Week 4 class 2 - Chaos and Fractals (lab)

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The structure of scientific revolutions

Kuhn was a historian of science by training, and firmly believed that philosophers had much to learn from studying the history of science. Insufficient attention to the history of science had led the positivists to form an inaccurate and naïve picture of the scientific enterprise, he maintained. As the title of his book indicates, Kuhn was especially interested in scientific revolutions – periods of great upheaval when existing scientific ideas are replaced with radically new ones. Examples of scientific revolutions are the Copernican revolution in astronomy, the Einsteinian revolution in physics, and the Darwinian revolution in biology. Each of these revolutions led to a fundamental change in the scientific world-view – the overthrow of an existing set of ideas by a completely different set.

Of course, scientific revolutions happen relatively infrequently – most of the time any given science is not in a state of revolution. Kuhn coined the term 'normal science' to describe the ordinary day-to-day activities that scientists engage in when their discipline is not undergoing revolutionary change. Central to Kuhn's account of normal science is the concept of a *paradigm*. A paradigm consists of two main components: firstly, a set of fundamental theoretical assumptions that all members of a scientific community accept at a given time; secondly, a set of 'exemplars' or particular scientific problems that have been solved by means of those theoretical assumptions, and that appear in the textbooks of the discipline in question. But a paradigm is more than just a theory (though Kuhn sometimes uses the words interchangeably). When scientists share a paradigm they do not just agree on certain scientific propositions, they agree also on how future scientific research in their field should proceed, on which problems are the pertinent ones to tackle, on what the appropriate methods for solving those problems are, on what an acceptable solution of the problems would look like, and so on. In short, a paradigm is an entire scientific outlook – a constellation of shared assumptions, beliefs, and values that unite a scientific community and allow normal science to take place.

What exactly does normal science involve? According to Kuhn it is primarily a matter of *puzzle-solving*. However successful a paradigm is, it will always encounter certain problems – phenomena that it cannot easily accommodate, mismatches between the theory's predictions and the experimental facts, and so on. The job of the normal scientist is to try to eliminate these minor puzzles while making as few changes as possible to the paradigm.

Incommensurability and the theory-ladenness of data

Kuhn had two main philosophical arguments for these claims. Firstly, he argued that competing paradigms are typically 'incommensurable' with one another. To understand this idea, we must remember that for Kuhn a scientist's paradigm determines her entire world-view – she views everything through the paradigm's lens. So when an existing paradigm is replaced by a new one in a scientific revolution, scientists have to abandon the whole conceptual framework which they use to make sense of the world. Indeed, Kuhn even claims, obviously somewhat metaphorically, that before and after a paradigm shift scientists 'live in different worlds'. Incommensurability is the idea that two paradigms may be so different as to render impossible any straightforward comparison of them with each other – there is no common language into which both can be translated. As a result, the proponents of different paradigms 'fail to make complete contact with each other's viewpoints', Kuhn claimed.

THE HISTORIAN OF SCIENCE Thomas S. Kuhn describes a disturbing experiment conducted by a pair of psychologists in the 1940s. Subjects were given glimpses of playing cards, one at a time, and asked to name them. There was a trick, of course. A few of the cards were freakish: for example, a red six of spades or a black queen of diamonds.

At high speed the subjects sailed smoothly along. Nothing could have been simpler. They didn't see the anomalies at all. Shown a red six of spades, they would sing out either "six of hearts" or "six of spades." But when the cards were displayed for longer intervals, the subjects started to hesitate. They became aware of a problem but were not sure quite what it was. A subject might say that he had seen something odd, like a red border around a black heart.

Eventually, as the pace was slowed even more, most subjects would catch on. They would see the wrong cards and make the mental shift necessary to play the game without error. Not everyone, though. A few suffered a sense of disorientation that brought real pain. "I can't make that suit out, whatever it is," said one. "It didn't even look like a card that time. I don't know what color it is now or whether it's a spade or a heart. I'm not even sure what a spade looks like. My God!"

Professional scientists, given brief, uncertain glimpses of nature's workings, are no less vulnerable to anguish and confusion when they come face to face with incongruity. And incongruity, when it changes the way a scientist sees, makes possible the most important advances. So Kuhn argues, and so the story of chaos suggests.

Kuhn's notions of how scientists work and how revolutions occur drew as much hostility as admiration when he first published them, in 1962, and the controversy has never ended. He pushed a sharp needle into the traditional view that science progresses by the accretion of knowledge, each discovery adding to the last, and that new theories emerge when new experimental facts require them. He deflated the view of science as an orderly process of asking questions and finding their answers. He emphasized a contrast between the bulk of what scientists do, working on legitimate, well-understood problems within their disciplines, and the exceptional, unorthodox work that creates revolutions. Not by accident, he made scientists seem less than perfect rationalists.

> Central to Kuhn's ideas is the vision of normal science as solving problems, the kinds of problems that students learn the first time they open their textbooks. Such problems define an accepted style of achievement that carries most scientists through graduate school, through their thesis work, and through the writing of journal articles that makes up the body of academic careers. "Under normal conditions the research scientist is not an innovator but a solver of puzzles, and the puzzles upon which he concentrates are just those which he believes can be both stated and solved within the existing scientific tradition," Kuhn wrote.
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> Then there are revolutions. A new science arises out of one that has reached a dead end. Often a revolution has an interdisciplinary character—its central discoveries often come from people straying outside the normal bounds of their specialties. The problems that obsess these theorists are not

Those who recognized chaos in the early days agonized over how to shape their thoughts and findings into publishable form. Work fell between disciplines—for example, too abstract for physicists yet too experimental for mathematicians. To some the difficulty of communicating the new ideas and the ferocious resistance from traditional quarters showed how revolutionary the new science was. Shallow ideas can be assimilated; ideas that require people to reorganize their picture of the world provoke hostility. A physicist at the Georgia Institute of Technology, Joseph Ford, started quoting Tolstoy: "I know that most men, including those at ease with problems of the greatest complexity, can seldom accept even the simplest and most obvious truth if it be such as would oblige them to admit the falsity of conclusions which they have delighted in explaining to colleagues, which they have proudly taught to others, and which they have woven, thread by thread, into the fabric of their lives."