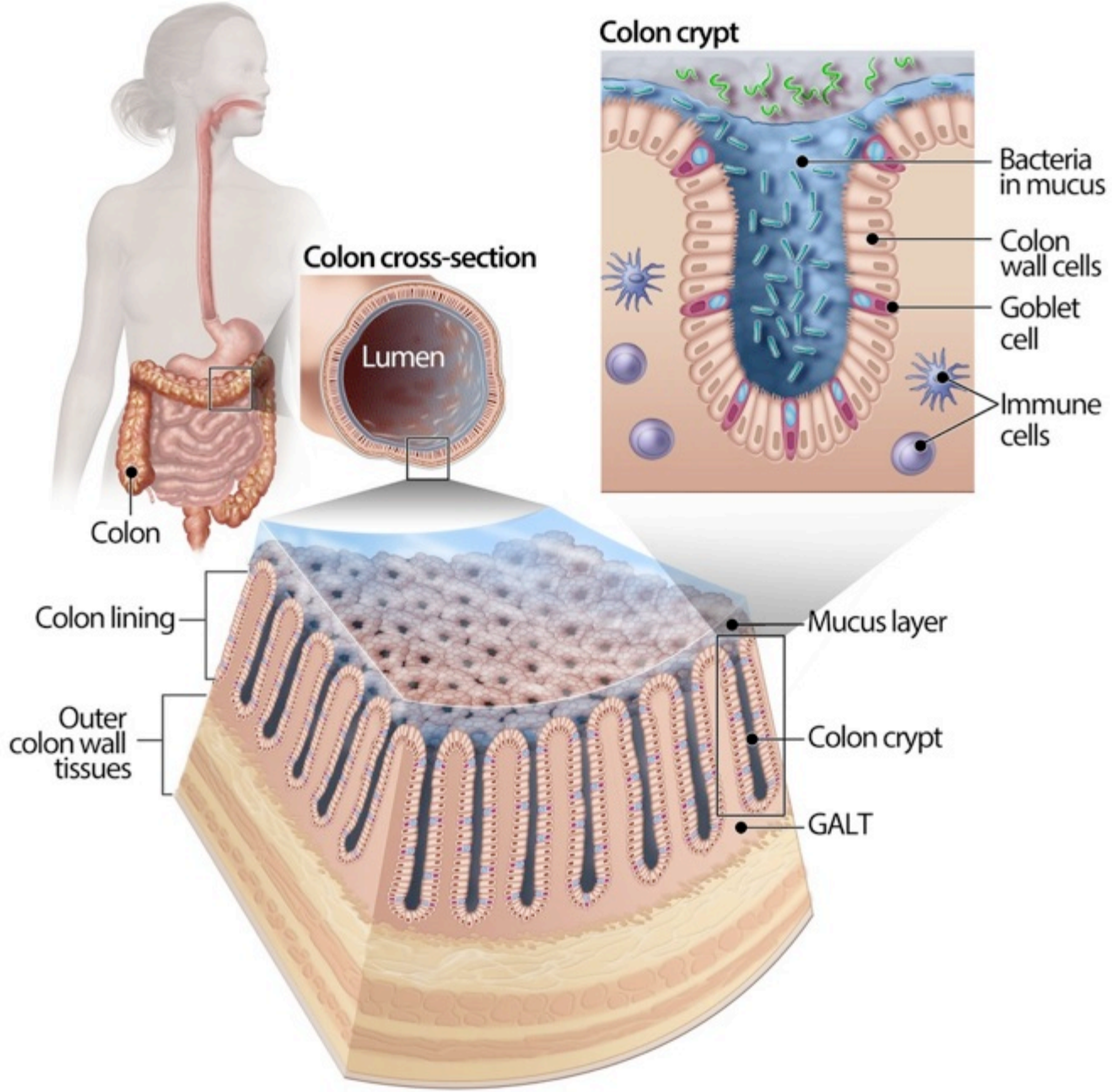


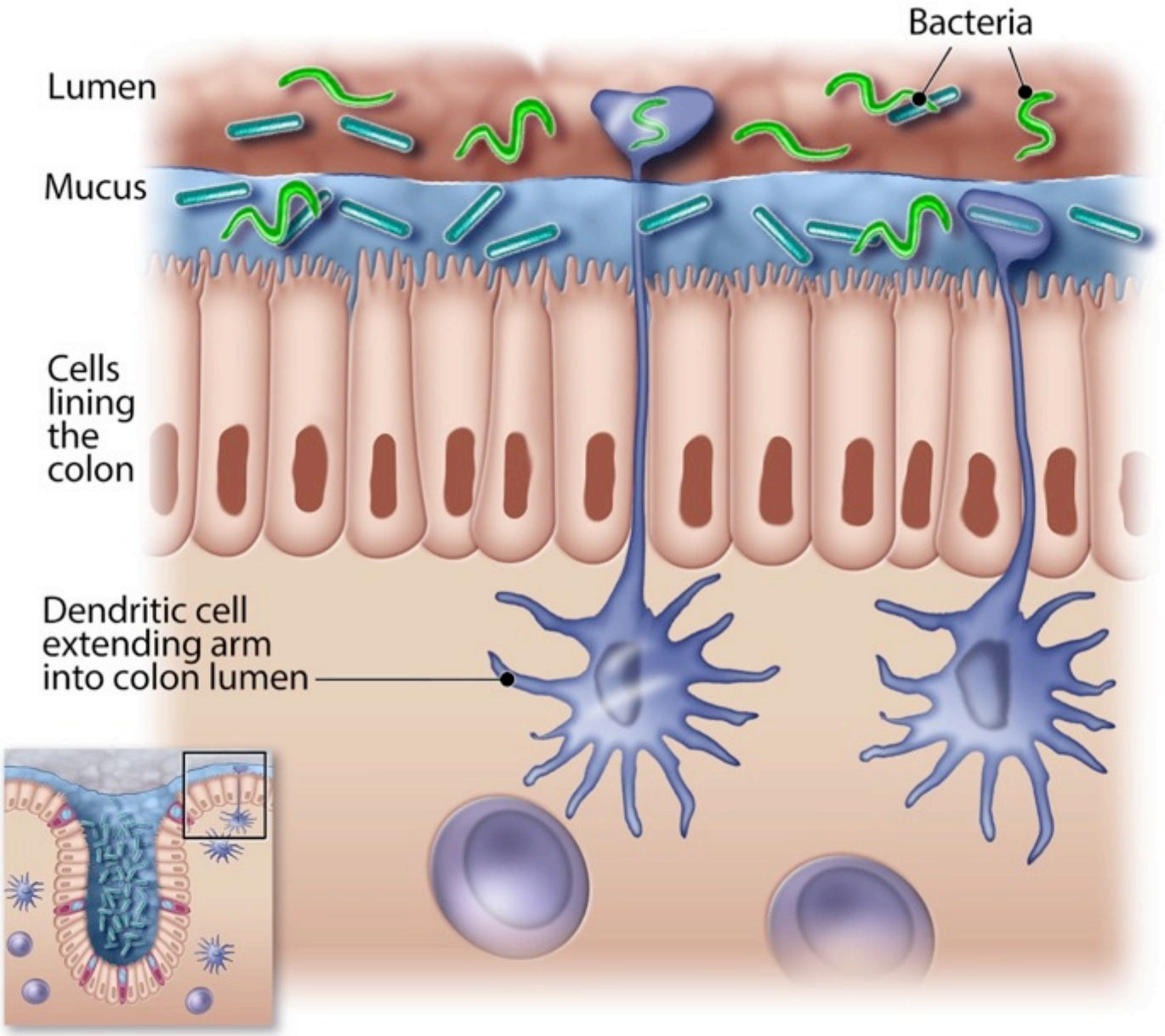


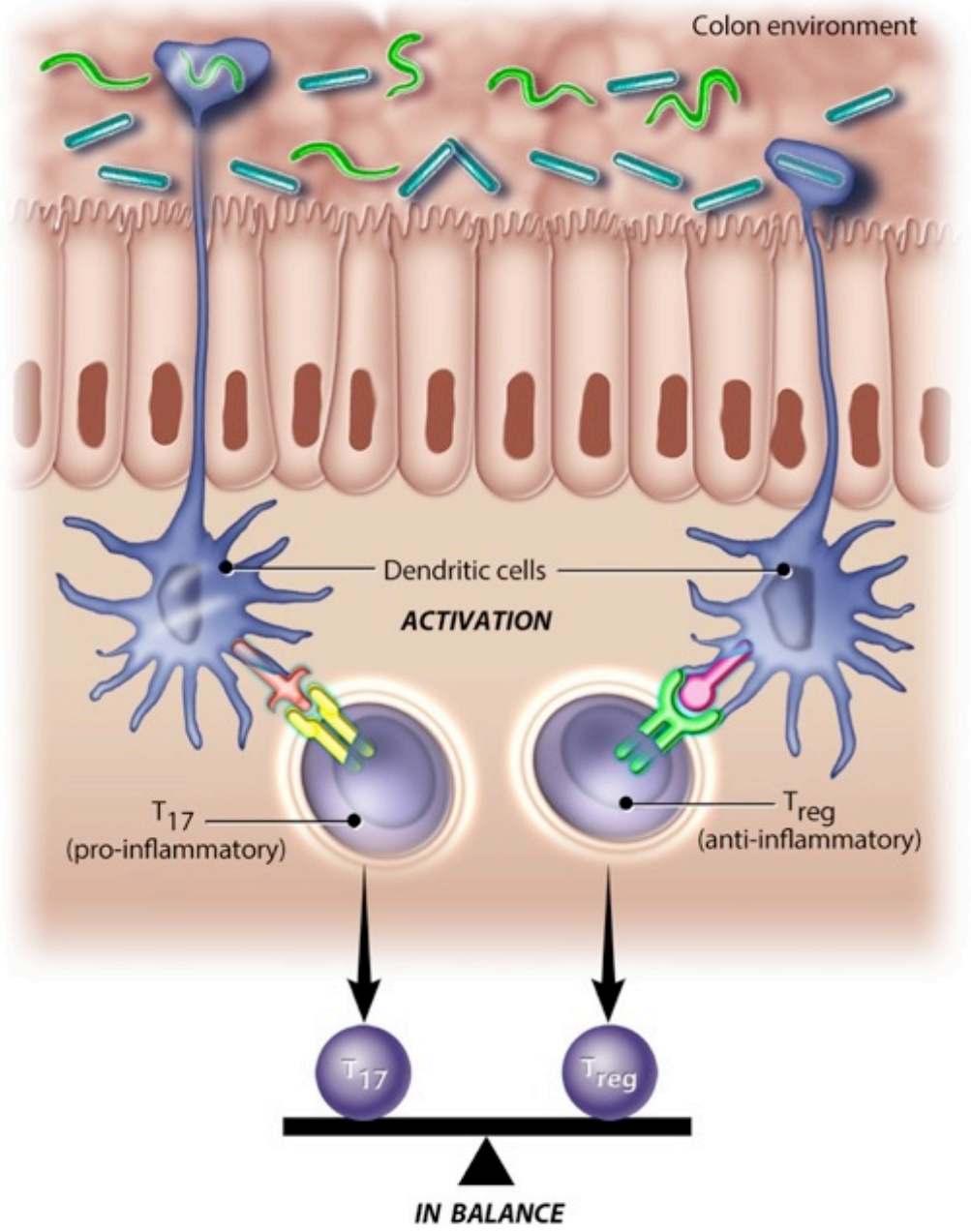
Life came back to our yard in the same order as it evolved on Earth (without the dinosaurs) … microbial life below ground fueled an explosion of life above ground.


Archaea
Bacteria
Fungi
Viruses
Protists

Cells Genes Health


Colon crypt
Bacteria in mucus
Colon wall cells
Goblet cell
Immune cells
Colon cross-section
Lumen
Colon
Colon lining
Outer colon wall tissues
Mucus layer
Colon crypt
GALT


Bacteria
Lumen
Mucus
Cells lining the colon
Dendritic cell extending arm into colon lumen


Colon environment
Dendritic cells
ACTIVATION
T17
(pro-inflammatory)
Treg
(anti-inflammatory)
T17
Treg
IN BALANCE

Change in Infectious and Chronic Disease

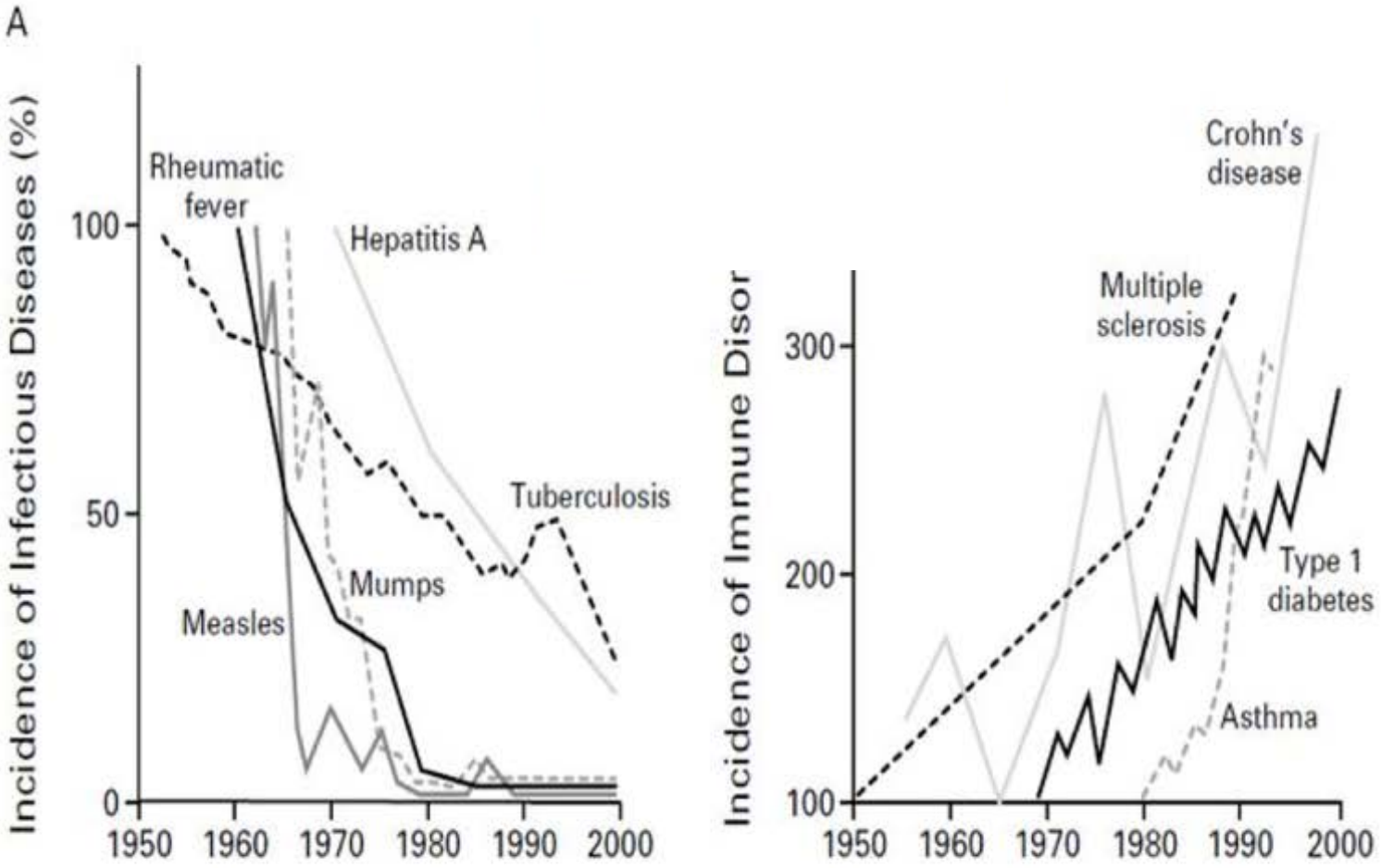
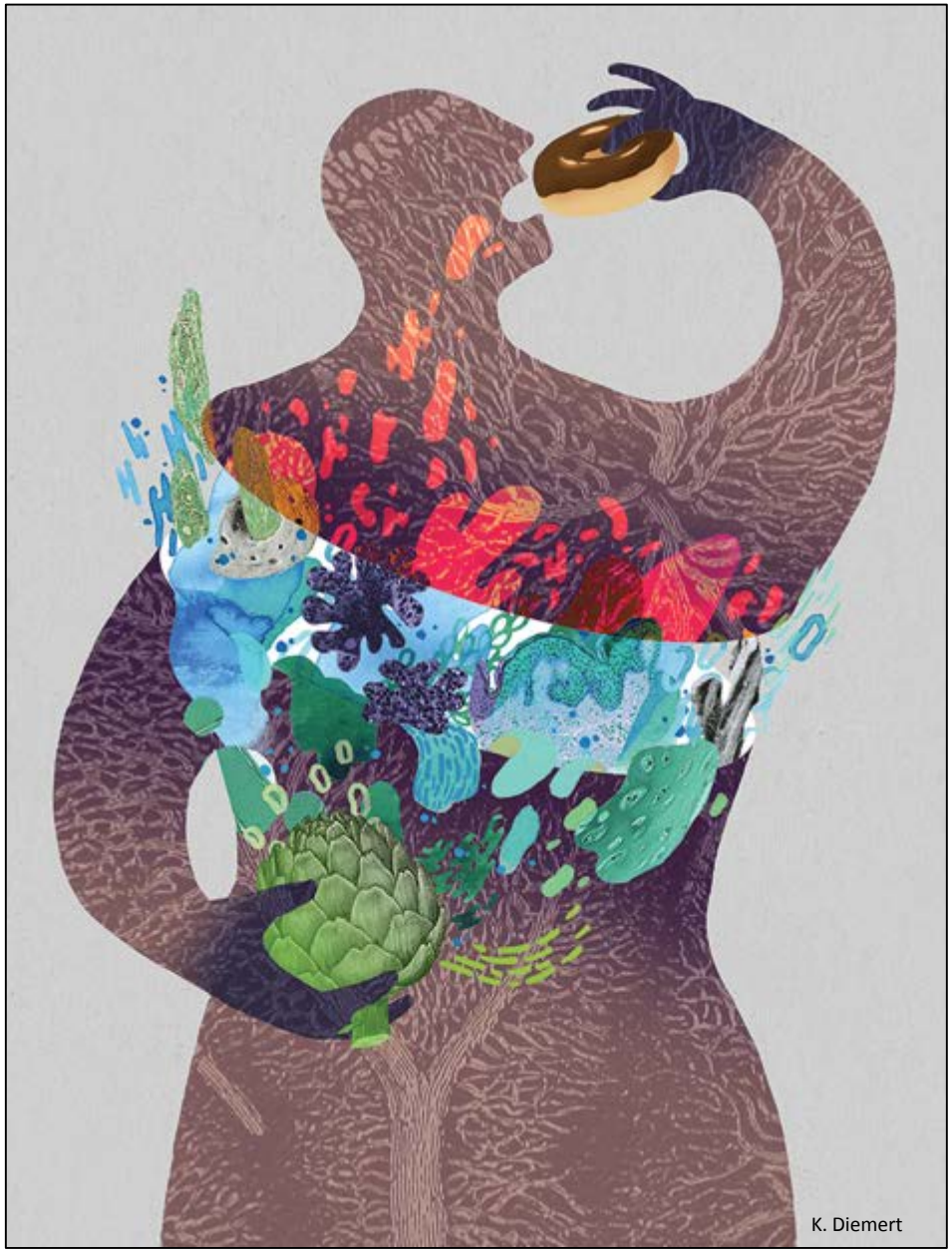
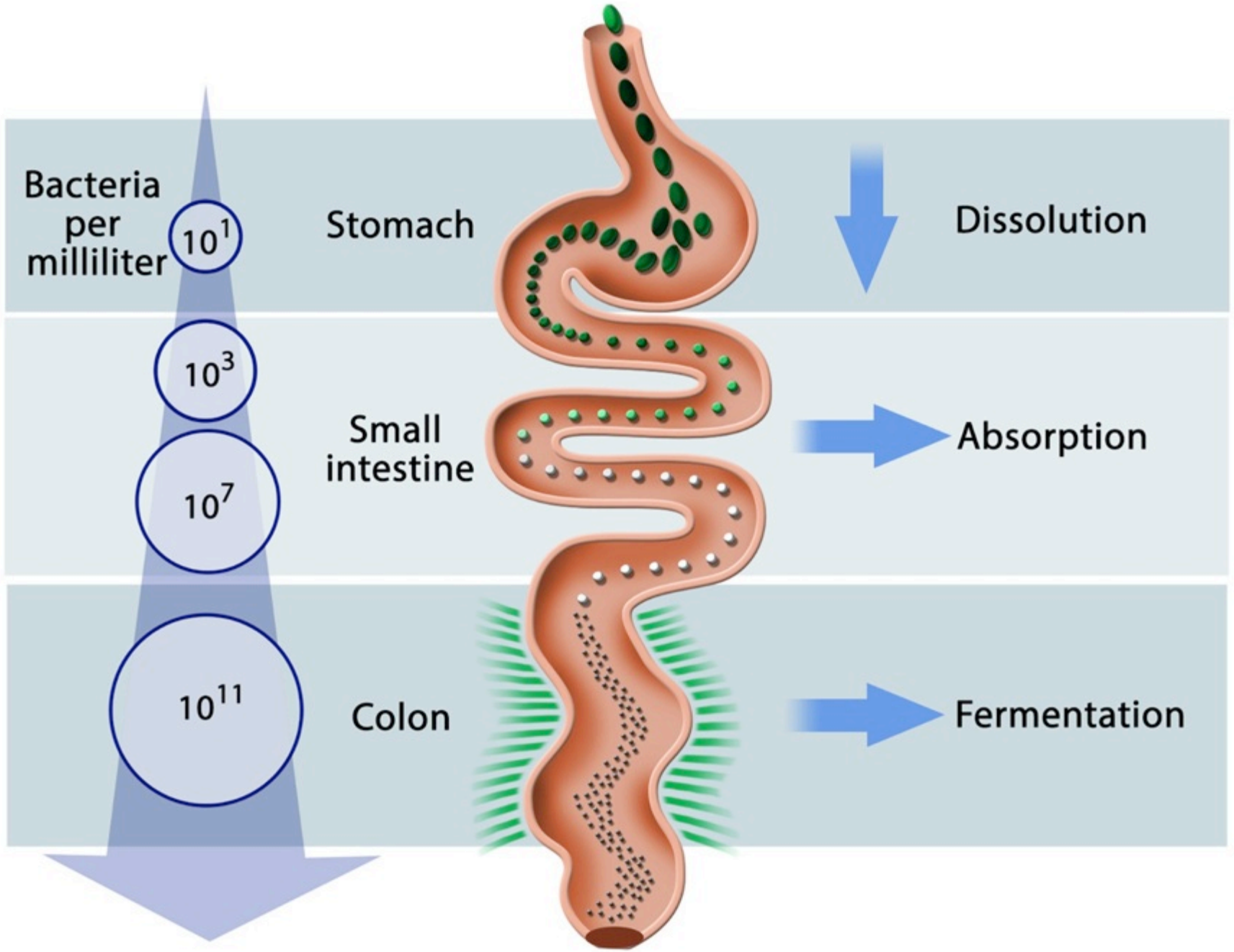
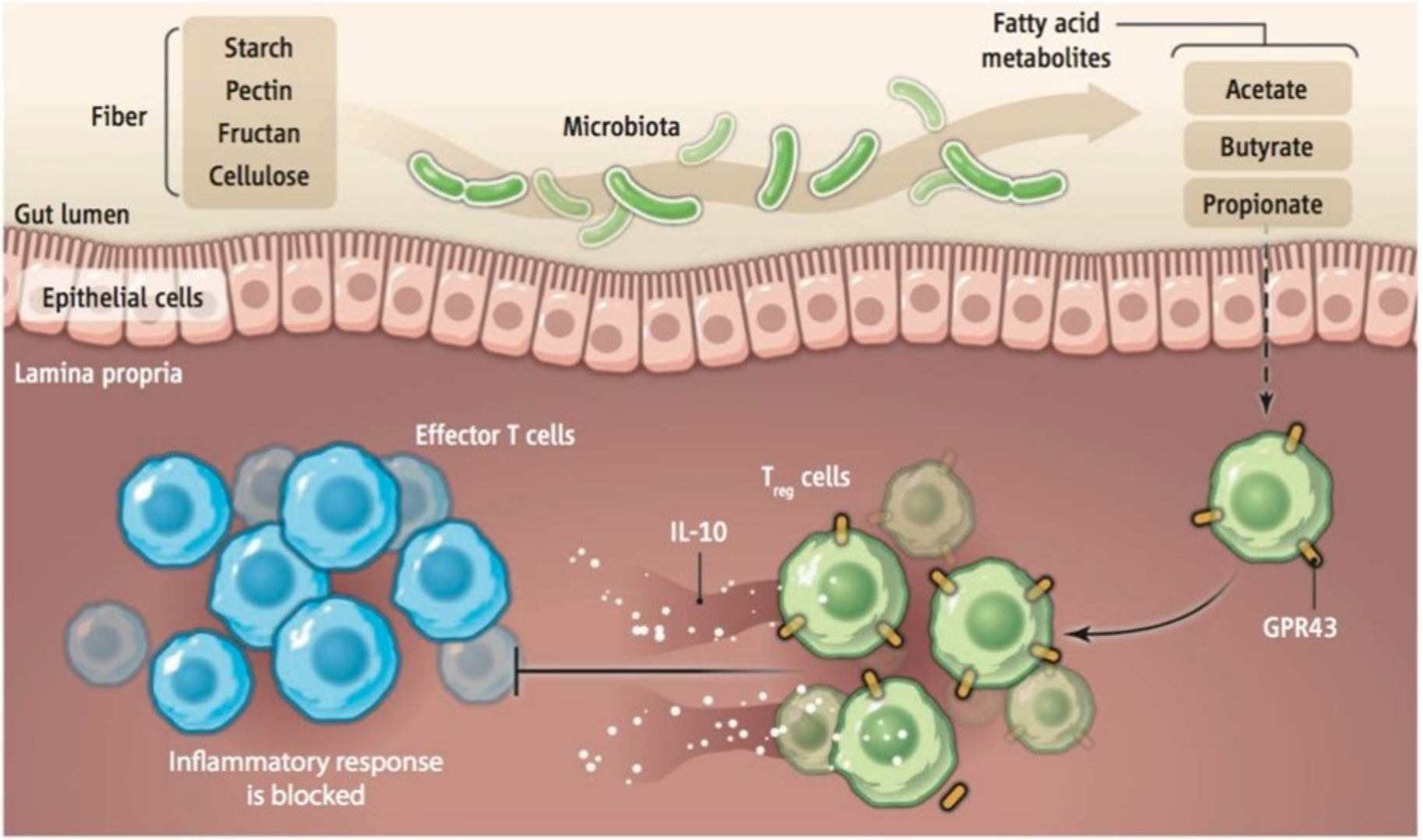


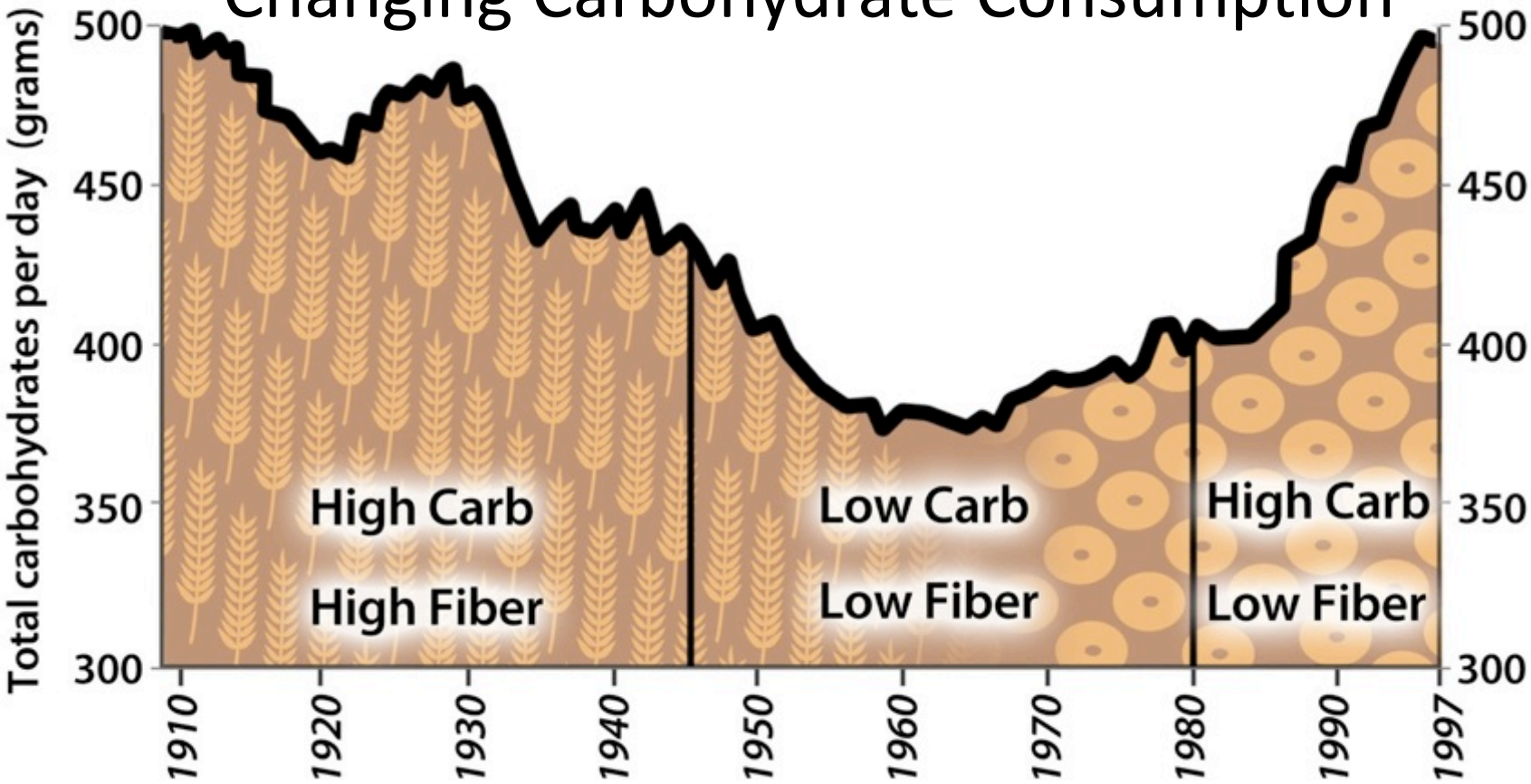
Figure 1. Inverse Relation between the Incidence of Prototypical Infectious Diseases (Panel A) and the Incidence of Immune Disorders (Panel B) from 1950 to 2000.


K. Diemert


Bacteria per milliliter
10^1
10^3
10^7
10^{11}
Stomach
Small intestine
Colon
Dissolution
Absorption
Fermentation


Fiber
Starch
Pectin
Fructan
Cellulose
Microbiota
Fatty acid metabolites
Acetate
Butyrate
Propionate
Gut lumen
Epithelial cells
Lamina propria
Effector T cells
T reg cells
IL-10
GPR43
Inflammatory response is blocked

Changing Carbohydrate Consumption



Allergies, Asthma, Autism, Bacterial vaginosis, Cardiovascular disease, Certain cancers, Crohn's disease…

Depression, Inflammatory bowel disease, Leaky gut syndrome…

Multiple sclerosis, Obesity, Type 1 and type 2 diabetes…

The Root is the Gut (inside-out)

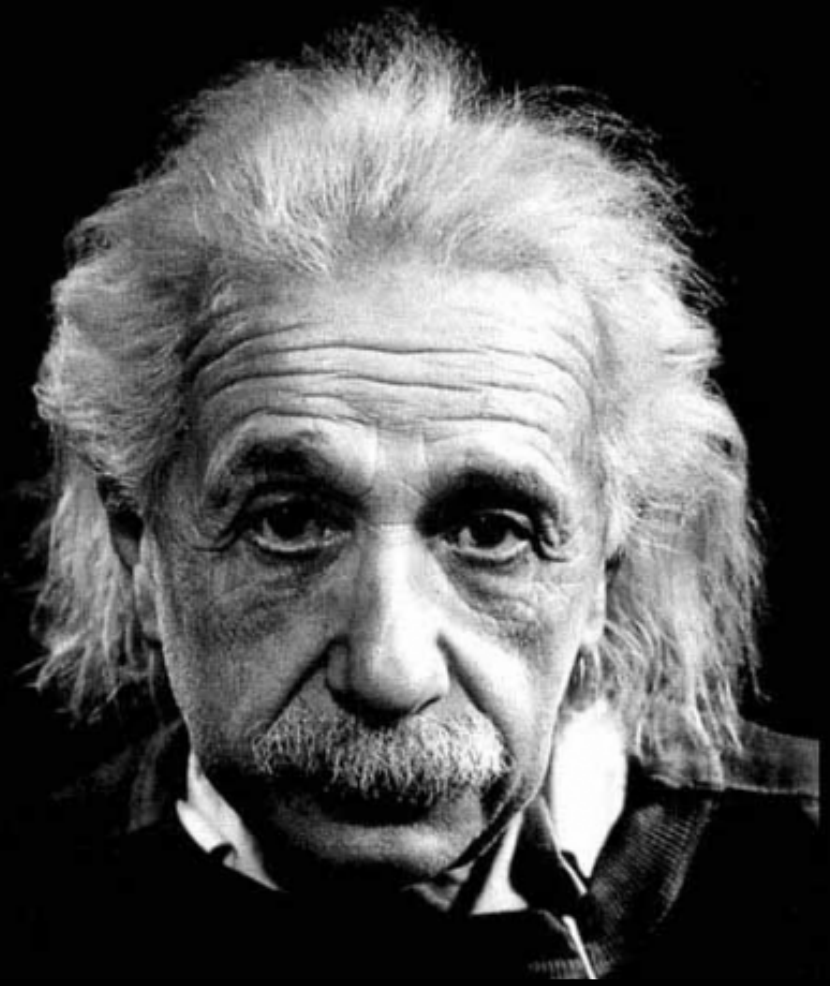
Roots

- Exudates feed microbiome
- Microbes acquire nutrients and make critical metabolites
- Communication /Plant defense

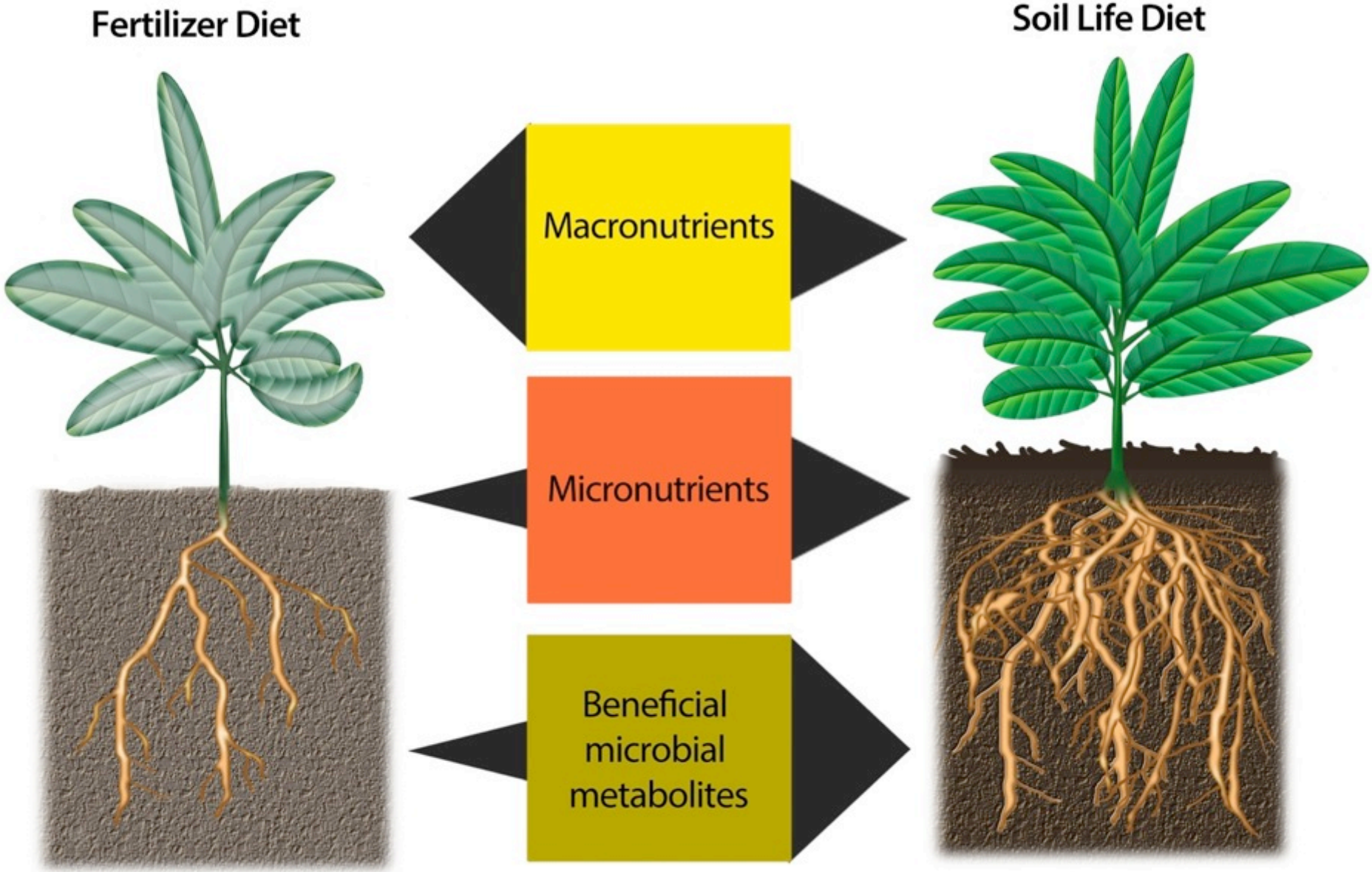
Gut

- Diet & mucus feed microbiome
- Microbes make critical metabolites from host diet
- Communication /Immune system

Time For A New View of Soil?



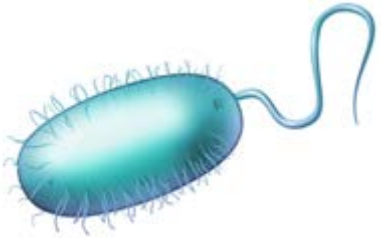
"*The significant problems we face cannot be solved at the same level of thinking we were at when we created them*."


Fertilizer Diet
Soil Life Diet
Macronutrients
Micronutrients
Beneficial microbial metabolites

Principles of Conservation Agriculture (FAO)

- minimal or no disturbance / direct planting of seeds (e.g., no-till)
- permanent ground cover (retain crop residues and include cover crops in rotations)
- diverse crop rotations (to maintain soil fertility and break up pathogen carryover)




Got Dirt?
Get Soil.

Forthcoming spring 2017, Montgomery, D. R., *Triple Harvest* (W. W. Norton)

The principles of conservation agriculture work and are scalable.

This is not really a question of low tech organic versus GMO & agro-tech…

The real question is how to apply an understanding of soil ecology and soil building to the applied problem of profitably sustaining high crop yields in a post-cheap oil environment.

Healthy Soil: No Silver Bullet, But A Secret Weapon?

Restoring soils can help:

- Feed the World
- Slow climate change
- Conserve biodiversity

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