HSS102
History of Science
Lectures 5, 6

Lecture 5: Revolutions in Science

Lecture 6:Thomas Kuhn’s *The Structure of Scientific Revolutions* (1962)

Revolution

- Two sets of meaning:

A) Rebellion, Revolt, Insurrection, seizure of power…change in the mode of production, etc. CHANGE. [more modern usage, became popular only after the "Glorious Revolution" of 1688].

B) An instance of revolving/a circular movement: 'the movement of an object in a circular or elliptical course around another or about an axis or centre' Turn, Rotation, Spin, etc. [more ancient usage]: "The earth makes one revolution around the sun in about 365 days".

- Need to maintain both the meanings to understand Scientific Revolution in general and the Copernican Revolution in particular.

Broad Issues/Questions?

- What's the revolutionary way of understanding science? How was such an idea canonized in HoS? Was there a scientific revolution, or many? What does a revolutionary understanding of the past leave out? Who were the revolutionaries and who won the revolution?
- Today's Discussion: What's the revolutionary way of understanding science?

Revolutionary Historicism

- Revolutionary Historicism: Understanding revolution as a single process and reducing all past developments as somehow leading to a revolution>refers to a “linear, irreversible and a unidirectional conception of time” (Shapin 1996).
- The “traditional” notion of scientific revolution >a one time-one space phenomenon which first originated in Western Europe and then became global over time through diffusion and adaptation>denial of coevalness.>eclipse of the meaning II of revolution by meaning I: the political understanding of revolution which the West underwent between the end of 18th c and the beginning of the 20th c.

Scientific Revolution: A Mid 20th century Historical Project

- Alexandre Koyre: “Galileo Studies” (1939) was first to popularize the term (Shapian 1996). Before that, some authors used the term revolution in science in the end 19th c.
- Only in 1954, two influential historians of science introduced the term in their book titles: A Rupert Hall, “The Scientific Revolution”, J. D. Bernal, “The Scientific and Industrial Revolutions”.
- Many so-called revolutionaries of science in the mid-17th century were aware of the dawn of a new epistemic era, but, they didn’t describe themselves as revolutionaries of science.
- In fact, in the 17th century, science was yet to emerge as a “single and coherent cultural entity” to understand, explain and control the natural world, nor was there a universal understanding of a scientific method for deriving what’s later known as scientific knowledge (Shapian 1996).

The Traditional View [Koyre]

1. Transformation of worldview from a geo-centric universe to a helio-centric universe.
2. A new conception of motion and of the creation of space as a void.

- The traditional view attributes these transformations to the expanding process of mathematization of nature, i.e., the subjection of the growing range of empirical phenomena to mathematical treatment in ways generally suitable to experimental testing [we've discussed].

Key Contributors [traditional view]

1. Copernicus (1473-1543): computation of planetary trajectories in a Sun-centred setting.
2. Johannes Kepler (1571-1630): turning of Copernicus' formulation into "celestial physics" leading to the conceptualization of planets' elliptical path.
3. Galileo (1564-1642): mathematization of a significant terrestrial as opposed to a celestial phenomenon: falling and projected bodies which countered some of the major objections to the Copernican formulation.
4. Rene Descartes (1596-1650): mathematical understanding of space and particle interactions in space.
5. Newton (1642-1727): capping of these developments by uniting terrestrial and celestial physics in a mathematically exact, empirically supported conception of universal gravitation.

Features of the Traditional View

- A hierarchy exists between mathematical science and the experimental science.
- Koyre says, Galileo used experiments as a check on the theories he devised by mathematical reasoning.
- Kuhn refines this model:

A) Classical physical science [mathematics, astronomy, harmonics, optics, and statics]>experiments driven by theory, not clearly distinguished from thought experiments>outcomes presented in universal, law-like generalizations.

B) Baconian science [electric, magnetic, chemical, and heat phenomena]> experiments are at the heart with detailed circumstantial information aided by some of the new instruments that were invented in the seventeenth century (such as thermometers, air pumps, and electrostatic generators).

What's a "Paradigm" in the *Structure*

- Every major science discipline navigates two stages of metamorphosis: "Pre-paradigmatic" stage and "Paradigmatic stage".
- Pre-paradigmatic Stage: Coexistence of multiple modes of practicing science, availability of more than one school of thought (and hence, heterogenous), no consensus about methods. A contemporary example: Climate Science.
- Paradigmatic Stage: Emergence of consensus, disappearance of schools of thoughts, uniformity in inquiry, uniformity envelops plurality in doing science. This transition happened first in Astronomy [Ptolemy] and then in Physics [Newton], Chemistry [Lavoisier, Dalton] and Biology [Darwin]. The emergence of paradigm distinguishes science from art, literature and social sciences—where plurality in methods and practices defines merit.
- A paradigm specifies the exact ways in which inquiry in a certain field should/ought to proceed—what problems to handle and how to handle them. "Paradigms are universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (p. vii). Paradigm thus refers to the ground rules, the master-explanatory framework and a disciplinary matrix for a group of professional scientists in a given time.

“Normal Science”

- Once a science reaches the stage of a paradigm, it advances a “normal science tradition”. Normal science refers to the everyday conduct of problem-solving premised upon the conceptual apparatuses made available to the community by the paradigm. It is a cumulative and tradition-bound exercise. The practitioner of the normal science is a scientist who internalizes the paradigm of his/her time through university education.
- A shared commitment to a paradigm ensures that its exponents probe into the kinds of research questions to which their own theories can straightforwardly supply answers. This explains the ubiquity of textbook culture in the realm of science education.
- A scientific community cannot act science without commonly agreed-upon beliefs (p 4) in the sense that paradigmatic rules are to be taken for granted in order to conduct normal scientific activities. Hence, normal science resists radical thinking in the sense that its practitioners conform to the existing paradigm while adjusting “existing theory or existing observation in order to bring the two into closer and closer agreement”, and extending “existing theories to areas that it is expected to cover but in which it has never before been tried” (p. 233). It is normal science that makes science a highly successful socio-cultural enterprise.
- Normal science refers to a period of stable and coherent growth in science.
- So, what is the relation between a paradigm and a normal science?>This is where Kuhn appears to draw from structuralist philosophy in linguistics (Saussure), Psychoanalysis (Freud) and sociology (Durkheim)>follow the lecture.

“Anomaly”, “Crisis”, “Revolution”

- The stable growth of normal science is, at times, punctuated by anomalies—moments when conceptual boxes provided by the paradigm fails to resolve certain newly observed anomalies in nature. Anomaly “subverts the existing scientific practice” (p 6). Anomaly leads to the recognition that nature has violated the paradigm-induced expectations that govern normal science
- A puzzle continues to remain a puzzle until it acquires enough critical mass (i.e., the manifestation of many major puzzles) calling for a certain rethinking of the conceptual matrix itself. This might take decades and might involve bitter fights within the community of scientists. The old-guard of the scientific community resists the changes in their belief-system.
- The deepening of the crisis eventually forces the community to re-evaluate and re-construct prior assumptions and facts. This is not an event but a time-consuming process. This is the moment of scientific revolution. It is only during this moment of transition from one paradigm to another that the scientific community take part in radical debates about the nature of their vocation and tests competing theories: Schools of thought resurface.
- Remember, temporally speaking, normal science has a much longer life than revolutionary science.
- However, when a shift takes place, "a scientist's world is qualitatively transformed [and] quantitatively enriched by fundamental novelties of either fact or theory" (p 7).

A Few Illustrations of anomalies that led to new paradigms

- Navigators noticed that it was always the top of a ship’s mast which was visible from a distance. This finally led to the paradigm that earth is round and not flat.
- With the aid of his telescopes Galileo noticed that the moons of Jupiter orbited around Jupiter. This observation brought crisis to the prevalent geocentric paradigm of the universe. This observation provided empirical support for the new heliocentric theory (Copernican revolution) in which the planets revolved around the sun.
- Discovery of wave-particle duality. Newtonian physics> nature had "an independent verifiable existence, unaffected by the observation of the experimenter." The wave-particle duality phenomenon established that the experimenter also in turn affected the outcome of an experiment, no matter what she accomplished. The anomaly led to a paradigm shift through the invention of quantum physics.

Emergence of a New Paradigm and the Question of “Choice”

- The known methodologies and approaches of the existing normal science is of no help when the scientific community has to make a choice for the new paradigm because all such approaches emanate from the old paradigm which is in crisis to solve emergent puzzles. Einstein famously said, “It seems as though we must use sometimes the one theory and sometimes the other, while at times we may use either. We are faced with a new kind of difficulty. We have two contradictory pictures of reality; separately neither of them fully explains the phenomena of light, but together they do”.
- The context-specific “value-commitments” of the scientific community which is external to the realm of mere logic and mathematical precision. The ultimate explanation of a theory choice is not just methodological but sociological. Hence, it is axiomatic that the scientific community is a social entity.

What then is the relation between the old paradigm and the new one?

- The new paradigm is not a logical development of the old, nor does it give you a better access to a higher realm of “truth”. The two paradigms have completely different set of apparatuses to conceive nature and hence they “cut the world differently”. The two paradigms use different languages and even when they use the same language, meaning changes>Example> “atom”. In ancient Greek natural philosophy, atom referred to the “uncuttable”, uncreated and eternal. In his Law of Multiple Proportions, Dalton refers to atom to explain why “elements react in ratios of small whole numbers”. Again, with the invention of sub-atomic particles, the idea of atom changed further.
- The relationship between two successive paradigms is therefore not that of logical succession but of complete incommensurability without having a common standard of measurement. Hence, truth is intra-paradigmatic and not inter-paradigmatic.
- Kuhn becomes extremely provocative and radical in his opinion when he says, “the world changes when paradigm changes”. Therefore, doing science is not just about understanding the nature as it is out there. Rather, it is about changing the nature while performing science.

How Kuhn's Thesis Works