In this module we will look at just two scientific ideas (there are a lot more) that have influenced recent ecological thought: general systems theory, and evolution theory.

**General Systems Theory**

One reason radical ecology is so compelling is that it has considerable scientific backing. Since Einstein, physics has lost its classical mechanistic' view of the world and has become more holistic, relativistic and stochastic. Probabilities have replaced laws,' we have entropy and the uncertainty principle, and Einstein's most famous equation showed that matter and energy are interchangeable. Using these new theories, biologists have been much more successful in explaining how ecosystems work - why species die out, how matter and energy cycle through the system, and so forth. All of this supports the deep ecology claim that nature is an interconnected dynamic system in which every "part" is not a discrete part at all, but a manifestation of huge continuing processes, and every event or action has a ripple effect. (Example: I think of my body as more or less separate from the rest of nature, and more or less permanent, but it is not; it was formed by certain process and will be dissolved by other processes, and in the meantime, it constantly exchanges matter and energy with its environment. My "common-sense" view is a relic of pre-Einstein physics.)

Even more important than modern physics is the new (established in the 1930s) science called "general systems theory." Its founder,**Ludwig von Bertalanffy** (that's him in the photo), realized that any entity (a machine, a human body, a galaxy) can never be fully understood by analyzing all its parts; it must be looked at as a whole. Another, much older way of saying this is, "the whole is greater than the sum of its parts," but classical science has always said, "the whole is the sum of its parts." You might also say: nothing exists as a discrete, separate entity; everything is connected to everything else; everything causes everything else. A "system," then, is a collection of processes which come together to form something that we can recognize and name; but when we name it and separate it off from its surroundings, we are being somewhat arbitrary. Still, systems are real, and can be analyzed. General systems theory argues that systems are dynamic and self-governing; the keep themselves running by a mechanism called "autopoiesis" (Greek for self-making') or "feedback." A very simple example: your thermostat, which of course does not "think," but "knows" when to turn the furnace off and on based on feedback it gets from a thermometer. Living systems (a human body, a swamp ecosystem) are a lot more complicated, but still follow the same rules of feedback. A system can function indefinitely as long as it has a stable interchange of matter and energy with its environment (that is, it's an "open system"). If that interchange is interfered with, it can destabilize. An "attractor" is a a factor (thing or process) that interferes and causes instability. If the attractor is big or strong enough, it can cause the system to break down entirely (then it is a "chaotic attractor"). Your body is a complex system with many sub-processes. An attractor called a "virus" can get in and mess up the stability of some of those processes, and you get sick. If the virus is too powerful, or if the systems are too weakened by other attractors, you can die. Systems theory is now fundamental to the science of ecology, and it seems to prove many things that the deep ecologists have been saying.

You should know a little about where the "classical" scientific paradigm came from. Before the 1500s, science was largely Platonic and therefore not much concerned with experiment, observation, and the like - science was more about abstract principles that often had little connection with the real world. (Consider alchemy and astrology.) Most people looked at the world of nature as magical and sacred, full of things that could never be explained logically: nature was alive, and when you looked at it, it looked back. But the Renaissance and the Scientific Revolution changed all that, bringing back a more concrete Aristotelian approach. This new science brough enormous changes in technology, and gave us the modern world of airplanes, computers, vaccines, and indoor plumbing (but also unfortunately such nightmares as cell phones, nuclear weapons, nerve gas, the electric chair, and the talking Barbie doll!). Many people contributed to the Scientific Revolution, but you should know three men in particular: Francis Bacon, who developed scientific method; René Descartes, who developed a purely mechanistic and logical explanation for the physical universe; and Isaac Newton, who reduced it all to a handful of mathematic principles. When this "unholy trinity" was finished, Nature had been reduced to a mere resource, operating according to laws of physics and chemistry, and shorn of all its magic and mystery. The stage was set for Western civilization's next big project: trashing the planet.

**Evolution**

This is an enormous topic, always (if you'll excuse the expression) evolving, and controversial too, at least to some people. Here we will look at just one aspect of the debate, chosen because it has a special connection to radical ecological theory, and helped generate social ecology, which is the topic of the next module.

The man who coined the term "social ecology" is Murray Bookchin, and you will learn a lot more about him shortly; but that's not his picture at right and, for a reason, it is not Darwin's - that's **Prince Peter Kropotkin**(1842-1921), the Russian anarchist philosopher. He was the first to realize that there is a link between the way we treat nature and the way we treat each other - and for that simple discovery, your humble instructor considers him the greatest mind produced by Western civilization in the last four or five centuries, and also the first great mind of post-Western civilization, whatever that may turn out to be.

You need a brief biography of Kropotkin before you can understand how he put two and two together. He was a member of the highest Russian aristocracy, and had a very sheltered childhood - this in a time when a vast ocean of illiterate Russian peasants were virtually owned by a tiny aristocracy, who lived extremely well off the profits and knew almost nothing about the people they exploited. As was expected of young men of that class, Kropotkin joined the army in his late teens (as an officer, of course). But his real interest was in botany and geology; he was fascinated by Darwin's recently published work on evolution; so he asked to be posted to Siberia, where he could explore the wilderness, collect plants and study the terrain. He was assigned to the garrison of a camp for political prisoners. Talking with them, he gradually came to realize that these dangerous revolutionaries' only wanted to bring a measure of democracy and freedom to the oppressed Russian people; and he realized that he himself was one of the oppressors. As he formulated his ideas (that is, slowly became an anarchist) he published and spoke on the geology and geography of Siberia, and earned some reputation as a budding scientist. When he resigned his commission and came out of the closet' as an anarchist, he was arrested. Friends helped him escape from prison, and he went into exile (almost all his anarchist writing was done in London). In 1917 when the Tsar was overthrown, he was an old man; but he came back to Russia in hopes that Lenin and the Bolsheviks were about to create a socialist utopia. He was wrong, and died a disappointed man in Moscow - though Lenin arrested and killed many anarchists, he never touched Kropotkin, who was too well known and popular. He is buried at an Orthodox convent just outside Moscow - the designer of this course has made the pilgrimage there. Not much to see but a dilapidated headstone.

Here is the crux of Kropotkin's philosophy: Darwin was right about evolution, but he was wrong about its mechanism: species do not change and progress through competition ("survival of the fittest"), but through cooperation (what biologists now call "symbiosis"). The most successful species is not one that kills and destroys, but one that learns how to fit into its ecological niche. Since humans are obviously a successful species, we must have survived because of our cooperative skills. Competition does exist, of course, but it is not fundamental. Because of the recent rise of an economic system based on competition - that is, capitalism - we have learned to think of competition as natural and even desirable. This has created a world of oppression and violence. The solution is anarchism - the overthrow of all systems, whether political or economic, that allow one human being to dominate and exploit another. Kropotkin's most famous book, *Mutual Aid*, describes his theory of evolution and carries it forward into human society, concluding that it is more natural for us to live in cooperation and harmony than in competition and strife.

The great biologist Stephen Jay Gould says it like this: Kropotkin and Darwin agree that there is a "struggle for existence." Darwin says that species, and individuals within species, struggle against each other (say, for scarce food), and the fittest survive. Kropotkin doesn't deny that this happens, but says that the real struggle is between the individual or species and its environment: those who learn to live with their environment survive, and usually the best way for an individual to survive is to cooperate (consciously or not) with other individuals. Could our distant ancestors have successfully hunted game if each person had acted alone?

**Some implications for other disciplines**

The fact that Kropotkin was an anarchist probably delayed the development of his insights by other philosophers and scientists. "Anarchism" is a word that still frightens and disturbs many people (usually, because they don't know what it really is). Still, he helped inspire new trends in psychology, sociology and evolutionary biology, and - for our purposes, this is the main point - in both the science and philosophy of ecology. He is recognized as a pioneer by many who have no interest in his anarchism as such. A great paradigm shift was just beginning in the sciences, and Kropotkin saw it coming - but he was ahead of his time. Some forty years after his death, Murray Bookchin picked up where he had left off and formulated the new, and very radical, world view called "social ecology." More on that later.

For now, you should know about some controversies raised by these new ideas on living systems and evolution; which 'side' a scientist or philosopher takes will affect how he or she thinks about environmental ethics.

Cybernetics (the word is Greek, and related to "govern") is basically the study of how complex systems govern themselves through feedback loops. (The thermostat example mentioned above is the simplest example). But the whole vast world of computers and the internet would be impossible without cybernetics. Since World War II, cybernetics has been applied to many other fields, including medicine, engineering and even management. It is also essential to environmental science: ecosystems operate according to feedback rules. A very simple example: if a predatory forest species like the owl increases too much, the population of mice and other small animals will decrease; if they die out, the owls will die out too, or go elsewhere. For environmental ethics, cybernetics helps us understand the pros and cons of ecosystem management: is it 'ethical' to shoot some of those owls, to help maintain a normal balance of populations in the forest?

Sociobiology is now a somewhat outdated term; it has evolved into various new fields such as behavioral ecology, evolutionary psychology and biocultural anthropology. But 'sociobiology' is still useful as a a catch-all concept. Its basic premise is that natural selection, as defined by Darwin, can explain nearly all behaviors of all living organisms and systems. Many people who can accept this rather commonsense idea get upset when it is applied to human beings, because certain conclusions can be drawn that we may not like. For example: the fact that black Americans on average score lower on IQ tests than whites might be due to their race, rather than to their environment; or that males have inherently better mathematical skills than females. Sociobiologists counter that we have to accept and deal with scientifically proven facts, wherever they might lead; and they also claim that they are deliberately misunderstood and distorted for political reasons. Here, we are just concerned with the implications for environmental ethics. Sociobiology may, for example, 'prove' that it is natural for humans to dominate nature and each other; but just because it is 'natural' (that is, a product of evolution) that does not make it *right*.

Evolutionary psychology is even more controversial, since it involves human beings and our poorly understood minds. It proposes that nearly all of our behavior - if not all - is governed by the rules of evolution. That is, we behave as we do because the behavior in question has 'adaptive' value - a technical term meaning that in the distant past, it helped us survive and reproduce. Today many of these behaviors may no longer be adaptive, but genetic heredity means we are stuck with them. An example: our taste for fatty and sweet foods. A million or two years ago, this was a good thing - the body stores fat, and our ancestors might go a long time between meals; sugar gives us energy to run away from those lions or wolves. Today, these things no longer matter, but the taste remains, and so we get obese. Critics of evolutionary psychology are often politically and philosophically on the left - that is, they support ideologies that want to improve or perfect human society, like socialism, anarchism or liberalism. You can see the problem: if our behavior is "hard-wired" by evolution, then there is very little hope of 'engineering' people into better behavior by education or persuasion. Soviet Communism, for example, tried this and failed; it had to resort to force and repression to change people's behavior. The evolutionary psychologists respond: cooperation and altruism are also products of evolution; we can still improve human society by emphasizing and rewarding that kind of behavior and making a conscious choice not to follow our more aggressive tendencies. (I may crave sugar, but after all, I can choose not to eat it, hard as that might be.) In any case, it is absurd to think that human nature is *not* a product of evolutionary adaptations, since everything else in every organism is.