Controlling the Environment: Crash Course History of Science #39

Crash Course: History of Science
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[Intro]
The development of ecology revealed a deeply connected world: we all inhabit one big biosphere - one big house. We share one hydrosphere, one atmosphere...you get the idea.

But the flip side of finding this connection was learning about various kinds of environmental collapse already in motion. We share one *fragile* house.

We've said here that sciences generally move from understanding natural phenomena to controlling them. Today, we'll examine scientific efforts to control the *whole world*, that is to say capital "N" **Nature**. Some have saved lives, but there are downsides...frequently devastating.

[Main Video]
During the Cold War, attempts to control Nature by technological means involved both Soviet and American plans for weather control-- in part because each side worried that the other would figure it out first. Spoiler alert: neither did.

The U.S. conducted one secret rainmaking project, Operation Popeye, during the Vietnam War. They ineffectively tried to make the monsoon season last longer in Southeast Asia, hampering the North Vietnamese army's movements by deteriorating roads and bridges through flooding. That's some James Bond villain stuff!

The U.S. also carried out an operation at home called **Project Stormfury** from 1962 to 1983, seeding dangerous tropical storms with silver iodide in order to freeze some of the water in them and slow them down, making them less dangerous. This didn't work well in practice, but the experimental flights were valuable to meteorology.

Other grand-scale engineering projects focused on power and agriculture. This included many irrigation canals and gigantic dams, like the Aswan High Dam in Egypt, built between 1960 and 1970. These projects allowed people in dry regions or ones subject to seasonal flooding to have more control over when they planted and to grow more harvests per year.

In the United States, the Reclamation Service, later the Bureau of Reclamation, worked starting in 1902 to irrigate the Western Plains. Today, that Bureau is the largest wholesaler of water in the U.S.

Overall, across industrial societies, agriculture changed a lot as engineers developed machines like tractors, chemists created new fertilizers and pesticides, and plant geneticists bred hybrid seeds.

Plants need the nutrient **nitrogen** to grow. But plants can't "fix" their own nitrogen from air, so they need bacteria or human-made fertilizers like ammonia to do it for them. In the early 1900s, German chemists **Fritz Haber** and **Carl Bosch** developed a way to take nitrogen *right out of the air*.

This seemed like a big win. Any industrial society could use the Haber-Bosch process for synthetic nitrogen fixation to make millions of tons of fertilizer and grow more crops. And synthetic ammonia from the process was also used to make nitric acid, which was necessary to make explosives. So again, war and professional science were tightly linked.

But the bigger problems, long term were environmental. The Haber-Bosch process requires fossil fuels like oil or natural gas to work. Which seemed fine; industrialists didn't know that burning these fuels would disrupt earth's climate cycles.

A more obvious problem is runoff: to make plants take up lots of nitrogen, industrial farming treats them with more fertilizer than they need. Rain washes the leftover fertilizer into waterways, leading to *eutrophication* or too many nutrients in the water. This leads to a build up of algae, which use up all of the oxygen in the water, making it deadly for fish.

Another seemingly "big win" with unintended consequences was an improvement in staple crops. In the 1930s, after decades of research, agricultural scientists in the U.S. rolled out **hybrid crop varieties**. These crosses of pure strains produced much higher yields. But farmers started using *only* these seeds.

Commercial fields became **monoculture**, or "one-plant." This means fewer plants are commercially available today. And pests can more easily wipe out any one plant. This is the *opposite* of growing many plants together, or **polyculture**, which can help restore nutrients to soil without synthetic chemicals.

So on the one hand, synthetic fertilizers and hybrid crops seemed like easy wins. On the other hand, there were negative long-term consequences. And also on a...third hand...even these advancements didn't prevent environmental problems and growing fears that agricultural innovation just couldn't keep up with rapid population growth.

For example, part of the U.S. experienced severe droughts in the 1930s and was farmed in unsustainable ways. This led to massive dust storms, collectively called the **Dust Bowl**, which forced many farmers to abandon their farms *during the Great Depression*.

And this was the United States! Most of the world's farmers remained smallholders: they worked plots of land smaller than ten hectares, largely without industrial machines. Populations were growing, but storms and wars threatened to lead to famines.

So many scientists, taking note from that crotchety preacher who inspired Darwin, Thomas Malthus, wrote pessimistically about humanity's future. Probably the most famous of these "neo-Malthusian" thinkers was American biologist **Paul Ehrlich** whose 1968 bestseller, The Population Bomb, predicted that famines would soon kill millions of people, especially in India. Which *didn't happen.*

Arguably the biggest example of humans controlling our environment was the **Green Revolution** in the 1950s and 60s, when crop yields went up for farmers in *less* industrialized countries...*way up.* In one sense, it's a simple story of science *applied*: scientists from rich countries offered new techniques built on hybrid seeds. In another sense, it's science in the service of politics.

This revolution was organized by International Agricultural Research Centers or IARCs which were funded by federal grants from developed and developing countries and by private foundations like Rockefeller and Ford.

The IARCs believed that the best way to improve yields was through *smart breeding*. They wanted to focus on breeding plants *resistant* to pests in specific areas...and simultaneously to make these plants take up more nitrogen and grow more edible material.

Lots of people were involved in this work particularly in the U.S., Mexico, and India. But people *love heroes* so Green Revolution stories often focus on American agronomist and plant geneticist Norman Borlaug who was, to be fair, an awesome scientist.

Thought Bubble, introduce us! Borlaug joined the Rockefeller Foundation's group in Mexico in **1944**. He had never worked on wheat, maize, or beans before *and* he didn't speak Spanish. But he

eventually learned it and stayed in Mexico for 16 years working mostly in **Sonora.** He developed a hybrid what that withstands a common fungus called rust blight.

How? Lots of painstaking *research* into plant *genetics*, courtesy of other geneticists, and lots of *field trials*.

Borlaug took **Norin 10** -- a wheat bred by Japanese scientist Gonjiro Inazuka that was short, but produced lots of food if given lots of nitrogen and defended with chemical pesticides and bred a semi-dwarf wheat specifically for Mexican climates.

Starting around **1950**, Mexican agriculture shifted toward high-yielding varieties of wheat, synthetic nitrogen, and pesticides. And this revolution in farming soon spread to Colombia, Chile, and India.

The Ford Foundation pushed the Indian government to adopt the same changes. So *Indian* scientists worked with *Mexican* scientists and *hybrid semi-dwarf Mexican wheat seeds* were shipped to India in time for the 1963 planting season. This lead to astounding growths in yield.

Also in the 1960s, an international team of scientists and farmers worked to develop a new variety of high-yielding semi-dwarf rice called **IR8** -- sometimes called "miracle rice." In 1971, the **Rockefeller** and **Ford Foundations** created the **Consultative Group on International Agricultural Research** to further extend the IARC research.

Borlaug won the Nobel in 1970, no Mexican, Indian, or Japanese scientists shared the prize. **Thanks, Thought Bubble.**

Meanwhile, with minimal support from the Soviet Union, the Maoist Chinese state fostered its own scientific farming including a system of **experimental agricultural stations**, and **hybrid sorghum**, and **hybrid rice** varieties.

Agriculturally, the Green Revolution was an immediate success. Thousands of tons of seeds moved from Mexico to India. Food prices dropped. India because a rice exporter and currently *overproduces* wheat. But in the longer-term, **the *Green Revolution* meant that way more farmers started practicing *monoculture*, essentially betting their chips on a small number of hybrid crops.**

Thousands of traditional varieties are no longer cultivated. Only four crops-- **wheat**, **maize**, **rice**, and **soy**-- provide *more than half* of our food today.

Socially, industrial farming requires investing in expensive equipment and hybrid seeds which aren't produced by the previous year's harvest. This changed the business cycles of farmers.

Zooming out, the Green Revolution changed what defines a "**modern**" **society**. It now meant using synthetic nitrogen, pesticides, and tractors on large monoculture farms. The idea of the Revolution had been to end hunger, and it probably prevented millions from starving. But ***famine* has always been linked to *distribution*, or the political-economic process of *moving food* around, not only how much food is produced.**

And the Green Revolution was also always about the United States flexing its scientific muscle around the world buying allies with bread-- including India, the world's largest democracy. This is **soft power**.

Meanwhile, also in the 1950s and 60s, synthetic pesticides were used to control bugs that spread human illnesses. The most famous was **dichlorodiphenyltrichloroethane**, which you have probably heard of as DDT...so you don't have to say that whole thing. That was sprayed on fields, and urban green spaces, right on the little kids...just everywhere.

It had, seemingly, miraculously dropped mosquito populations during World War II, helping fight the spread of malaria and typhus. Only it turned out that DDT, while not immediately toxic to humans, was toxic to lots of other living things, like birds and fish. And it wasn't good for humans in the long-run either.

After years of careful research, all of which angered scientists working for the chemical industry. American biologist and pioneering environmentalist **Rachel Carson** wrote a series of articles that became the book *Silent Spring* in 1962. she explained in simple, beautiful language how some kinds of synthetic pesticides work and why they are often a terrible idea. With this book, along with her other books, numerous op-eds, and appearances, Carson helped spark the modern environmentalism movement in the United States.

In addition to long-term effects, pesticides have also been involved in acute disasters. In 1984, a Union Carbide India chemical plant in the city of **Bhopal** had a serious accident. This plant produced the insecticide Sevin, using a highly toxic chemical called methyl isocyanate gas. The accident released 32 tons of methyl isocyanate, half a million people were exposed, 4,000 people died immediately; 2,500 died that year. Bhopal is widely regarded as the worst industrial disaster in history.

Only two years later, in 1986, the **Chernobyl** reactor melted down in Ukraine. Clouds of radioactive material billowed across Europe and then the world. Conflicting, politically inflected epidemiological studies put the long-term casualties from cancer due to Chernobyl at anywhere between 10,000 and hundreds of thousands.

So controlling nature hasn't been a total slam-dunk for humankind and most of humankind has had no say in these projects. The effects, good or bad, just happened to them and this is still the case. In fact, the Intergovernmental Panel on Climate Change warns that global food supplies are in danger because stable crops like **rice**, **wheat**, and **corn** are now facing a slowdown in the rate at which their yields go up.

Meaning, back to Malthus, we might soon have more hungry mouths than food, even if agronomists keep making incremental gains. So some serious scientists are returning to the idea of controlling the climate. In 2006, Nobel-winning atmospheric scientist Paul Crutzen called for humanity to use **geoengineering**-- the modification of the climate, to keep our world habitable.

Next time, we'll look at control over living things at a different scale: it's the characterization of **DNA** and the birth of **biotechnology**.

[Outro]
Crash Course History of Science is filmed in the Dr. Cheryl C. Kinney Studio in Missoula, Montana and it's made with the help of all these nice people. And our animation team is Though Cafe.

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