Theses held by Logical Positivism

(1) Scientific theories are chosen on the basis of observation;

(2) Theories succeed one another by reduction (which preserves what is correct in an earlier theory and so illuminates the history of science as progress.)

- **Thomas Kuhn** was among the first to search the history of science for *non-observational factors* that explain the theory choice;
- Kuhn **challenges** both theses.

Kuhn's Historical Studies

<u>Kuhn</u> showed that

- well-educated people in the past embraced unscientific myths for the same sort of reasons that we embrace contemporary scientific theories: the aim was to *understand the world*.

This discovery leads to two possible consequences:

1. If it is these sorts of reason that support a belief that make it scientific, then these myths were science;
2. Our latest scientific beliefs could be myths, just like those unscientific ones they replaced.

Kuhn held (1), but (2) is considered much more damaging to science.

Kuhn's Main Topic: Scientific Change

- In *The Structure of Scientific Revolution*, Kuhn contends that the scientific change, viz. that how the broadest theories replace one another during <u>periods of scientific revolution</u>, has the following **FOUR** phases:
  - Pre-paradigmatic Stage
  - Norm Science
  - Anomalies
  - Revolutionary Stage

E.g. from Aristotelian to Newtonian physics; Phlogiston (燃素化学) to Lavoisier's chemistry (氧化还原) Non-revolutionary to Darwinian biology Newtonian to Relativistic & Quantum physics

Normal Science

- Direction, methods, instruments, and problems are fixed by the established theory (*paradigm*);
- Unlike the empiricist's view that science is guided by data, observation & experiments, **normal science** dictates the direction of scientific progress by **determining**
  - what counts as an experiment and,
  - when observations need to be corrected to count as data.
    - What the established paradigm cannot explain is anything *outside* of its intended domain;
    - Within its domain what it cannot predict is *plain old experimental error* or the clumsy misapplication of the paradigm's rules by *a scientists* **(failure of scientists, not of the paradigm)**.

Textbooks

- **Normal science** is *characterized* by the uniformity of textbooks. These textbooks conveys:
  - same material;
  - same demonstrations, experiments, and similar lab manuals;
  - same sorts of problems at the back of each chapter.
- A lack of textbook uniformity is a *sign* of **pre-paradigmatic science**.
  - The lack of commonality among textbooks reveals *an absence of consensus*.
  - Social science & philosophy are typical examples.
  - "How the competition in pre-paradigm science gives way to a single winner, [...] Kuhn does not tell us." [p.210]

Tasks of Normal Science

- Redetermining previously established observational claims to greater precision;
- Establishing facts without significance or importance for themselves but which vindicate the paradigm;
- Undertaking experiments to solve problems to which the paradigm draws our attention.
  - Failure to accomplish any of these tasks reflects the failure of scientists attempting them, not the failure

What is a *Paradigm?*

- The paradigm of Newtonian mechanics was not just Newton's laws of motion, it was also the model or picture of the universe as deterministic clockwork in which the fundamental properties of things were their position and momentum, from which all the rest of their behavior could eventually be derived.
- 有学者总结称，在《科学革命的结构》一书中，Kuhn一共在21种不同的意味上使用过范式(*paradigm*)这个词[1]。
- 在《科学革命的结构》1969年版本的《后记》以及收录在《批判与知识的增长》(1970)中的《对批评的反思》一文中，Kuhn认为，范式是一种学科基质(*disciplinary matrix*)，应该包含如下四个方面的成分[2]：
  - <u>符号概括</u>。它们是指那些团体成员能无异议也不加怀疑地使用的公式，能够用形式化的语言来概括，例如符号语言$F = ma$或$I = \frac{V}{R}$，或者文字表达"*元素以固定的重量比例相结合*"，或"*作用等于反作用*"；
  - <u>共同信念</u>。指的是共同体成员承诺的形而上学信念或是特定的模型。例如近代科学相信所有自然现象都是微粒运动及相互作用的结果，这是形而上学信念。特定的模型如：*电路可以看做是一个稳态流体动力学系统*等；
  - <u>共享价值</u>。例如，理论的精确性、一致性、广泛性、简单性和富有成效性作为判断理论好坏的标准等。共享价值相对于范式中的其他因素而言更具开放性，可以为不同的共同体所广泛共有；
  - <u>范例(exemplar)</u>。指学生们在他们的科学教育一开始所遇到的具体的问题解答。如，斜面，圆锥摆，开普勒轨道等问题。

Reference:
[1] As seen in 何华青, 2009, 新实验主义研究, p.32
[2] As seen in 何华青, 新实验主义研究, pp.32-3.

Priority to Theory over Data

- During **the normal science**, scientists give priority to theory over data. This thesis undermines empiricism.
- Examples:
  - **Newtonian mechanics and the planets Neptune and Uranus.** In 19th century, astronomers found that the path of Saturn suggested an orbit different from that which Newtonian theory predicted. This data would be treated as an falsifying observation according to empiricists; instead, the ruling paradigm dictated that this data be treated as a *puzzle*, a problem with a correct answer to be discovered by the ingenuity of the physicists and astronomers. A physicist's failure to solve a problem within the paradigm simply discredited the physicist, not the physicist's paradigm.
    - Solution: postulate one or more additional planets whose Newtonian gravitational forces would cause Saturn to move in the way we observed. Astronomers eventually discovered Neptune and Uranus and thus solve the puzzle.
- Kuhn: the paradigm was never in doubt and so neither needed nor secured additional empirical support from the solution to the puzzle.

Thesis of Theory-Ladenness

- Is there a hard distinction between **observational terms** and **theoretical terms**?
  - This problem is long faced by empiricism. It seems that observation is *inadequate* to justify the explanatory theories about unobservable events. Quine describes empiricism as "meagre input and torrential output" (用贫瘠的输入臆补出汹涌的输出)
- Kuhn argues there isn't a vocabulary that describes observations that is neutral between competing theories. There are theory-ladenness in three aspects.

Perceptual Loading

- Perceptual psychologists found that subjects who were briefly shown anomalous playing cards, e.g., a black four of hearts, reported having seen their normal counterparts e.g., a red four of hearts. It took repeated exposures to get subjects to say the anomalous cards didn't look right, and eventually, to describe them correctly. Things don't look the same to observers with different conceptual resources (Kuhn 1962, 63).
- By analogy, when observers working in conflicting paradigms look at the same thing, their conceptual limitations should keep them from having the same visual experiences (Kuhn 1962, 111, 113–114, 115, 120–1).
- When Priestley and Lavoisier watched the same experiment, Lavoisier should have seen what accorded with his theory that combustion and respiration are oxidation processes, while Priestley's visual experiences should have agreed with his theory that burning and respiration are processes of phlogiston release.

Semantical Loading

- Theoretical commitments exert a strong influence on observation descriptions, and what they are understood to mean (Kuhn 1962, 127ff, Longino 1979,38-42).
- If so, proponents of a caloric account of heat won't describe or understand descriptions of observed results of heat experiments in the same way as investigators who think of heat in terms of mean kinetic energy or radiation. They might all use the same words (e.g., 'temperature') to report an observation without understanding them in the same way.

Salience Loading

- If Galileo and an Aristotelian physicist had watched the same pendulum experiment, they would not have looked at the same things.
  - To the Aristotelian paradigm, **"the weight of the stone, the vertical height to which it had been raised**, and **the time required for to achieve rest** (my emphasis, Kuhn 1992, 123)" are the *most salient* variables to measure
  - To Galileo, **radius, angular displacement**, and **time per swing** (my emphasis, Kuhn 1962, 124) are the *most salient* variables.

观察负载理论 (Theory-Ladenness)

- 观察负载是后实证主义科学哲理论的普遍观点，一般具有如下两个观点[1]：
  1. 科学家们的感觉和其他一般人一样，都被一些前在的（prior）信念、期望引导，这些观察具有整体论特征；
  2. 科学家的观察依赖于他们所接受的理论，观察术语的意义取决于他们所来自的理论情景。
- Norwood Hanson (1958) 的《发现的模式》一书中首先提出了认为存在中立的科学观察陈述的观点[2]。
  - 『看（seeing）是一项「理论负载」的活动，对X的观察被X的前在知识所塑造。另一个对观察的影响在于我们用来表达我们所知的东西的语言和记号，并且离开它们我们将没有什么东西可以识别出作为知识（Hanson, 1958）』
- Hanson给出的例子[3]：
  - 假定有两位生物学家在显微镜下观察同一张已制备好的玻片，如果问他们看到了什么，他们也许会做出不同的答案。一位把面前的细胞看成一堆异物，比如是一种人为现象或者是一块由于染色技术不当而产生的凝结物。另一位看到的是一个细胞器官，即「高尔基体」。
  - 两个生物学家观察同一单细胞动物——阿米巴虫，一个人说看到了一个单细胞动物，另一个人却说看到了无细胞动物。
  - 开普勒与第谷登山同观日出，开普勒说他看到了太阳是固定的，是地球绕着太阳转，而第谷观察到的却是地球是固定的，是其他天体绕地球旋转。
- 由于不同的人他们的背景理论知识和期望不同，这种理论和期望渗透在了观察中，从而会得到不同的观点

Reference:
[1] 何华青，新实验主义研究, 27-8.
[2] As seen in 何华青，新实验主义研究，29.
[3] Ibid.

My Question

- Kuhn's **perceptual loading** and **salience loading** seem to suggest the observation must depend on and be laden with a systematic theory/paradigm.
- **Counterexample 1**:
  Hey, wait a minute! But **there are** *pure observations* motivated by nothing but curiosity!
  E.g. Robert Brown's pollen observation (1827). He looked through a microscope at pollen grains suspended in water, and discovered their random motion. However, he did not and did not try hard to provide any explanation other than some merely speculative guesses (e.g. pollen has LIFE!). The phenomenon is explained by J. Perrin and Einstein.
- **Another Possible Objection**:
  Observations ≠ experimentation. Observing is a more passive activity, while experimentation is more active in intervening the world to *"twist the lion's tail"* (Bacon's wording) that forces nature to yield secrets that were not perceivable under normal circumstances.

Period of Crisis: Anomalies

- A small number of **puzzles** continue to persist:
  - Unexpected phenomena that the paradigm cannot explain for an extended time;
  - Phenomena predicted by the paradigm that don't turn up;
  - discrepancies in the data beyond the margins of error;
  - Major incompatibilities with other paradigms.
- **Scientific Revolution** occurs when one of these *anomalies* resist solution long enough.

Paradigm Choice

- During the **period of crisis**, the competition between old and new paradigms cannot be settled by *observation or experiment* because:

1. There is little or no difference between the competing paradigms when it comes to predictive accuracy.
   E.g. Ptolemaic geocentric astronomy was predictively as powerful and no more mathematically intractable (both relies on epicycles), than its Copernican heliocentric rival.
2. Observation and experiments are laden with prior theories. They are not the neutral tribunal court.

Incommensurability

- Paradigms are **incommensurable** with one another.
- The term *incommensurable* is a mathematical metaphor in geometry: the radius of a circle is not a rational fraction of its circumference, but is related to it by the irrational number *π*. Therefore, when we calculate *π*, the result is never complete but always leaves a remainder. When one paradigm is invoked to explain away another one, it always leaves a **remainder**.

What is a *Remainder?*

- Is **remainder** partially constituted by **explanatory loss?**
  - E.g. Newtonian mechanics cannot explain the mysterious *"action at a distance"*. Aristotelian physics did not have to explain this.
  - Kuhn: Remainder is not constituted by explanatory loss. Because there might be a net gain in explanatory scope for the new paradigm, e.g. Newtonian mechanics.
- Is **remainder** partially constituted by **untranslatability?**
  - E.g. Poems in one language are often untranslatable. Similarly, phlogiston theory cannot be incorporated into its successor (Lavoisier's theories of oxidation and reduction). Therefore, paradigms cannot be translated into one another.
  - This is Kuhn's view.
- Two consequences of *remainder as untranslatability*:
  1. Paradigms do not improve on one another;
  2. Science does not accumulate in the direction of successive approximation to the truth.
  3. History of science is history of change, not of progression.

Scientific Progression

- Scientific progression relies on empiricists's concept of **reduction**:
  - **Reduction** is the interrelation of theories;
  - **Reduction** is *synchronical*:
    - E.g. chemistry is reducible to physics;
  - **Reduction** is *diachronical*:
    - E.g. Newtonian mechanics developed in 17th century are reducible to 20th century special theory of relativity.

Kuhnian View

- Reduction of the laws of one theory to the laws of a more basic theory requires that the terms of the two theories share **the sameness in meaning**, and that is impossible.
- **Example. 1** The notion of space, time, and mass should be the same in Newton's theory and in Einstein's theory of special relativity, but that's not the case. Recall the Lorenz transformation:

$$m_{rest} = m_{motion} \cdot \sqrt{1 - \frac{v^2}{c^2}}$$

The notion of mass is different.
  - The Lorenz transformation requires the mass being dependent of its velocity, which is **a polyadic/relational property of matter**;
  - the Newtonian mass sis a conserved constant independent of relative/absolute velocity, it is **a monadic property of matter**.
- **Example.2** There is no way to express the Aristotelian *impetus* in the Newtonian mechanics.

A Possible Reply from Physicists

- "The way we teach the special theory of relativity in the textbooks is by first teaching Newton's theory and then showing it's a special case via the Lorenz transformations. It is after all a case of reduction. Einstein was standing on the shoulders of Newton, and special relativity reflects the cumulative progress of science **from the special case to the more general one.**"

A Kuhnian Reply

- What is reduced is not Newton's theory, but **what we imagine** is Newton's theory (in a post-Newtonian, Einsteinian era). "To prove otherwise requires a translation that would inevitably attribute incompatible properties to mass." [p.215]
- Once **normal science** is established, it **rewrites** *the history of previous science* to make it appear just another step in the long-term continuous progress of science to cumulative knowledge of everything.
  - **The success of normal science requires the disciplining of scientists not to continually challenge the paradigm, but to articulate it in the solution of puzzles.**
  - One way to enforce this is to rewrite the textbooks to make it appear as much as possible that what went before today's paradigm is part of an inevitable history of progress that leads up to it.

Lakatos's Methodology of Scientific Research Programmes (MSRP)

- Scientific theories are components of larger cognitive units: **research programmes (RPs)**;
- In Lakatos, research programme ≈ Kuhn's paradigm;
  - A RP only contains **statements, propositions,** and **formulae**;
    - Has a **hard core**;
    - Has a **protective belt;**
  - A paradigm contains **artifacts, experimental devices, measuring equipments,** and **associated philosophical theses**.

Hard Core

- <u>**Hard core**</u> := A set of assumptions about the world that are constitutive of the program and cannot be surrendered without giving up the research programme altogether. (**hard core** is the central theses)
- Examples
  - The inverse square law of gravitational attraction is part of the hard core in Newtonian RP;
  - $PNS_{principle\ of\ nature\ selection}$ is part of the hard core in Darwinian RP.

Protective Belt

- <u>**Protective belt**</u> := A set of further claims of the theory that function as auxiliary hypotheses that
  1. They are needed by the **hard core** to explain and predict phenomena;
  2. They may be changed when the prediction is falsified by evidence.
- Examples
  - Darwin's own theory of heredity (it's mistaken) was surrendered without doing any harm to the RP of evolutionary biology; Mendel's theory of heredity was introduced to the **protective belt** to replace Darwin's own theory.

Lakatos & Falsification

- Lakatos is a protégé of Popper.
- In Lakatos, the **hard core** is often unfalsifiable in two senses:
  1. Scientists working within the programme are typically reluctant to give up on the claims that constitute the hard core;
  2. The hard core theses are usually, *by themselves*, devoid of empirical consequences.
     E.g. Newtonian mechanics *by itself* (three laws of motion + gravitational law) won't tell you what you will see in the night sky. To derive an empirical prediction, a whole set of auxiliary hypotheses (viz. **protective belt**) about the **positions, masses,** and **relative velocities of the heavenly body** are required.
- Point (2) is related to Quine-Duhem Thesis. Recall that this thesis says that:
  - (a) Our beliefs face the *tribunal of experience* not **singly**, but in a body (collectively).
  - (b) There are typically no *crucial experiments* to decide which of the competing theories is correct;
  - (c) The available data typically *underdetermine/does not pick out a unique theory* as being correct.
- Point (2) is concerned with (a)
  - In science, the following *modus tollens* argument is prevalent:

$$\begin{array}{l} \text{If } \{T \wedge A_1 \wedge A_2 \wedge \ldots\}\text{, then } O. \\ \neg O. \\ \hline \therefore\ \neg(T \wedge A_1 \wedge A_2 \wedge \ldots) = F \\ \hline \therefore\ \text{Either } T, A_1, A_2, \ldots, \text{ is/are wrong} \end{array}$$

An Example

- In a chemistry lab session, you're given a beaker of unknown liquid and your teacher ask you to test its boiling point. You, however, secretly learned from students who just finished the previous lab session that the unknown liquid is ethanol. So you would expect that its boiling point is 78.5℃. Unfortunately, after you performed the experiment, it turns out that the sample does not boil at 78.5℃. Students who typically get C- would reason that:

If {the sample in the beaker is ethanol}, then{I should observe the sample boiling at 78.5°C}.
I do not observe the sample boiling at 78.5°C.
∴ The sample in the beaker is not ethanol.

And that's why you get C-

- An A- answer should look like this:
  Let T = the sample in the beaker is ethanol;
  O = I should observe the sampling boiling at 78.5°C/the observed value lies outside of the 90% confidence interval;
  A_1 = the thermometer is working properly;
  A_2 = the atmospheric pressure in the lab is 1 atm;
  A_3 = the beaker is thoroughly rinsed before the lab session.

$$\begin{array}{l} \text{If } \{T \wedge A_1 \wedge A_2 \wedge A_3\}\text{, then } O. \\ \neg O. \\ \hline \therefore\ \neg(T \wedge A_1 \wedge A_2 \wedge A_3) = F \\ \hline \therefore\ \text{By \textbf{negative heuristics}, either } A_1, A_2, \text{ or } A_3, \text{ is/are wrong.} \end{array}$$

Positive & Negative Heuristics

- **Positive and Negative Heuristics** are methodological rules that guide changes in the protective belt and enjoint revision of the hard core.
- **The negative heuristic** bids us to retain the hard core but modify the auxiliary hypotheses:

> "The negative heuristic of the programme forbids us to direct the *modus tollens* at this "hard core". Instead, we must use our ingenuity to articulate or even invent "auxiliary hypotheses", which form a protective belt around this core, and we must redirect the *modus tollens* to these. It is this *protective belt* of auxiliary hypotheses which has to bear the brunt of tests and gets adjusted and re-adjusted, or even completely replaced, to defend the thus-hardened core."
> (Lakatos, 1978, *The Methodology of Scientific Research Programmes*, p.55)

- Therefore, when a potentially falsifying evidence strikes, the scientists would constructs a new theory with the same T but modified As. In order to do so, the **positive heuristics** comes into play:

> "The positive heuristic consists of a partially articulated set of suggestions or hints on how to change, develop the 'refutable variants' of the research programme, how to modify, sophisticate, the 'refutable' protective belt."
> (Lakatos, 1978, p.57)

  - E.g. if Saturn does not move in a smooth ellipse that it ought to follow, then if
    - (a) the Newtonian mechanics are correct;
    - (b) there are nothing but the sun and the other known planets of the solar system to worry about;
  - The **positive heuristics** instruct you to look for another heavenly body.

Scientific Progression in Lakatos

- A RP can be **progressive or degenerate.**
  - A RP is **progressive** if it can accommodate new data and falsifying data (by modifying the protective belt)
    - Examples: the discoveries of Neptune and Uranus to the Newtonian mechanics.
  - A RP is **degenerate** if it ceases to generate new predictions and/or persistently invokes *ad hoc* changes in the protective belt.

Ad hoc? What's that?

Something is *ad hoc* when it's introduced for a particular purpose in lieu of general reasons. For example, let's say that we stipulate ***bird*** as ***any creature that can fly***. Then, some reject this stipulation by citing mosquitos as a counterinstance: they can fly but they aren't birds. If you fix up this in this way:

- A bird is any creature that can fly, and which is not a mosquito.

Then it is an *ad hoc* amendment to your stipulation because it is introduced for a particular purpose. If you fix up the claim by stating that:

- A bird is any creature that can fly, and which has a backbone.

Then it is not an *ad hoc* amendment because it is independently motivated (not targeting at merely responding to this specific counterexample).

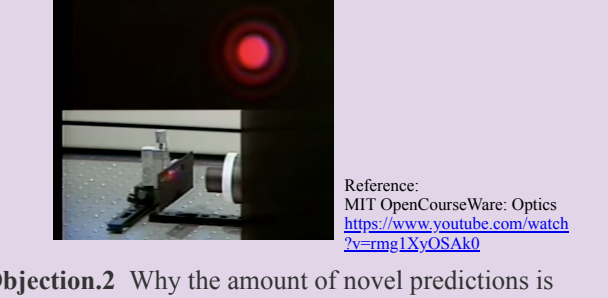
Reference: http://www.jimpryor.net/teaching/vocab/glossary.html

Scientific Change in Lakatos

- Scientists persist in the articulation of a RP so long as it remains **progressive**. If the RP ceased to be so, scientists would start to challenge its hard core and introduce new ones.
- Scientific change thus understood proceeds in line with **rational standards of belief change**.

Kuhnian Replies

- Lakatos neither does nor can give us a litmus test for when it becomes unreasonable to cling to a degenerating research program, still less a measure that would enable scientists to rank programs for progressivity.
  - **Objection.1** Counterexamples can be found in history of science where theories degenerated for a long period of time while retaining the confidence of scientists, and then began again to be progressive.
    - **Example.1** Particle theory of light degenerated badly in 19th century due to Fresnel's diffraction experiment.



Reference:
MIT OpenCourseWare: Optics
https://www.youtube.com/watch?v=nng1XyOSAk0

  - **Objection.2** Why the amount of novel predictions is a criterion for progressivity?
    Biology or **palaeontology** (古生物学) hardly ever seek novel predictions.

- Lakatos account of scientific change can accommodate **Objection.1** with ease. But this is problematic, because it is too easy for his account to respond to this sort of challenge. Whether a scientists sticks with a research program, he can always be defended as rational.

- For **Objection.2,** Lakatos would argue that science seeks theories with **greater empirical content**, and RP whose theory makes novel predictions has greater empirical content than ones that fail to do so.

- **Problem 1**: How can we distinguish the *empirical content* of a theory from its *non-empirical content*?
- **Problem 2**: What if two competing theories have the same amount of *empirical content*?
- **Problem 3**: Why should we buy into this epistemology?

- Lakatos's followers may respond that if science seeks knowledge, and novel predictions are justified true belief, then making new predictions is the unique way to attain knowledge.
- But again, why should we buy into **this** epistemology? Kuhn would argue that such an epistemology is not a "first philosophy" prior to science, that can stand in judgment of its rationality and epistemic progress. It is part and parcel of a paradigm.

of the paradigm.

replace Darwin's own theory.

part and parcel of a paradigm.