# A Cartoon History of Soil Microbiology

M. S. Coyne*

ABSTRACT

**Students reviewing the history of soil microbiology may see great microbiologists as icons rather than real people. I employ cartoons to present a historical perspective of soil microbiology that makes this information more entertaining and consequently more palatable to introductory students. Basic historical facts and major accomplishments of the pioneering soil microbiologists are present in a factual but tongue-in-cheek survey. The material is either presented as a slide show in class or as a part of a manual students may read at their leisure. Comments about this approach have generally been favorable, but it lacks a rigorous test demonstrating whether it achieves its intended goal. This type of multimedia presentation should have potential application to a wider range of introductory course material.**

STUDENTS in introductory soil microbiology should be able to appreciate its place within the context of other natural sciences after being introduced to its intellectual past. However, this exercise fails if accomplishments of outstanding microbiologists seem like unattainable standards. Students may see pioneer microbiologists as icons rather than as role models. Consequently, one challenge in giving a historical survey of soil microbiology is to present that history in a way that is both relevant and unintimidating.

In an era of multimedia presentations, it's easy to overlook the usefulness of cartoons. They're models of simplicity; and they encapsulate messages and images within limited space and with limited words. Humorous cartoons are particularly endearing because they convey their message while making us laugh (either inwardly or outwardly). Gary Larsen's portrayal of science and weird science in *The Far Side* cartoon and Sidney Harris' sophisticated analyses of industrial science are classic examples of the genre. They're funny while simultaneously conveying either the principles, foibles, or stereotypes of scientists and their science.

Much of the humor in these cartoons lies in knowing enough science to appreciate the jokes. For several years I've been using cartoons to illustrate microbial principles for students taking introductory soil microbiology at the University of Kentucky. What follows is a presentation I use to introduce these students to the history of soil microbiology and the key players who made the discipline what it is today. It's written specifically for students following a prepackaged slide show, either independently or in class. The presentation isn't intended as a substitute for a true history. Several suitable reviews already accomplish that purpose (Allison, 1961; Clark, 1977). Rather, it's an attempt to place the development of soil microbiology in a relevant human context using humor as a vehicle.

## A HISTORICAL REVIEW OF SOIL MICROBIOLOGY

The *Glossary of Soil Science Terms* (SSSA, 1987) says that soil microbiology is "the branch of soil science concerned with soil inhabiting microorganisms, their functions, and activities." But what does that really tell us about soil microbiologists? Who are these people? What do they do? Where do they come from?

The last question is a crucial one if we want to explore soil microbiology. Do soil microbiologists emerge, fully grown, from benchtop petri plates (Fig. 1)? No. Modern soil microbiologists are the heirs of a long scientific tradition. So, in this article, we'll take a brief tour through the history

Department of Agronomy, N122 Agricultural Science Building North, Univ. of Kentucky, Lexington, KY 40546-0091. Contribution of the Kentucky Agric. Exp. Stn. Received 7 Oct. 1994. *Corresponding author (mscoyn00@ukcc.uky.edu).

Published in J. Nat. Resourc. Life Sci. Educ. 25:30–36 (1996).

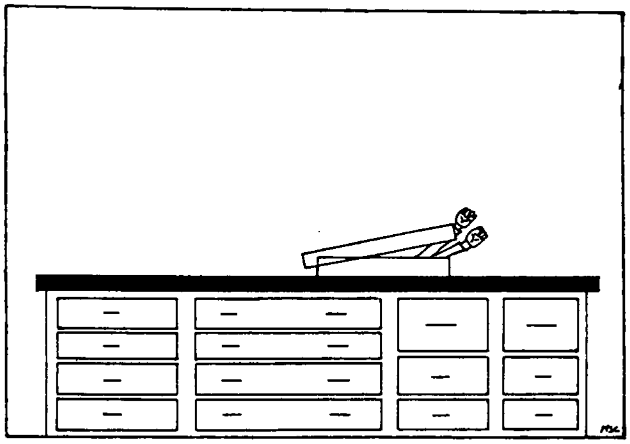

Fig. 1. Origin of microbiologists.

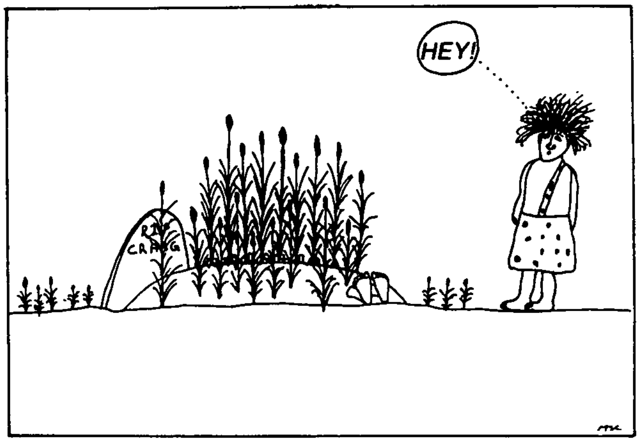


Fig. 2. Seminal moments in soil biochemistry.

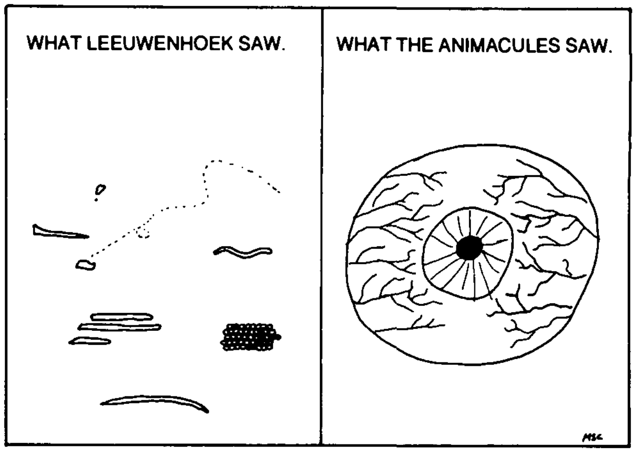


Fig. 3. Leeuwenhoek discovers microbes.

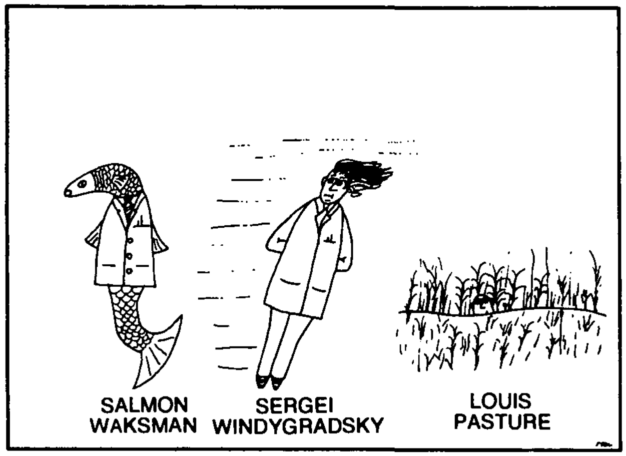


Fig. 4. When famous microbiologists' names are mispronounced.

of soil microbiology. Knowing where soil microbiologists have been in the past will make it easier to understand them in the present, and predict what they'll do in the future.

## THE EARLY YEARS

Soil microbiologists date back to the beginnings of agriculture when the first cave man (or cave lady) noticed that organic matter made plants grow a lot better. You could say that they were the first soil microbiologists observing the effects of microbial decomposition at work (Fig. 2). Soil microbiologists, unrecognized as such, were fermenting grain in ancient Egypt. Eventually, Robert Hooke (1635–1703), a member of the Royal Society in England, got around to writing a soil microbiology book. It was a monograph published in 1665 that described microscopic molds and spores for the first time.

Most people would agree, however, that this history really begins with Antonie Van Leeuwenhoek (1632–1723). He was a 17th century janitor and part-time lens grinder in Delft, Holland, who made the first microscopes good enough to resolve microbes as small as bacteria (Fig. 3).

Leeuwenhoek wasn't shy about what he looked at with his microscopes and this meant that some of his most interesting samples came from stuff he scraped off of his neighbors' teeth. This isn't surprising since Leeuwenhoek's 17th century neighbors rarely brushed, were less likely to floss, and hardly ever went to their dentist (given the state of dentistry in the 17th century, prior knowledge that the local barber–surgeon might draw a pint of blood and then look at your teeth was not an incentive to go for annual checkups).

After Leeuwenhoek's death, years passed while scientists like Lazzaro Spallanzani (1729–1799) and John Needham (1713–1781) debated whether or not microbes were spontaneously generated. Although this seems like a waste of time, it was a useful exercise in developing what passed for the scientific method in the 17th and 18th centuries: state hypothesis, test hypothesis, revise hypothesis, savage anyone who disagrees with your hypothesis.

## THE GREAT AGE OF RESEARCH

The next great era in soil microbiology research opened in the mid 19th and early 20th centuries with the work of soil microbiologists like Sergei Winogradsky, Louis Pasteur, and Selman Waksman (Fig. 4).

Sergei Winogradsky (1856–1953) was from Mother Russia, but he's called "The Father of Soil Microbiology" because: he was a man, and he discovered lots of interesting things before anyone else did. Winogradsky developed the Winogradsky Column while studying the sulfur cycle. He investigated microbial growth on $CO_2$ and inorganic ions

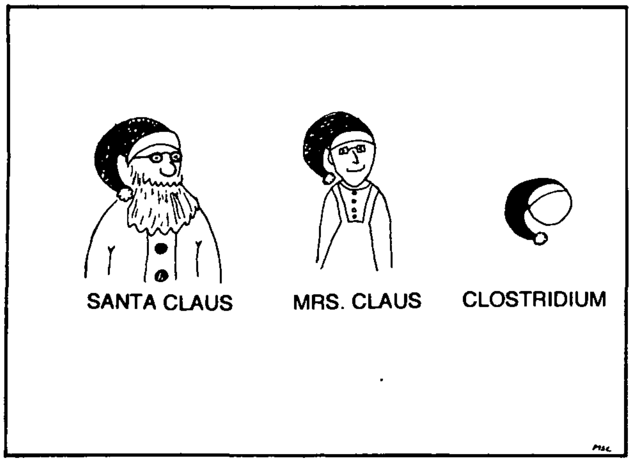


Fig. 5. *Clostridium.*

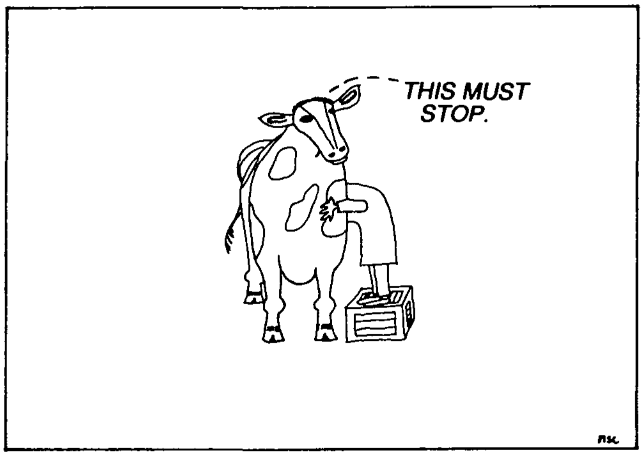


Fig. 6. Investigating the animal rumen.

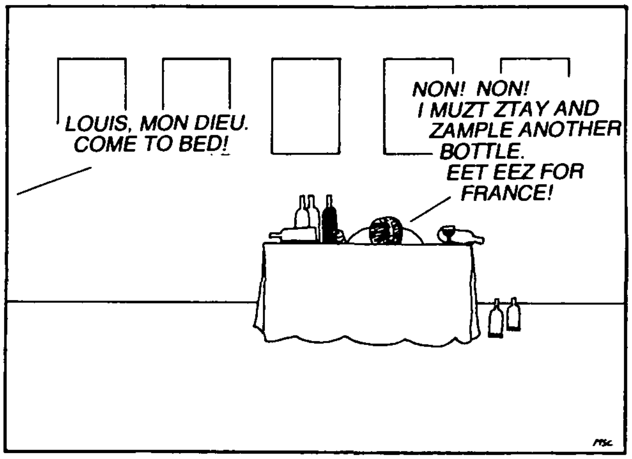


Fig. 7. The testing of pasteurization.

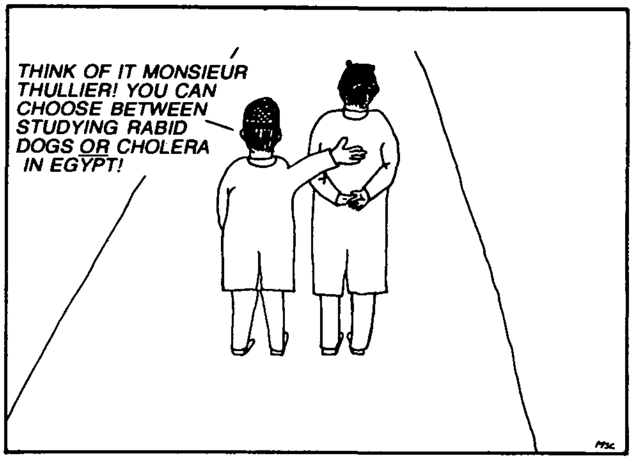


Fig. 8. Working with Pasteur was no fun.

(chemoautotrophy). He studied nitrification (a microbial process where $NH_4^+$ is ultimately converted into $NO_3^-$). *Nitrobacter winogradskii*, one of the nitrifying bacteria, is named after Sergei Winogradsky.

*You know you've made it in microbiology when your friends name a microbe after you.*
*You know what they really think about you if it's a pathogen.*

Winogradsky investigated chemoautotrophic oxidation of ferrous iron (ferrous iron is the reduced form of ferric iron, an essential component of rust—the material your joints turn into the moment you turn 30). Winogradsky also isolated *Clostridium*, an anaerobic (growing without air), spore-forming, nitrogen-fixing (converting $N_2$ to $NH_3$) bacilli (rod-shaped bacterium) (Fig. 5). We see the fruits of his pioneering work with anaerobes in modern research with obligately anaerobic microbes in special environments such as the animal rumen (Fig. 6).

Winogradsky's anaerobic, nitrogen-fixing cocci wasn't named *Clostridium winogradskii*, because Winogradsky did much of his work at an institute named for another great microbiologist of this era—Louis Pasteur (and *his* friends named *Clostridium pasteurianum* and other, nastier microbes after him).

Pasteur (1822–1895) was a giant in the early age of soil microbiology. He began working as a chemist and earned a reputation for himself by separating crystals of tartaric acid into mirror image isomers. This was boring, so he soon took up microbiology. Pasteur is noted for the process that bears his name. He tried to use pasteurization to make French beer the best in the world (Fig. 7). Naturally, this was impossible (which made Pasteur irritable). Pasteur also didn't like beer (which made him even more irritable).

Those who really suffered because Pasteur was brilliant and irritable were his students. For example, Louis Thuillier was one of Pasteur's best students. He never became famous for developing the rabies vaccine with Pasteur because, after years of back-breaking labor inoculating French cattle and sheep with Pasteur's attenuated Anthrax vaccine, Thuillier went to Egypt (at Pasteur's request) and promptly died of cholera (Fig. 8).

When you're feeling blue, just think of Pasteur's students. Whatever mindless, boring thing you have to do, at least your professor didn't ask you to collect rabid dog spit with a mouth pipette.

*Pasteur once said, "Chance favors the well-prepared mind."*
*Pasteur only took multiple-choice exams.*

After the Franco-Prussian War, Pasteur developed a consuming hatred for Germany and Germans (he even returned his honorary degree from the University of Bonn). One


**Fig. 9. Young Koch.**

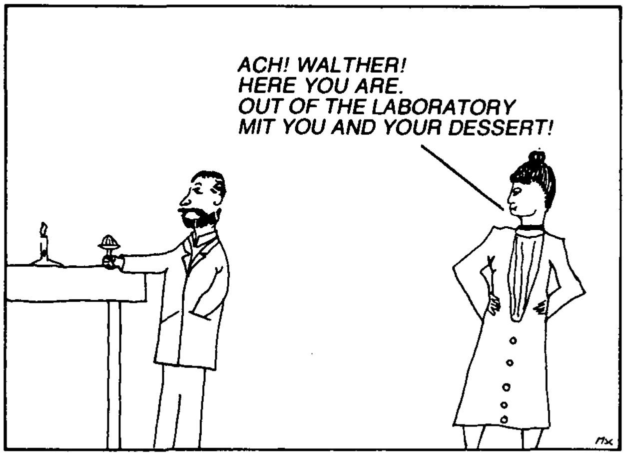


**Fig. 10. Another in the series of domestic disputes between Walther and Angelina Hesse that leads to the development of agar media.**

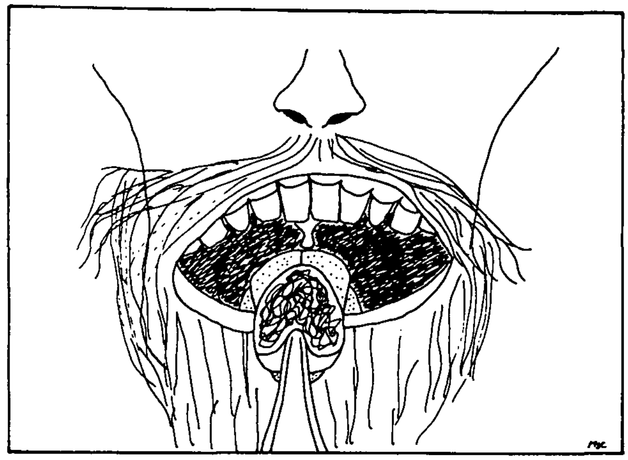

**Fig. 11. The first (and last) view *Lactobacillus bulgaricus* has of Èlie Metchnikoff.**

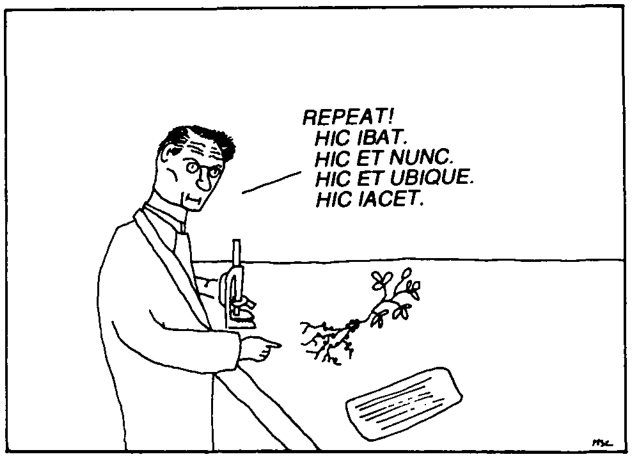


**Fig. 12. Beijerinck cultures *Rhizobium* from root nodules.**

German whom Pasteur particularly hated was Robert Koch (1843–1910). Koch, a rural doctor, earned his reputation by developing pure culture techniques. Since Pasteur was never really good at pure culture technique, this was something else that made him irritable.

Koch's pure culture techniques were originally developed on inconvenient substrates like potatoes or gelatin (from eyeballs) (Fig. 9). They would never have been so successful without the help of a special woman. No, it wasn't his wife. This woman was Frau Angelina Hesse who was married to one of Koch's assistants (a group no less abused than Pasteur's students). She made exquisite semisolid desserts from red algae extracts (avid readers can find reference to this in Johann Wyss' classic, *Swiss Family Robinson*, the story of an oppressively cheerful family shipwrecked in Disneyland).

One day, Angelina's husband Walther Hesse decided to grow some microbial cultures on one of these desserts. It worked; they grew; agar media was born; Koch's reputation was made; and Walther Hesse probably slept on the couch that night (Fig. 10).

Koch's Postulates are named for Robert Koch. I can summarize them for you with this example: (i) isolate Anthrax bacilli from diseased guinea pig; (ii) infect healthy guinea pig with Anthrax bacilli; (iii) watch guinea pig die of anthrax; (iv) isolate Anthrax bacilli from dead guinea pig; and (v) repeat steps 1 to 4, 10 000 times. Being German, Koch was very thorough.

Èlie Metchnikoff (1845–1916) was an eccentric, even among the early soil microbiologists (odd when you consider that collecting dog spit and killing thousands of guinea pigs wasn't considered eccentric). Metchnikoff was a suicidal, sour-milk–drinking Russian who thought that removing the large colon was a great idea. He was in step with his time, though, because this really was a popular medical procedure in the Victorian Age. He also discovered phagocytosis, which shows that insanity is no barrier to good microbiology. Metchnikoff believed he could prolong his life by consuming huge quantities of yogurt (milk fermented by *Lactobacillus bulgaricus*). As it turns out, Metchnikoff kept his colon and died (probably of a yogurt overdose) at age 71 (Fig. 11).

While Pasteur fumed in Paris and Koch plated in Berlin, another great school of microbiology developed in Leeuwenhoek's old stomping grounds, Delft. It was led by Martinus Beijerinck (1851–1931). Beijerinck cultured the first isolates of symbiotic (in association with another organism) and asymbiotic (free-living) nitrogen-fixing bac-

Fig. 13. Fleming at tea-time.

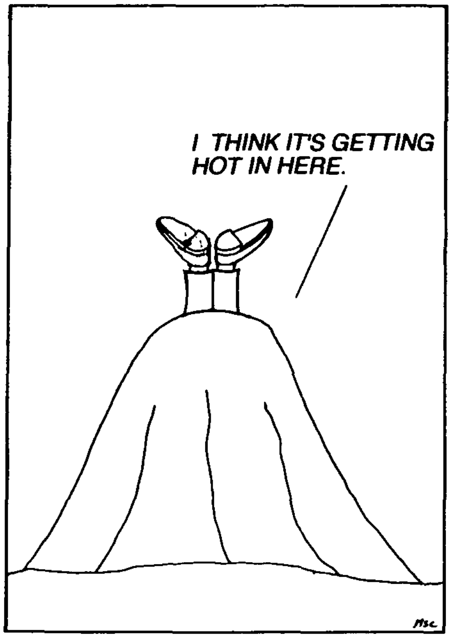


Fig. 14. Early composting studies.

teria (*Rhizobium* and *Azotobacter*, respectively) (Fig. 12). Beijerinck is often attributed with this quote, "Everything is everywhere, but the environment selects." Blame your next case of athlete's foot on that.

Meanwhile, in England, everyone knew that Alexander Fleming (1881–1955) was a little different. They just weren't quite sure why (Fig. 13). Then one day in 1928, Fleming announced that a fungus, *Penicillium notatum,* contaminating an old plate of *Staphylococcus* in his lab, was surrounded by a clear zone of dead and lysed cells. He had discovered the first antibiotic, Penicillin. It didn't make him rich (although the cash from his Nobel Prize in 1945 helped a little), but he did get a knighthood, and he never threw anything away again.

This naturally leads us to Selman Waksman (1888–1973). Waksman was born in Russia but emigrated to the USA and ended up working at Rutgers University. Waksman is often called "The Father of American Soil Microbiology," but you rarely hear about his early work on

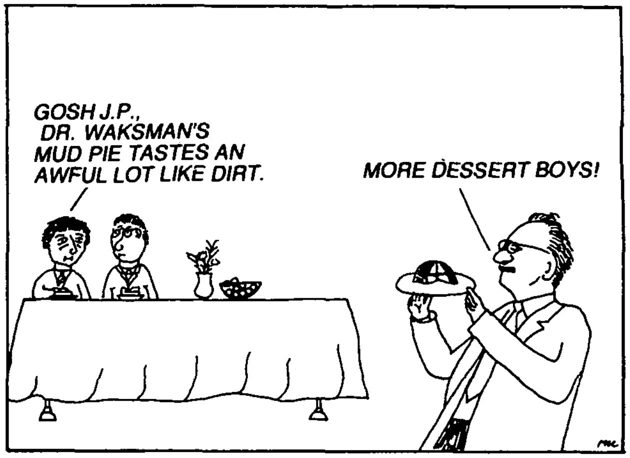


Fig. 15. Waksman's students were often unwitting participants in his more obscure actinomycete research.

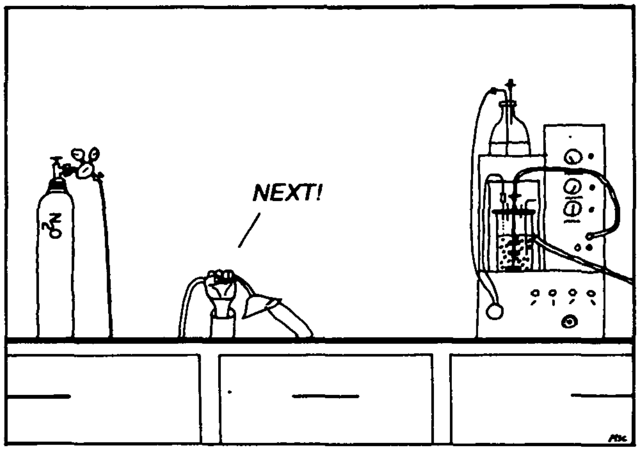


Fig. 16. The allure of denitrification.

the microbial ecology of compost (Fig. 14). You don't hear about it because around 1944, Waksman and his research associate, René Dubos, found a soil actinomycete, *Streptomyces*, with antibiotic properties like Fleming had found with *Penicillium.* It was Waksman who actually coined the word "antibiotic" and he won a Nobel Prize in 1952 for discovering streptomycin.

Waksman's laboratory ultimately became devoted to finding antimicrobial properties in soil microbes (Fig. 15). But, unlike Pasteur and Koch's students who vaccinated and plated without much reward, Waksman's students became rich because the pharmaceutical industry greedily hired them when they graduated. All of them, that is, except J.P. Martin, who chose instead to do some elegant, but unprofitable work with fungi.

## SOIL MICROBIOLOGY ENTERS THE MODERN ERA

You should be seeing a pattern develop. In soil microbiology, periods of slow, steady progress are separated by great leaps in technology and discovery. A great leap occurred when Leeuwenhoek manufactured the first really good microscopes. A great leap occurred when Koch devel-

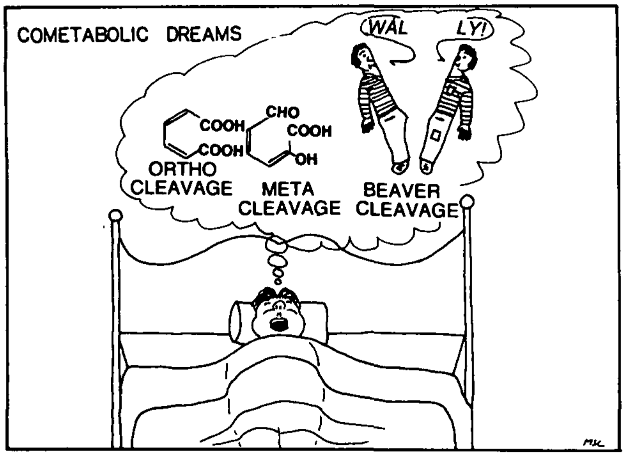


Fig. 17. Cometabolic dreams.

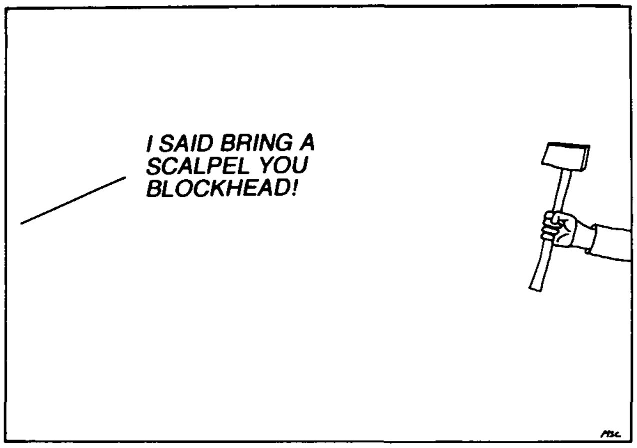


Fig. 18. Early molecular biologists lacked a sense of scale.

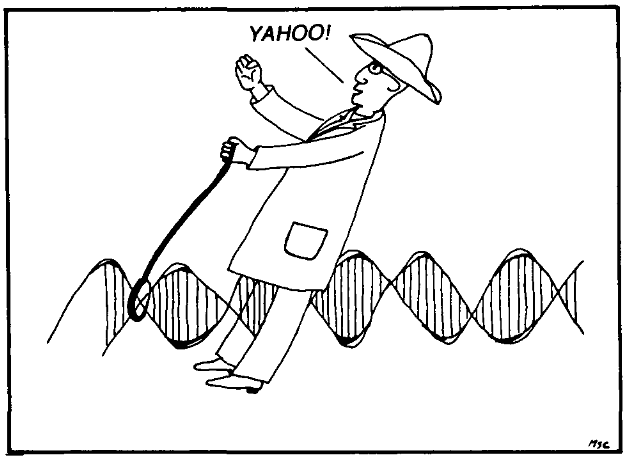


Fig. 19. Gene jockey.

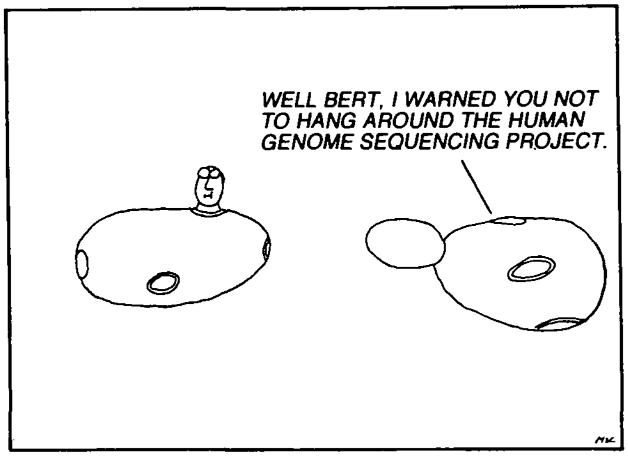


Fig. 20. The human genome project.

oped pure culture techniques. Another great leap occurred when William Payne at the University of Georgia and Roger Knowles at McGill University in Canada independently announced in 1976 that acetylene ($C_2H_2$) blocked the reduction of nitrous oxide ($N_2O$) to nitrogen gas ($N_2$) (as with much of soil science, a Russian named R.I. Fedorova had already reported this in 1973). Suddenly, soil microbiologists such as James Tiedje at Michigan State University, who were studying denitrification (the reduction and loss of $NO_3^-$ as gaseous N), could generate almost limitless amounts of $N_2O$—laughing gas. Just as suddenly was the increase in very relaxed soil microbiologists interested in denitrification (Fig. 16).

By the early 20th century, organisms were evolving that directly affect soil microbiology today. Of course, I'm talking about organic chemists. Some of the cleverly designed compounds they've created have a common feature—people would like to get rid of them as soon as possible. Consequently, the modern era is full of soil microbiology labs, such as Martin Alexander's lab at Cornell University, that are dedicated to unraveling the decomposition of these organic molecules through such pathways as Ortho Cleavage, Meta Cleavage, and the lesser known Beaver Cleavage (Fig. 17).

Soil microbiologists have even gone molecular in the modern era. Initially, there were some problems with scale (Fig. 18). Eventually, however, molecular genetics became fairly routine and its practitioners acquired the moniker (name) of Gene Jockey (molecular engineers) in MoBo (molecular biology talk) (Fig. 19).

## THE FUTURE?

What does the future hold for soil microbiology? Soil microbiologists have contributed to mapping the genome of *Escherichia coli,* and it is now possible to think about mapping the human genome. For example, several bazillion dollars are annually allocated to discovering the elusive male pattern baldness gene (Fig. 20).

Perhaps one day it will become difficult to distinguish soil microbiologists from the organisms they study (Fig. 21). If that happens, we may find that instead of the soil microbiologists studying microbes, the microbes will study the soil microbiologists (Fig. 22).

## CONCLUSION

I offer this cartoon history of soil microbiology as both a slide show in class and as reserve material in the library.

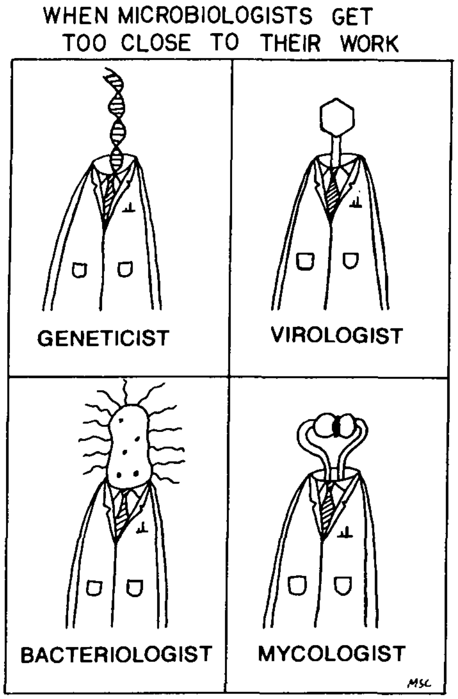


**Fig. 21. When microbiologists get too close to their work.**

Although I've never had enough students to justify separate class sections, thereby testing whether this method really improves learning, few students miss exam questions based on historical figures. Anecdotal response has always been favorable.

This technique is a useful twist on the idea of multimedia presentations. It should apply to teaching any natural science that can utilize an image to convey a concept or fact. It's simple, requires minimal drawing skills (most students seem to overlook artistic incompetence), and is entertaining—if not for the students, for me personally. That, of course, is one of my goals in teaching soil microbiology. I want students to learn, but I want to enjoy it too.

## ACKNOWLEDGMENTS

I am indebted to the students, staff, and faculty at the University of Kentucky and Michigan State University for their commentary on this article and to S.B. Coyne for her editorial remarks. This work forms the introductory portion of a larger manual, *So You Want to Be a Soil Microbiologist*, that is used as supplemental reading in introductory soil microbiology.

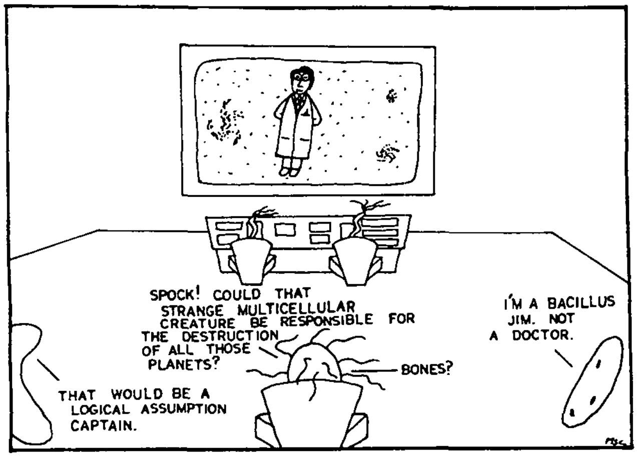


**Fig. 22. Microbial dreams.**

## REFERENCES

Allison, F. 1961. Twenty-five years of soil microbiology and a look to the future. Soil Sci. Soc. Am. Proc. 26:432–439.

Clark, F.E. 1977. Soil microbiology—it's a small world. Soil Sci. Soc. Am. J. 41:238–241.

Soil Science Society of America. 1987. Glossary of soil science terms. SSSA, Madison, WI.

## ADDITIONAL READING MATERIAL

Baldry, P.E. 1965. The battle against bacteria. Cambridge Univ. Press, Cambridge.

Bardell, D. 1988. The discovery of microorganisms by Robert Hooke. ASM News 54:182–185.

Bibel, D.J. 1988. Èli Metchnikoff's bacillus of long life. ASM News 54:661–665.

Brock, T.D. 1961. Milestones in microbiology. Prentice-Hall, Englewood Cliffs, NJ.

De Kruif, P. 1926. Microbe hunters. Harcourt Brace, New York, NY.

Hesse, W. 1992. Walther and Angelina Hesse—early contributors to bacteriology. ASM News 58:425–428.

Vallery-Radot, R. 1937. The life of Pasteur. Garden City Publ. Co., Garden City, NY.◆