Ecology: Crash Course History of Science #38

Crash Course: History of Science
https://youtube.com/watch?v=KrwtWKPAcRs
https://nerdfighteria.info/v/KrwtWKPAcRs

We've explored the origins of modern biology, the earth sciences, and even the sciences of outer space. Now it's time to put these disciplines together. Starting around 1900, but picking up during the Cold War, scientists looked beyond individual species to ask questions about how whole systems of living and nonliving things change together over time. Where geneticists looked to model evolution in the laboratory, these nature focused, systems thinking scientists looked to bring laboratory style research - meaning reproducible and empirical - into the literal field. It's the birth of ecology and earth systems science.

[intro sequence]

As with other modern disciplines, ecology has lots of roots in different places and times, but it became a formal science in the late 1800s and early 1900s. The detailed, wide ranging and data drive work of Darwin, Wallace, and others inspired other life science researchers to travel and observe the complexities of the living world. And Darwin's German hype man, biologist Ernst Haeckel, coined the word "ecology". This means the study of "oikos", meaning home, or metaphorically, the environment. Haeckel introduced popular readers to many environments in his masterwork of scientific illustration, *Art Forms in Nature.*

But okay, what exactly would doing a science of the environment look like? It would involve studying life and the nonliving things that affect life like water and soil. Mediating between the living and nonliving things are nutrients like carbon, nitrogen, and oxygen which cycle in and out of organisms in different ways. So early ecologists tend to include life scientists like Haeckel and earth scientists, as well as those studying evolution like geneticists working on flies and those studying landscapes lice botanists.

Botanical gardens remained key places to conduct research, as did natural history museums that collected bones, fossils, and preserved specimens in jars. Bones could be compared to bones, leaves to leaves, and so one. Mexican-American Ynes Mexia started field work at the age of 51 and went on to collect more than 150,000 wild botanical specimens, at least 500 of which were new species, and her work is still being processed.

Meanwhile Russian-Ukranian polymath Vladimir Vernadsky pioneered ways to analyze nature holistically. One was geochemistry, or using the methods of chemistry to understand minerals. Another was bio-geochemistry, which analyzes living and nonliving processes. Vernadsky promoted a new mode of ecological thought, "What is life?" At the highest level of analysis, it's the whole observable-by-humans planet. The nonliving, or abiotic, dimension of earth is the geosphere, which cradles and interacts with the biosphere. Vernadsky even proposed another level, the noösphere, the totality of human thought, which he imagined cradled by and interacting with the lower levels. Vernadsky also pioneered radiogeology, the study of radioactive elements in the crust. And. And. He worked on the Soviets' atomic bomb because so many scientists worked on weapons.

[shrugs]

Around the time that Vernadsky worked, ecology became a discipline. English botanist Arthur Tansley first obsessed over ferns and then later, all plants. He wanted to map all of the different types of vegetation across England and he thought other botanists should want the same. So, he founded clubs to map plant types. In 1913, Tansley organized the first professional society of ecologists and he became the first editor of the *Journal of Ecology.* In terms of epistemic work, Tansley is remembered for one word: ecosystem. See, scientists are pretty into units. Tansley re-framed the study of nature. Instead of groups of individual living things, say some birds and some trees, it's the study of dynamic interactions between living and nonliving things in one area.

Tansley's rival was American botanist Frederic Clements. His epistemic contributions similarly involved what ecologists should study. Clements argued that plant formations are best studied as units called communities. A plant community is not just like a living organism, it *is* an organism. It's born, grown, eats, and dies. And Clements focused on how an area's climate determined which plants will grow there. For example, a pond dries up and becomes first a meadow, then a forest. This was a version of an older concept: ecological succession, how the makeup of groups of organisms in an area change over time. But Clements championed his own, highly deterministic climax community version of succession.

Tansley hated this, arguing that nature is messier than Clements described in his work. Tansley and Clements fought about ecology from 1905 all the way to World War II, but both agreed that ecologists should promote conservation, or working to actively maintain the health of nonhuman environments. Conservation has its own history, but ecology as a way of making knowledge has always been tied to conversation as an *ethos* or practice. A way of doing something in the world.

This isn't a technology in the same way the lightbulb or a computer is, but the practice of conserving ecosystems is as important as lighting up cities or making sick memes. To name just two wins in conservation, US president Teddy Roosevelt created the National Park System in the first decade of the 1900s, helping preserve vast areas of forest, desert, and other wilderness. And in 1972, the Marine Mammal Protection Act helped to radically lessen the threat humans present to dolphins, seals, and whales in US waters, although the threat still remains.

But early ecologists didn't have many of the tools they needed. For many of those, we can thank English-American polymath George Evelyn Hutchinson, his student Howard T. Odum, and Howard's older brother, Eugene. Take us there, Thought Bubble.

[entering the Thought Bubble]

After World War II, they established ecosystem ecology as a richly quantitative discipline. They took Tansley's essential insight and ran with it, showing how to model the processes at work in a given ecosystem. All three men used experiments to generate mathematical models tracing the flow of energy from non-living sources into primary producers, like plants, primary consumers, like herbivores, and then into meat eaters and the eaters of dead things, fungi and bacteria. He was the first to use very small amounts of radioactive particles as tracers to map how particles move around in a pond, including how plants take up radiation.

The Odums went on to develop this radiotracer as tool technique further, which is still used today to study how water moves and how pollutants move through environments. They also helped establish radiation ecology, which studies the effect of radioactive materials on living systems. The Odums researched ecosystems from coral reefs in the Pacific to riversheds in Georgia. Eugene Odum taught at the University of Georgia actually from 1940 to 2002. He pushed all biology students to study ecology - which got a big laugh in the forties, but is now part of the common sense of the life sciences. Of course you have to study how weather, plants, animals, and soils relate. And Eugene definitely summarized, with some help from his bro, much of their work in the book *Fundamentals in Ecology* in 1953. This book unified ecology, offering a range of useful techniques to all budding plant scientists, animal scientists, and rock scientists. For years, it was the only textbook in ecology and revised, it's still used as a textbook in many classes to this day. Thanks, Thought Bubble.

[exit the Thought Bubble]

The Odums work encompassed observational and empirical methods, some of which were focused on specific parts of ecosystems. But the Odums were also pioneers of a sub-discipline of ecosystems ecology, confusingly called "systems ecology". This is the holistic study of complex living systems as systems. Including the interactions among their non-living inputs, their boundaries, how they adapt to new conditions, how they interact with their systems, and the unpredictable emergent properties they exhibit.

Inspired by Hutchinson's work on feedback loops, Howard modeled how energy flows within ecosystems. He borrowed concepts from thermodynamic and computing in his work on systems ecology. You could even say that the Odums were trying to understand ecosystems as really complex, but not random machines. In fact, in the 1960s, they applied multiple times for money from NASA to engineer self-regulating closed ecosystems of algae and plankton, a whole biosphere in miniature. These would serve as life support systems for astronauts. They based their proposals on their study of the energy flows of the coral atoll Enewetok in the Marshall Islands. Alas, NASA thought their plans were too complex, and the Odums returned to earthly matters.

The question of life in space intrigued scientists modelling the relationship between energy, chemicals, and organisms. In the 1960s, NASA hired English scientist James Lovelock to build instruments to analyze the atmosphere of Mars and look for signs of life. Lovelock thought about why Mars's atmosphere has certain properties different from ours, and what that means for the evolution of life. He arrived at the "Gaia Hypothesis", named after the Greek earth goddess. This says the earth's biogeosphere is self-regulating within broad limits. (?~9:32 video definitely says living things, but I'm pretty sure he means to say nonliving things) Living things - air, rocks, and water - interact in complex ways so that living things can stick around. This was a hugely controversial claim. It suggested a self-awareness to the earth.

But Lovelock's evidence for a regulatory function between what's in the atmosphere and oceans and what's alive, breathing that air or water, was pretty convincing. And he picked up major support from revolutionary biologist Lynn Margulis. She discovered that some of the tiny organs inside cells, like mitochondria and chloroplasts, used to be free floating bacteria that evolved to live entirely within larger organisms. This idea, endosymbiosis, was also hugely controversial. Not because it was too touchy feely, but because it seemed to have nothing to do with the work of Darwin. But Margulis also demonstrated lots of evidence, so biologists and ecologists were confronted with complex systems over here, superorganisms over there, communities all the way up and all the way down in scale.

Today, this shift is capture in the name of the meta-discipline that applies systems thinking across many sciences, earth systems science. This means understanding how living and non-living processes relate, and looking at the entire Earth as one very big, but not infinite, house. This is a house that we humans can wreck, and we hope, repair. So just as the life sciences had to scale up to ecosystems and then to the entire Earth, they had to take into account how humans affect ecosystems and earth systems, a new branch, called human ecology, developed. If that all sounds a bit like what Vernadsky said 100 years ago, you're right. Human thought, non-human life, rocks, water... all connected. Or as Eugene Odum wrote, "The landscape is not just a supply depot, but is also the oikos - the home - in which we must live.

Next time we'll move from studying nature to controlling it, and losing control. It's time for the Green Revolution, pesticide pollution, and the birth of environmentalism.

[end credits]

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