SOIL 4400 Soil Ecology Introduction

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UNIVERSITY OF MANITOBA

Soil Ecology - SOIL 4400

Course in "Exploration of Living Soil"

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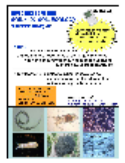
Soil Ecology - SOIL 4400 Home (winter 2013/2014)

Welcome to Soil Ecology!

This is an exciting time, we are about to embark on a marvelous journey through the most complex ecological system known, SOIL. In our journey we meet many organisms that collectively are the soil food web. Each one has a role in determining processes having agronomic and environmental implications from determining conditions for growth of a root tip to affecting our climate. The presence and activities of soil organisms can be "a canary in a coal mine" or signal "all is well" for the long-term productivity and health of soil, and also of the environment. Any exploration of soil organisms requires knowledge of interactions of individuals within a population of similar organisms, interaction with other types of organisms and also interaction with the soil environment. Thus this course has the titled Soil Ecology because it is an exploration of interactions between soil organisms and their soil environment.

Let's explore....

Soil Ecology SOIL 4400 Course Poster - Share it with family and friends!



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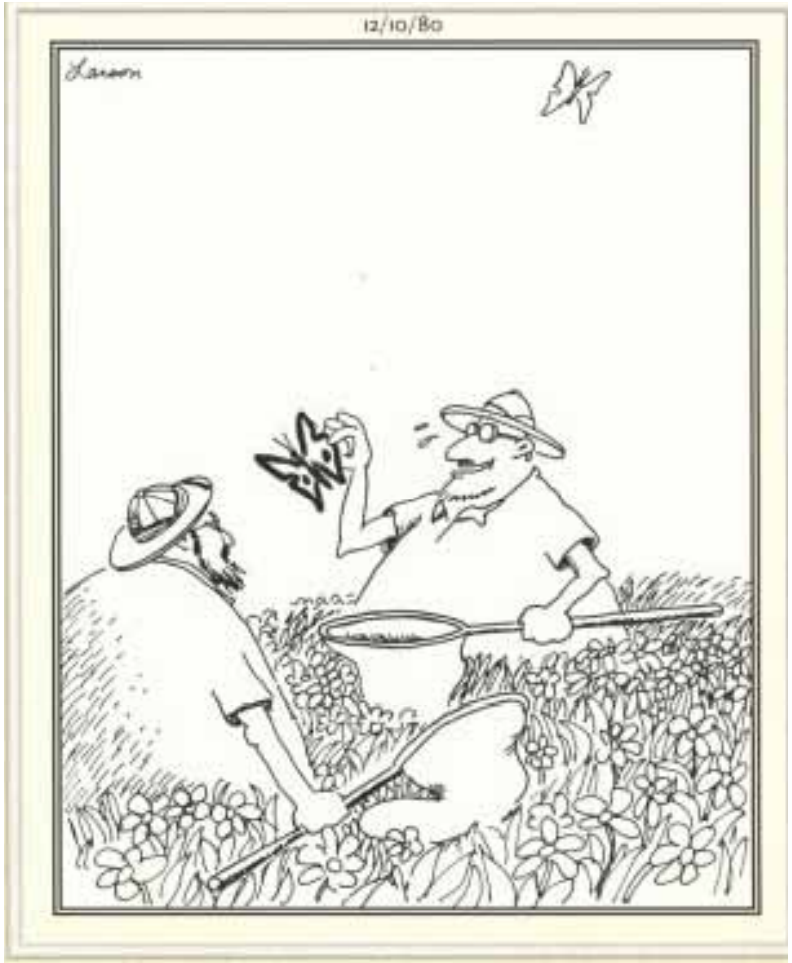
- What is Soil Ecology?
  - The study of soil organisms and how they interact with others of their own kind, other types of organisms and with the environment of soil

Approaches

- Biochemical
  - Rates of processes
  - Driving factors (substrate, physical, chemical)
  - Many organisms responsible so no need to examine them directly
- Diversity/abundance
  - Identify and enumerate organisms causing a process
  - Few organisms of interest so is possible to enumerate

More Approaches

- Reductionist
  - Treat soil as made up of simple systems and that these systems interact
- Holistic
  - Treat soil as a whole complex system and consider all interactions simultaneously



"An excellent specimen ... the symbol of beauty, innocence, and fragile life. ... Hand me the jar of ether."

Historical Soil Ecology

- Soil Ecology is a young science linked to Ecology, Biology and Soil Science
- Ancients recognized 3 areas today in the realm of Soil Ecology
  - Diseases of humans harboured in soil
  - Diseases of crops harboured in soil
  - Some plants are good for productivity

Human and Humus

- c.1250, from M.Fr. *humain* "of or belonging to man," from L. *humanus*, probably related to homo (gen. *hominis*) "man," and to *humus* "earth," on notion of "earthly beings," as opposed to the gods (cf. Heb. adam "man," from adamah "ground").

Source: Online Etymology Dictionary

Natural Function of Soil

- Support for living organisms
- Reservoir of organic and mineral substances
- Regulator of exchanges and flows in the ecosystem
- Location for transformation of organic matter
- Purifying system for toxic substances

Soil Function Related to Humans

- Essential basis of human life
- Location of agriculture and forest production
- Location where we live
- Location for food gathering
- Place for storing important substances and wastes
- Part of the landscape

- History of civilizations and cultures related to success (or lack of) in managing soil

Soil is an Ecological System

- Adheres to the Principles of Thermodynamics
- Has boundaries
- Has spatio-temporal hierarchical organization
- Internal evolution
- Has properties and functions resulting from combination of the sum of parts
- Responds to feedback
- Exchange of matter, energy, organisms etc. to other systems

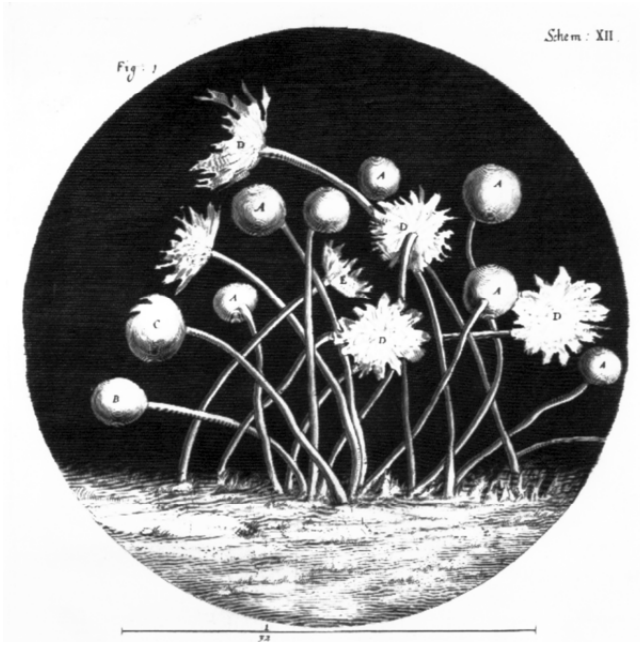
The history of a science is not merely a chronicle of discovery, but a study of the relation of methods and ideas in progress and the application of the conceptions…

L.J. Hendersen (1878-1942)

Soil Ecology Has Always Been With Us

- The Romans knew there was something in some soils that made legume crops grow better
- They didn't know what it was, but when they planted alfalfa on land that they had conquered, they knew to bring soil from where the crop grew well
- The origins of alfalfa is Iran

Hooke's Microscope

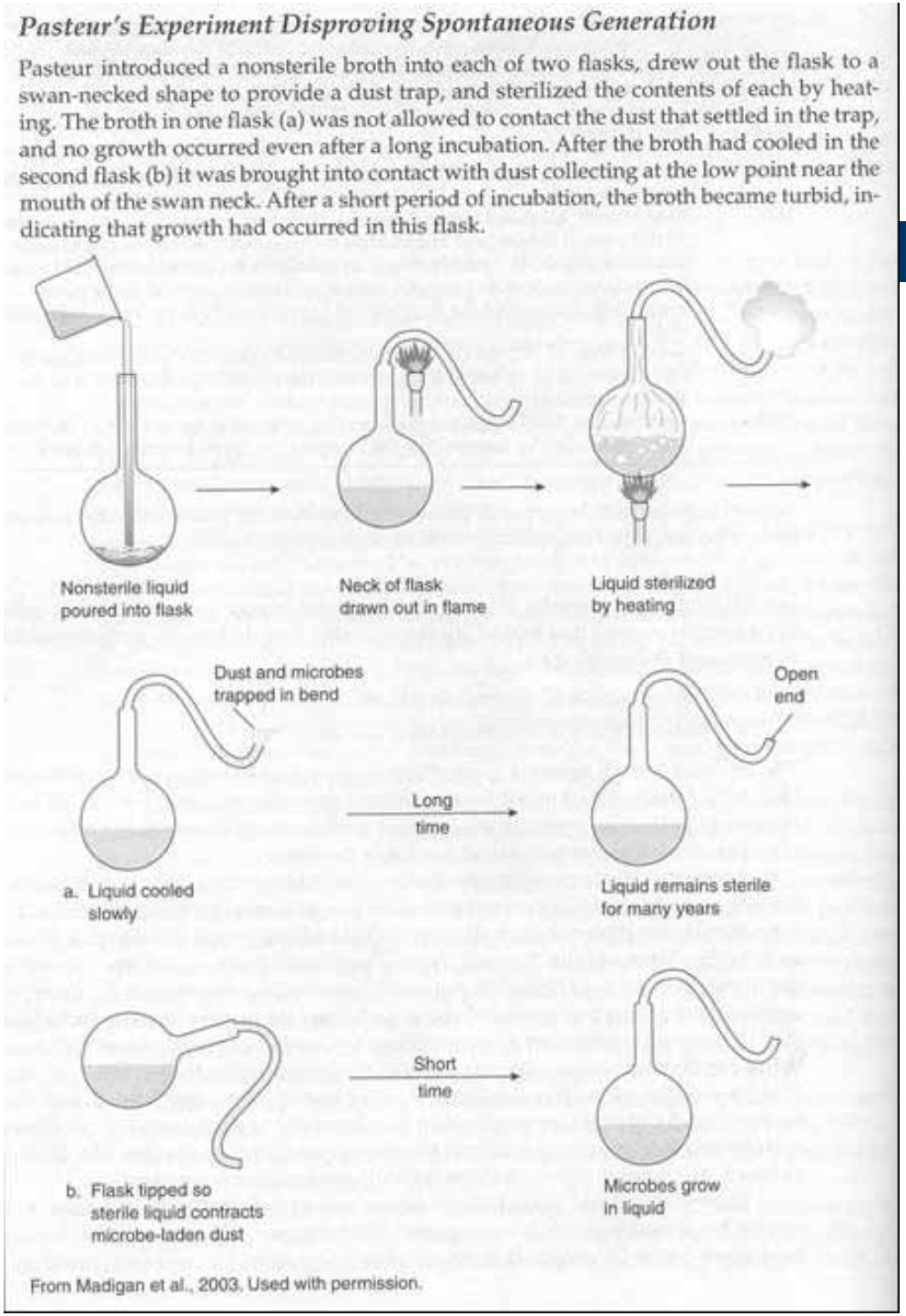


Robert Hooke 1664, viewed the fruiting structures of molds

Nine Major Revolutions in Soil Ecology

1. Repudiation of Spontaneous Generation
2. Origin of Contagious Disease
3. Some Microorganisms are Beneficial/Detrimental to Plant Growth
4. Microorganisms Involved in Biogeochemical Cycling
5. The Delft School
6. Concept of Factors of Soil Formation and Soil is a Biological Creation
7. We Know Little About Soil Organisms
8. Soil Health
9. Search for Extraterrestrial Life

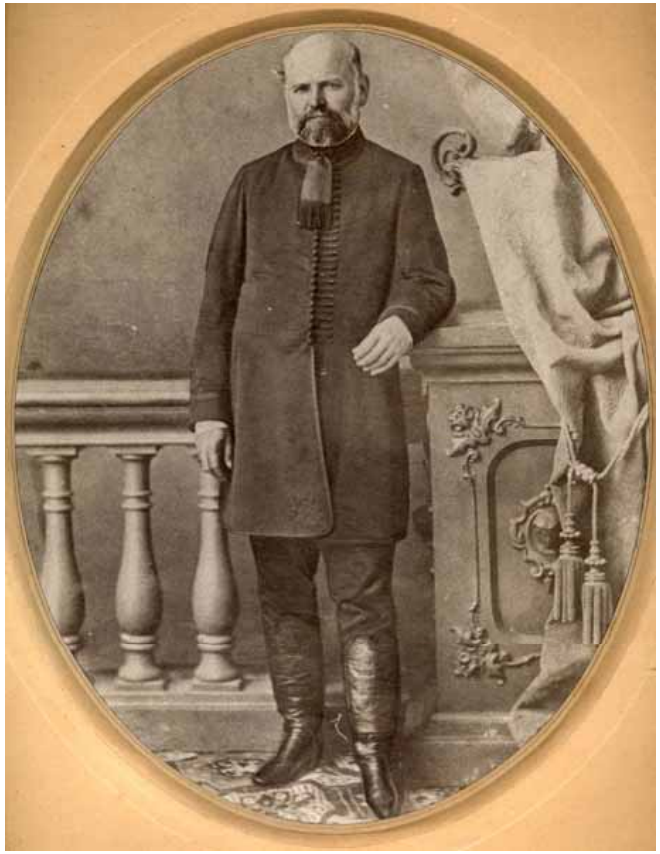
1. Pasteur's Experiment



1822-1895

2. Origin of Contagious Disease

- Ignaz Semmelweis, benefit of doctor's washing hands



Ignaz Semmelweis

Origin of Contagious Disease

Koch's Postulates

Worked on Tuberculosis using Guinea Pigs and Anthrax of Cattle

1. Microorganism must be detectable in infected host
2. Microorganism isolated and grown in pure culture
3. Host is infected and disease symptoms observed
4. Micoorganism re-isolated and grown in pure culture

Robert Koch 1879

3. Beneficial/Detrimental Microorganisms to Plants

- Hellriegel and Wilfarth in 1886 discovered bacteria in nodules of legumes capable of converting atmospheric nitrogen to a form available to plants (ammonium)

"Buckwheat, rape, mustard, sugar beets, oat and potatoes can take up their complete nitrogen from nitric acid or its compounds. If these plants are fed with nitrogen in the form of ammonia, then they can use it only as far as it is transformed into nitric acid by micro-organisms of the soil. Peas, lupines, seradella, vetches and clover in contrast do not depend on nitrogen bound in the soil but are able to take up nitrogen from the air; they do not use the bound forms but the free nitrogen of the air. These plants live and use the free nitrogen with the help of bacteria that form so-called nodules at their roots." (Hellriegel, H, and Wilfarth, H. "Untersuchungen uber die Stickstoffnahrung der Gramineen und Leguminosen." Beilageheft zu der Zeitschrift des Vereins fur Rubenzucker-Industrie Deutschen Reichs, 234 pp., 1888)

Plant Pathology

- **1853-65 –** Anton deBary demonstrated that fungus (*Phytophthora*) caused blight of potato
- Went through Koch's postulates before known as such

Anton deBary

4. Microorganisms Involved in Biogeochemical Cycling

- Sergei Winogradsky (1856-1953) discovered nitrifying bacteria

- Generated the Winogradsky Column demonstrating bacteria preference for oxygen levels in sediments and soil of chemoautotrophic bacteria

5. The Delft School

1. How does the organism interact with its abiotic and biotic environment?
2. How can principles of microbiology be applied to problems?
3. What is the place of micoorganisms in the natural world?

Martinus Beijerinck 1851-1931

Beijerinck's Rule

"Everything is everywhere
and the milieu selects"

6. Soil Formation is Biological – Hans Jenny

- Swiss born and professor at U Missouri and Berkeley (1899-1992)
- 1941 published *Factors of Soil Formation*
- Soil changes over time depending upon factors
- S = f(cl, o, r, p, t, ….)

cl=climate, o=organisms, r=topography, p=parent material, t=time, ….=there may be more factors

Hans Jenny in 1967 at age of 68

7. We Know Little About Soil Organisms

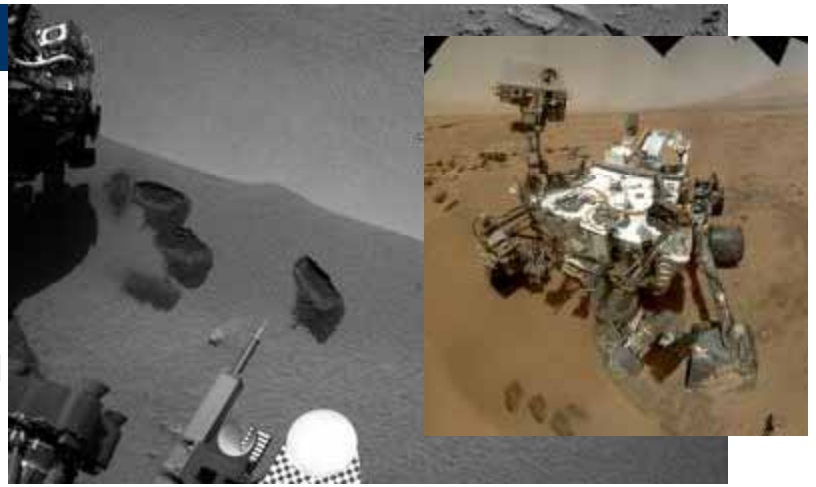
- Understanding of diversity of soil organisms and their role in soil based on lab rearing
- 1970's Direct counts – using epifluorescence microscopy – shows 10,000,000,000 bacteria g^{-1} soil but culturing shows 100,000,000 bacteria g^{-1} soil – *The Great Plate Count Anomaly*
- 1990's Molecular DNA analysis confirmed *The Great Plate Count Anomaly* to be true
- 2000's DNA codes but no known associated culturable organisms
- New ball game of understanding – what do the unculturable organisms do in soil?

8. Soil Health

- Recent acknowledgement
- An assessment of ability of soil to meet its range of ecosystem functions as appropriate to its environment and original state before detrimental human influence
- Ecosystem function is ability to
  - sustain plant and animal productivity and diversity
  - maintain or enhance water and air quality
  - Support human health and habitation
- Organic and sustainable movement I credit for this concept
- Soil has a place to grow plants and sustain humans results from its character of being a living, dynamic and ever changing environment.
- Soil is treated as an organism
  - Composite of parts that are intact and functioning
  - Functioning of parts are not lacking or severely restricted (ill state)
  - Parts cooperate well to realize a range of new functions

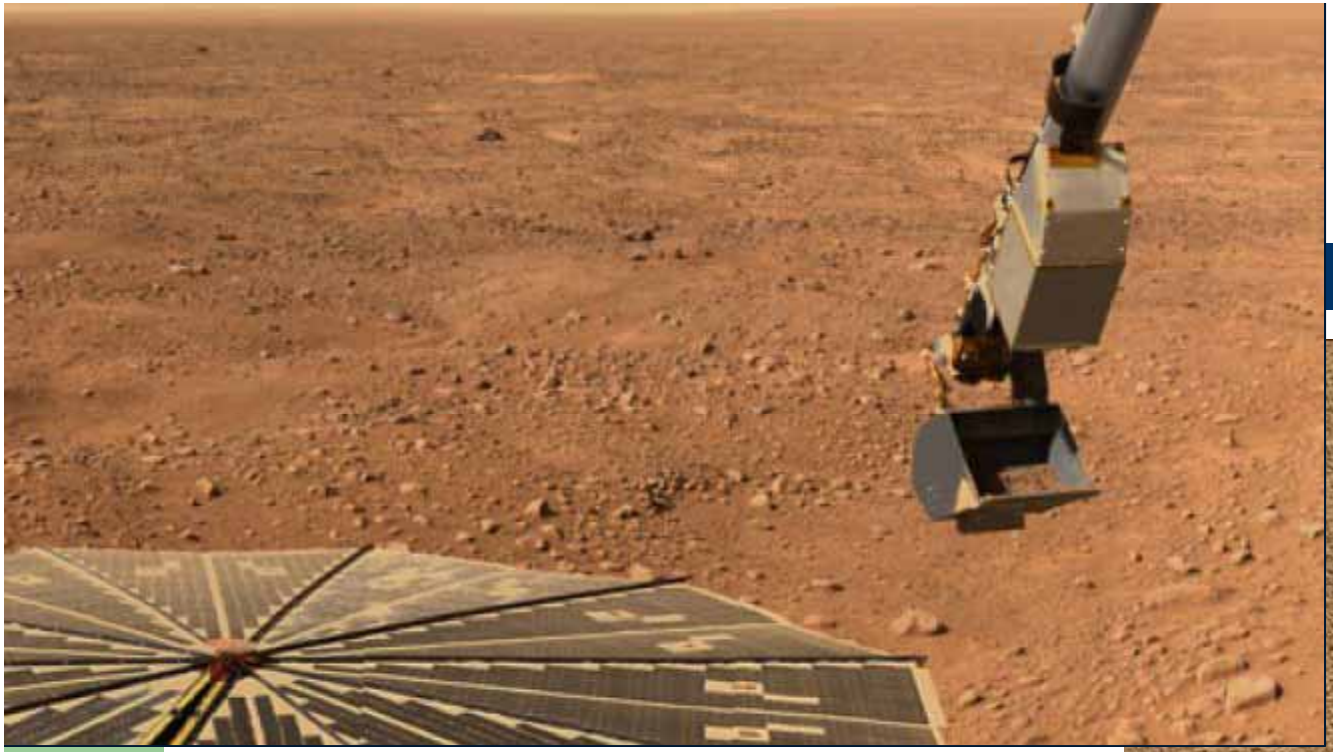
9. Search for ExtraTerrestrial Life

Viking Lander



Curiosity taking soil samples

- emphasized the search for chemical biosignatures of life in the soil and rocks at the planet's surface, and the search for biomarker gases in the atmosphere
- Viking probe to Mars (mid-70's). $^{14}CO2$ food source, nutrients and water with radiation sensor and GC-MS to detect organic compounds in soil
- Curiosity Rover 2012-now. Determine nature and inventory of organic carbon compounds, nature of building blocks of life (C, H, N, O, P, S), identify features that may represent the effects of biological processes (biosignatures)



Alpha Particle x-ray Spectrometer
- for soil elements below the rover

ChemCam
- Laser vaporizes distant soil and determines its elements

SAM
- carbon element analyzer, methane, carbon dioxide, CHNO compounds

Important Moments in Soil Ecology

Name	*Year*	*Country*	*Discovery*
Robert Hooke	1665	England	Observed fruiting structures of molds
Antonius van Leeuwenhoek	1676	Netherlands	The microscope and pond microorganims
Louis Pasteur	1830-1900	France	Repudiation of spontaneous generation, biological nature of nitrification
John Tyndall	1881	UK	Repudiation of spontaneous generation, understanding of sterilization processes
Ferdinand Cohn	1876	Poland	Taxonomy (*Bacillus*)
Robert Koch	1879	Germany	Koch's Postulates, gelatin plates for studying soil microorganisms
Jean Schloesing	1877	France	Nitrification a biologic process
Thomas Burrill	1878	USA	Demonstrates pear blight caused by a bacterium (*Micrococcus*)
Sergei Winogradsky	1856-1953	Russia	Isolation and taxonomy of chemoautotrophic bacteria, especially nitrifiers and sulfur oxidizers
Martinus Beijerinck	1851-1931	Netherlands	Isolation of legume root nodulating bacteria (thought they were insect galls), viruses, sulfur oxidizers
Angelina Fannie	1882	Germany	Agar-agar obtained from a algae better than gelatin plates to rear bacteria

Important Moments in Soil Ecology

Ulysse Gayon and Gabriel Dupetit	1883	France	Discovery of denitrifying bacteria
Hans Christian J. Gram	1884	Denmark	Differential staining of bacteria
Albert Frank	1885	Germany	Recognition of symbiotic association between some fungi and tree roots referred to as mycorrhizae
Julius Richard Petri	1887	Germany	Invented the Petri dish
Jacob Lipman	1901	USA	Concept of soil as a complex living entity; established Department of Soil Chemistry and Bacteriology at Rutgers University
N. L. Sohngen	1906	Netherlands	Discovery of Methanogens and Methanotrophs
John Russell	1912	England	Development of importance of soil-plant-micoorganisms interactions in agriculture and the environment
Alexander Fleming	1929	Scotland	Discovery of penicillin
Numerous		World	Importance of C:N ratio in mineralization/immobilization of nitrogen in residues
Hans Jenny	1941	USA	Publication of “Factors of Soil Formation” in which action of soil organisms is primal to soil development

Important Moments in Soil Ecology

Robert Starkey	1925	USA	Microbiology of the sulfur bacteria
Selman Waksman	1940	USA	Discovery of antibiotics from actinomycetes
Numerous	1945	USA/Europe/Russia	The Atomic Age and use of stable and radioactive isotope tracer techniques
James Watson and Francis Crick	1953	England	Discovery that DNA is the inheritable material
Viking 1	1975	USA	Examination of Mars soil for respiration activity and carbon compounds
Kary Mullis	1983	USA	Development of polymerase chain reaction to amplify DNA
Carl Woese	1990	USA	Universal phylogenetic tree of living organisms based on comparative sequencing of 16s and 18s rRNA
VigdisTorsvik	1990	Norway	Higher diversity of bacterial DNA found than predicted from culturing of soil
Sara Wright	1996	USA	Glomalin, important soil protein produced by fungi
Jo Handelsman	1998	USA	Metagenomics: molecular genetic study of communities of microbial organisms directly in their natural environments, bypassing the need for isolation and lab cultivation of individual species

Employment Opportunities for Soil Ecologists

- Bioremediation and decontamination of land (consulting)
- Waste managers (utilization of manures, biosolids etc. on land)
- Compost technicians
- Environmental officers and technicians (water and soil quality)
- Pest management (consulting, marketing, development, research)
- Agro-product companies (inoculum development and sales)
- Environmental toxicologist
- Environmental quality (research, consulting)
- Greenhouse gas creditor

Our Paradigm