Kuhn, Thomas S.
The Structure of Scientific Revolutions
1962, University of Chicago Press.

1. Introduction
   - 1.1 Puts science in a cultural context and subject to its basic assumptions.
   - 1.2 Deals with anthropological nature of knowledge models.
   - 1.3 Applies natural science use of term paradigm and analyses natural sciences.
     - Are social sciences subject to this?
   - 1.4 Need to distinguish between:
     - Epistemological paradigms and scientific paradigms
     - Is there a historical paradigm?
   - 1.5 Can the term be used to analyse ordinary thought of all people?
   - 1.6 Paradigm: 1) world view, geist, horizon
     2) general theory: scientific paradigm, historical paradigm, philosophical paradigm.
   - 1.7 Attacks contemporary view of science.
     - Influenced by Piaget and dev. psych.
     - By Gestalt and psych of perception
     - By Whorf and linguistics
     - By sociological of scientific community.
   - 1.8 Paradigm definition: "Universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners." (p. viii)

2. Historiography of Science:
   - 2.1 Old historiography: cumulative in nature
     - Problem: either the same methods formerly produced myths, etc., and now produce science, or the same methods produced theories we have now come to reject in science. But these were once thought to be science. Therefore science is not cumulative.
   - 2.2 New Historiography
     - No method provides a unique substantive conclusion to many sorts of scientific questions. One can generally think of an alternative.
     - The solution we chose is generally based on our prior experience and world view. Observations and experience can limit the range of beliefs but not determine them.
     - Differences between schools of thought is not in methodology, but in their incommensurable ways of seeing the world, and practicing science in it.
     - Science begins with basic postulates about what are the fundamental entities of which the universe is composed, how these interact with each other and the senses, what are legitimate questions and what are legitimate ways of seeking solutions.
     - Research is an attempt to fit experiences into these boxes provided by the scientific paradigm and its theorems. Normal science is the study of the world in the light of the paradigm.
     - The rise of incongruities and contradictory experiences leads to tensions and undermining of creditability of the paradigm.

- Revolution takes place when a new paradigm is proposed that does a better job of explaining the data.

3. Normal Science: PUZZLE SOLVING

3.1 Research with a particular perspective. PARADIGM
- Cumulative, summarized in text books.
- Defines legitimate problems and methods
- Attracts a set of followers
- Open-ended, allows these followers to explore further.
- Provides models for research, theory, methods, etc. These provide a basic aggreement over fundamentals. There is, therefore, an aggreement on rules of the game.

3.2 Paradigms grow out of some concrete scientific achievements. Exemplars.

3.3 Mature sciences grow by successive paradigmatic revolutions, e.g., light theory.

3.4 Early stages in science:
- Several competing paradigms, no one of which gains universal acceptance.
- Random gathering of data, all data equally relevant.
- The collection of facts rarely speaks for itself!
- Some theoretical or methological belief is needed to "integrate the data." (Including that in selecting data.)
- Differences in interpretations decrease, then disappear as a first paradigm appears. It does so by focus on one area of the data. Acceptance of one theory that seems better than its competitors takes place. It does not explain all the facts, but it solves better than other paradigms a few questions considered to be particularly acute.
- Once accepted, a paradigm provides a higher degree of directionality for theory expansion and data collection
- Early stage books are important and are addressed to broad interested public. Late stage paradigm articles for colleagues are more important. Late stage sees rise of jargon and mystery to general public.

3.5 Paradigm a model--not for exact replacation but a model for application (by analogy) to new situations.
- Most normal science is mop up operations. No search for new phenomena, and those that do not fit the box are rarely seen. No search for new theory and often there is intolerance for new ones that are advanced.
- Has drastically reduced vision. When a model no longer is effective, the constraints are relaxed a bit.
- The past achievements, however, always remain permanent.

3.6 Fact Gathering in Natural Science:
1) Particularly those that are thought to be test cases that reveal the nature of reality (as these are seen by the paradigm).
2) Facts testing predictions made on the basis of the paradigm. These are the links that relate the paradigm to reality.
3) Facts to articulate the theory--to clear fuzzy spots, ambiguities and determine constants.
- There is a high degree of predictability of the facts that are

expected to be found. When the results do not conform to experience, the experiment is treated as a failure. The theory or paradigm itself is not questioned.

3.7 Theory in Natural Science.

1) To predict factual information of intrinsic value.
2) To display a new application of the paradigm or increase its precision. This relates to the difficulty of developing points of contact between theory and reality.
3) To articulate the paradigm--particularly in its qualitative stage. This includes reformulation of the details.

3.8 Puzzle solving:

- The solutions to most puzzles can be predicted. Then why try? There is the challenge to find a way to get to the answer. The answer itself may not be the goal.
- First test of a good puzzle is not its intrinsic value but the assured existence of a solution. Like a jigsaw puzzle in which the picture itself is not the primary value.
  = Those not thought to be solvable are rejected as metaphysical or belonging to another discipline.
  = A paradigm can insulate the community from socially and ultimately important problems because it cannot predict the answer in these areas.
  = Because it limits itself, progress in normal science is fast. It deals only with problems it predicts the answers to.
  = While a paradigm may broaden knowledge, test belief, etc., for most individuals the overriding activity and compulsion is problem solving.
- Second test of a good puzzle is that the solution must be sought in line with a set of rules.
  = High level rules. The ontological givens of the theory and of the relationships it defines.
  = Low level rules--styles, preferences, etc. By the instruments traditionally used.
  = Metaphysical assumptions.
  = Commitment to understand the universe by empirical study.

3.9 Priorities of Paradigms

- Wittgenstein: we perceive natural families not on basis of a set of defining characteristics, but by analogy to previous members of the set. Only nonnatural families are formed by explicit definitions. Natural families may have no explicit (or implicit) rules underlying them--only networks of felt similarities.
- Scientists are generally unaware of their own basic implicit assumptions.
- Rules analyzed only when the paradigm is questioned, or insecure.
- Explicit rules may be common to a broad range of a field while the paradigm need not be.

4. <u>Novelties</u>:

4.1 Discoveries--novelties of fact.

- Born out of observations that violate predictions.

- These are explored and later assimilated not by adding them to the paradigm but by a revolution that recreates the nature of perceived reality.
- Discovery is a complex process involving a recognition that something exists, and what it is. Discovery and assimilation to theory is a process that cannot be pinpointed exactly.
- Discovery that fits a paradigm produces no paradigm shift. But to see or discover something new that leads to a paradigm shift requires that the old be recognized as inadequate so one is looking for something new.
- Discovery is often by accident.
- Discovery often hampered by the fact that instruments and experiments are designed to discover certain things and therefore limit exploration.

4.2 In a preparadigm stage and in crisis periods of paradigm shift, alternative exploratory theories are proposed, leading to some new exploratory discoveries.

- Essentials: a) awareness of anomaly, b) emergence of observational and conceptual recognition, c) paradigm shift in theory and instrumentation.
- Resistance to change guarantees scientists will not be lightly distracted, and that anomalies will penetrate existing knowledge to the core before a paradigm shift occurs.

5. Crisis and Emergence of Scientific Theories.

5.1 How do new and revolutionary theories arise out of normal science?

- These are not sought, nor expected.
- These arise out of a profound awareness of anomalies.

New facts: Mind) $\Longleftarrow$ (experiences

New paradigms: Mind) $\Longrightarrow$ (experiences

5.2 Prerevolutionary stage:

- Anomalies increasingly challenge the credibility of old theory. Failure of normal problem-solving activity.
- Proliferations of variations and patching up of old theory.
- Research increasingly like that in the preparadigm period, random searching
- Rise of a novel theory in direct response to the crisis. The solution is often partly anticipated during a period when there is no crisis, but these anticipations are ignored in the absence of crisis.

6. The Response to Crisis.

6.1 Crisis causes loss of faith in a paradigm but not its renunciation. A scientific theory is declared invalid only if an alternative candidate is present to take its place. No paradigm is falsified by direct comparison by nature--it is replaced by one that does a better job of explaining nature. The act of judgment that leads scientists to reject a previously accepted theory is always based upon more than a comparison of the theory with the world. It involves a comparison of two paradigms with nature and with each other.

6.2 Advocates of the old paradigm do not see ambiguities as counterinstances discrediting their paradigm. They try to incorporate these by ingenious modifications of the existing paradigm.
6.3 There is no such thing as research without counterinstances. (p. 79)
6.4 Truth and falsity are determined by the confrontation of statement with fact. Normal science strives to bring theory and fact into closer agreement and does so by searching for confirmation or falsification.
- Science students, however, accept theories on the basis of the authority of teacher and text, not because of evidence.

6.5 Not all anomalies evoke crises, for there are always problems in the paradigm-nature fit. To cause crisis they must do one or more of the following:
1) Challenge the fundamental generalizations of the paradigm,
2) If it relates to some particularly useful application,
3) If change in the paradigm raises it to importance.
- Once the anomaly creates a crisis, it becomes the subject matter for analysis.

6.6 All crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research. The consequences are:
1) Either the problem is resolved in the old paradigm,
2) Or no solution is seen and it is labeled and set aside,
3) Or a new candidate for a paradigm arises that offers its solution. Then the battle for its acceptance begins. When this has been completed, the discipline will have a new view of the field, new methods, and new goals.

6.7 Often a new paradigm emerges in embryo before a crisis develops. At other times a new one only appears long after a crisis develops. Normal responses to crisis are:
1) Try to isolate and anlyse the anomaly.
2) Turn to philosophical analysis to unlock the riddle.
3) Try exploratory research not guided by normal science.

6.8 Most new paradigms are invented by young men or those new to the field. (p. 90)

7. Nature of Scientific Revolutions.
7.1 Scientific revolutions begun by a growing sense, often among a few, that an existing paradigm has ceased to function adequately in the exploration of an aspect of nature to which that paradigm has led the way.
7.2 Introduction of a new paradigm divides society into competing camps. Each argues its position on its own presuppositions and so its arguments are not compelling to the other. Selection of a paradigm can never be made unequivocally on the basis of logic and experiment alone.
- New discoveries are not derived from the logical structure of science.

7.3 Logical positivism makes it appear successive paradigms include the old unchanged. This is not so. The price of scientific advance is a commitment that runs the risk of being wrong. (p. 101)
7.4 Differences between paradigms deal not only with substances and nature of reality, but on the nature of the science itself--its legitimate questions, methods and goals. But the case for cumulative development of

paradigms is hard to make.
- Science provides people with maps of a world too complex and too varied to explore at random. It also provides them with guides to research. But even more it provides them the directions for map-making.

7.5 Because paradigms differ in fundamental assumptions debates between two schools end up with each talking past the other, and each talking in a circular argument.

8. Revolutions as Changes of World View.

8.1 Paradigm shifts are comparable to changes in world view, or gestalt shifts.
- Old no longer seen as less right, but as completely wrong.
- Even selection of data is colored by the language and interests of an existing paradigm.
- No one learns to see the world piecemeal, but as part of a larger interpretation of the universe.

9. The Invisibility of Revolutions.

9.1 Scientists and laymen take much of their image of scientific activity from an authoritative source that systematically disguises the existence and significance of scientific revolutions. This is done in the text-books and the popular and philosophical works modeled on them. These are written to expound the current normal science paradigm. Even the history they give is reinterpreted to fit the present views.

9.2 The view is that science adds bricks to the building of knowledge, but that is not the way it really develops. (p. 140)

10. The Resolution of Revolutions.

10.1 Generally led by a) young men or new men to the field who b) have focused intensely on the crisis area. They do not compare a new and an old paradigm on their probability in the light of the evidence that actually exists, for the tests themselves must be made from within one or another of the paradigms.
- Karl Popper suggests that one is rejected on the basis of falsification but this too does not hold. Falsification does not lead to rejection unless a new paradigm is present that is better in explaining the facts.
- A two stage verification-falsification testing seems to occur.
- Neither side will grant all the non-empirical assumptions the other makes so the battle is settled not by proof but by conversion of the majority from one side to the other.
- Proponents disagree on a list of problems, on the ways the elements of the paradigms are used, and in the worlds in which the science should operate.
- The old dies out not by conversion, but as the remnants of the old die out. The leaders of the old paradigm have too much invested in the old paradigm to convert.
- Proponants of the new generally claim they can solve the problems that led the old into a crisis.

10.2 A decision between two paradigms must be based less on past achievement than on future promise. One must have faith that the new paradigm will be more fruitful than the old.

11. Progress through Revolutions.
    11.1 In what way does science progress? By definition it is science if its body of knowledge does so. The extensive debates on whether a discipline is a science or not really is a question of why the field fails to move ahead. (p. 160)
    11.2 Viewed from within a normal science paradigm, the development inevitably appears to be progress.
    11.3 Viewed from without, no progress is achieved when competing schools constantly question the very foundations of the others. The arrival of the first paradigm frees the participants from the need to constantly re-examine their first principles.
    11.4 Part of the progress is the insulation of mature scientific communities from the laity. They can therefore concentrate on their problems. Partly it is due to the education of initiates through textbooks that blur past deviations, and reinforces a uniform approach.
    11.5 Progress in paradigm shifts is seen for the new triumphs over the old.
    11.6 Progress also requires that there be a community of scholars who decide the outcome, not politicians, etc., that the solutions satisfy most, and that they deal with the details of larger problems. Moreover they are committed to the growth of the assembled data that can be dealt with with precision and detail. To do some problems and anomalies must be banished. A science may grow in depth, but may not grow in breadth as well.

12. Postscripts:
    12.1 Paradigms and community structure: danger of a circularity--a paradigm is what members of a scientific community share and a scientific community consists of people who share a paradigm. We must begin by defining the community structure of science.
        - They are practitioners of a scientific specialty, have undergone similar educations, absorb the same technical literature, communicate with one another, etc.
        - There are levels: world-wide, national, etc.
        - A paradigm relates to a group of practitioners, not a subject matter.
    12.2 Paradigms and the constellation of group commitments.
        - Ambiguity in use of the term paradigm, so suggest a distinction between:
            a) disciplinary matrix= the common possession of the practitioners of a discipline (such as symbolic generalizations, jargon, concepts)
            b) exemplars= the concrete problem-solutions that students encounter and later emulate. The student acquires the ability to see in a variety of situations a similar gestalt, a way of seeing them that shows similarities in them all. Much of this is tacit knowledge (M. Polanyi) that is acquired by doing science rather than by acquiring rules for doing it.
    12.3 Tacit Knowledge and Intuition.
        - Intuitions are not the unanalyzable individual intuitions, but those tested and shared by the community.
        - Nor are these intuitions unanalyzable. Learning by doing is different than learning by rules, and should be analyzed in different terms. Learning by doing is to seek for linkages and patterns and rules--

these cannot be predicted before hand.

- We must not identify stimuli one-to-one with sensations. People in some sense do live in different worlds. (p. 193) But people of a community share many sensations, or how else is communication and communality possible?
- Gestalt or learning to see certain things as similar is learned by exposing the student to them and teaching them to see the similarities. Gestalts are not governed by rules, but become the "natural" way of seeing things.
- Must distinguish between interpretive process (analysis by applying rules, perception (gestalt) and involuntary neural activities (heart beat). Those ways of perception that have stood tests of the group are transmitted.
- Perception as knowledge is: 1) transmitted through education, 2) been found by the community to be more effective than its historical competitors in the group's current environment, and 3) subject to change through education and discovery of misfits.
- Primitive experience needs interpretation. Science is largely the interpretations of these, e.g., water vapor vs. electron tracks, etc.

12.4 Exemplars, Incommensurability and Revolutions.

- People in different paradigms use the same terms, but assign them different linkages to reality, so they communicate only poorly.
- Debates over paradigms deal with premises so there is no final logical way of proving one over the other.