Thinking about Natural Science

An introduction to philosophy for scientists
Lecture III

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Overview of the course

I) [3 Feb. 2025] Introduction and quick historical background
II) [10 Feb. 2025] Modern science and philosophical difficulties...
III) [17 Feb. 2025] (Neo)Positivism, Popper and post-popperian debate
IV) [10 Mar. 2025] Case studies (I): Reality, physical world and laws of Physics
V) [24 Mar. 2025] Case studies (II): Truth, what do the theories describe?
VI) [31 Mar. 2025] Guest lecture.

Overview of today

1. (Neo)Postitivism
2. Popper
3. Post-Popperian debate
4. References

Recap

1. Ancient Greece $\Rightarrow$ *Philosophy of Physis*
   - $\rightarrow$ Search for rational *causes* of the *Reality*
   - $\rightarrow$ *Rationalism* vs. *Empiricism*
2. Scientific revolution of the XVII-XVIII century
   - $\rightarrow$ *Philosophy of natural science*
   - $\rightarrow$ *Science of physics*

   - *Empiricist* approach: Bacon, Galileo, Newton
   - *Realism*: Galileo, Newton

Truth is the adequation of intellect to thing

Thomas Aquinas, *On truth* q.1 a.1

The book of the universe is written in the language of mathematics [...] without which it is humanly impossible to understand a single word of it

G. Galilei, *Il Saggiatore*, 6

In what sense do scientific statements differ from other statements?

(Neo)Postitivism

Logical positivism

Neo-positivism (logical positivism), in Vienna in the 1920
- Origing from *Positivism* by Auguste Comte (1798–1857) in the XIX century
- Germany and Austria amid the dominance of Hegelian metaphysics → neo-Kantianism

Logical form of the relationship between scientific knowledge and the facts

Scientific knowledge has to be derived from the *facts* by observation

- Verification principle: *verifiability criterion of meaning*
→ statement meaningful only if it can be verified through *empirical observation* or if it is a *tautology* (metaphysics, theology, ethics and aesthetics as cognitively meaningless)

Empiricism of David Hume (1711–1776), Auguste Comte and Ernst Mach (1838–1916)
Ludwig Wittgenstein's (1889–1951) *Tractatus Logico-Philosophicus* (1921)
The Vienna Circle: Moritz Schlick (1882–1936), Rudolf Carnap (1891–1970), Otto Neurath (1882–1945), Hans Hahn (1879–1934)

What is specific about scientific knowledge?

Science is not the only form of knowledge but it is the best, being the most successful epistemic enterprise in history

Moti Mizrahi, *What's so bad about scientism?*

I. The problem of demarcation:
the specificity of scientific statements

II. The problem of induction:
the progress and the solidity of the scientific knowledge

I. The problem of demarcation

A. (*Strong*) *scientism*: distinction *true* knowledge from *false* or *non sense* knowledge
⇒ *Positivism* (∼1830s) and *Neopositivism/Logical positivism* (∼1920s)
Auguste Compte, Rudolf Carnap, Stephen Hawking...
too high a value on science in comparison with other branches of learning or culture

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B. Weak Scientism: while non-scientific disciplines such as philosophy do produce knowledge, scientific disciplines such as physics produce knowledge that is superior
Moti Mizrahi (b. 1956)

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→ Scientific knowledge from non-scientific knowledge

C. Critical Realism, Perspectival Realism
Karl R. Popper, Thomas S. Kuhn, Imre Lakatos; Michela Massimi

II. The problem of induction

Basic logic: *Syllogims* Aristotle in *Prior Analytics*

From certain things laid down something different follows of necessity

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Basic logic: *Syllogims* Aristotle in *Prior Analytics*

From certain things laid down something different follows of necessity

1. All philosophy courses are boring
2. This is a philosophy course
3. This course is boring

(1) and (2) are the premises, (3) is the conclusion
It is not possible for (3) to be false once it is given that (1) and (2) are true
If the premises are true and the argument is valid then the conclusion must be true

How many data to be acquired
$\Rightarrow$ make a *universal* statement to be taken as *premises*

A turkey noted on his first morning at the farm that he was fed at 9 am.

After this experience had been repeated daily for several weeks the turkey felt safe in drawing the conclusuion: 'I am always fed at 9 am'. Alas, this conclusion was shown to be false when, on Christmas eve, instead of being fed, the turkey's throat was cut.

The turkey's argument led it from a number of true observations to a false conclusion, indicating the invalidity of the argument from a logical point of view.

Attributed to Bertrand Russel

Popper

Karl Raimund Popper (1902-1994)

- Vienna in 1902
- 1937 to New Zealand, becuase of Jewish origin
- 1946 at the London School of Economics
- died in London in 1994

Criticised psychologism, naturalism, inductivism, and logical positivism

Suspicious of the way in which he saw Freudians and Marxists supporting their theories

$\rightarrow$ these theories could never go wrong because they were sufficiently flexible to accommodate any instances

Induction does not old

- Induction by enumeration is not effective and neither is induction by elimination
- Induction does not exist: the premise of an inductive argument does not imply the conclusion with certainty
- However large the number of white swans observed so far, we cannot be certain that all swans we see in the future will be white

Test of Einstein's theory of general relativity carried out by Eddington in 1919

$\Rightarrow$ Scientific theories are falsifiable

Observation is guided by and presupposes theory

The Logic of Scientific Discovery (1959)
From the original *Logik der Forschung. Zur Erkenntnistheorie der modernen Naturwissenschaft* (1934)

- Research arises from problems, not from observations
- Hypotheses and conjectures are needed to solve problems
$\rightarrow$ inconsistency of the principle of verifiability
- The hypothesis, to be accepted, must be able to be falsifiable

$\Rightarrow$ The falsifiability of a theory
the *demarcation* criterion between science and non-science

A logical asymmetry between verification and falsification

Falsifiability as a criterion for theories

Conjectures and Refutations: The Growth of Scientific Knowledge (1963)

Hypotheses that are *tentatively* proposed with the aim of accurately describing or accounting for the behaviour of some aspect of the world or universe

A theory that makes definite claims about the world

Hypothesis must be falsifiable

$\Rightarrow$ there exists a logically possible observation statement or set of observation statements that are inconsistent with it

Degree of falsifiability

1. Mars moves in an ellipse around the sun
2. All planets move in ellipses around their sun

Law (2), the preferable law, is more falsifiable than (1) $\rightarrow$ any falsification of (1) will be a falsification of (2), but the reverse is not the case

Potential falsifiers

Kepler's theory of the solar system and Newton's $\rightarrow$ there are many more opportunities for falsifying Newton's theory than for falsifying Kepler's theory

Highly falsifiable theories should be preferred to less falsifiable ones

Progress of science

Advance of scientific knowledge similar to evolutionary process:

$$PS_n \rightarrow TT_n \rightarrow EE_n \rightarrow PS_{n+1}$$

- Response to a given problem in situation (PS_n) $\rightarrow$ number of competing *conjectures*, or *tentative theories* (TT_n)
- TT_n subjected to rigorous attempts of falsification $\rightarrow$ process, *error elimination* (EE_n), similar function of natural selection
- Theories that better survive are not more true, but rather, more fit for the problem situation (PS_n)
- Does not ensure continued survival, neither rigorous testing protect the theory from refutation in the future
- In biology: developed traits $\rightarrow$ more and more complex problems of survival

$\Rightarrow$ evolution of theories reflects certain type of progress: toward more and more interesting problems (PS_n)

We simply stop when we are satisfied and feel that
the supports are stable enough to support the structure

Schematic summary on Popper

Science starts with problems

Associated with the explanation of the behaviour of *some aspects* of the world or universe

Falsifiable hypotheses are proposed by scientists as solutions to a problem

The *conjectured* hypotheses are then criticised and tested

Metaphysics according to Popper's view

Not all metaphysical theories are meaningless

→ From a *psychological point of view*, scientific discovery is impossible without faith in metaphysical ideas
→ From a *historical point of view*, alongside metaphysical ideas that have hindered science, others that have developed into controllable theories

From a logical point of view
true is not identified with the *controllable*, with the *scientific*

Post-Popperian debate

Sophisticated falsificationism

Relative, rather than absolute, degrees of falsifiability. Popper's view too simplistic $\rightarrow$ hypothesis should be more falsifiable than the one for which it is offered as a replacement (independently testable)

Focus from the merits of a single theory to the relative merits of competing theories

Fighting *Ad hoc* solution

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Fighting *Ad hoc* solution

Wolfgang Pauli in 1930: *hit upon a desperate remedy*, that β-decay produced, in addition to the observed electron, another heretofore unobserved particle. He called this particle the *neutron* (then neutrino)

N.Emery, *Naturalism Beyond the Limits of Science*, 2023

Galileo's Moon

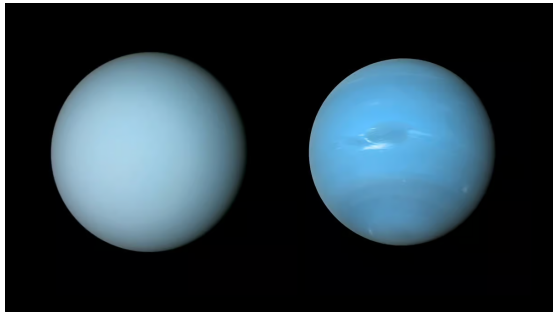
- Galileo reports the moon was not a smooth sphere
- Aristotelian adversary repeats and accepts the observations on the telescope
$\rightarrow$ there was an invisible substance on the moon filling the craters and covering the mountains: the moon's shape was perfectly spherical
- however no way in which it could be detected
- *Galileo prepared to admit the invisible, undetectable substance, but it was not distributed in the suggested way, but rather piled up on top of the mountains...*

A. Chalmers, *What is this thing called Science?*, p.71

The discovery of Neptune

Uranus's orbit departed considerably from that predicted on the basis of Newton's gravitational theory
$\rightarrow$ undetected planet in the vicinity of Uranus

Far from being ad hoc
$\Rightarrow$ save Newton's theory from falsification by Uranus's orbit
$\Rightarrow$ a new kind of test for the Newton's theory



Confirmation

A mistake to regard the falsification of bold, highly falsifiable conjectures as the occasions of significant advance in science

Significant advances will be marked by the confirmation of bold conjectures or the falsification of cautious conjectures

$\Rightarrow$ Confirmation of cautious hypotheses is uninformative

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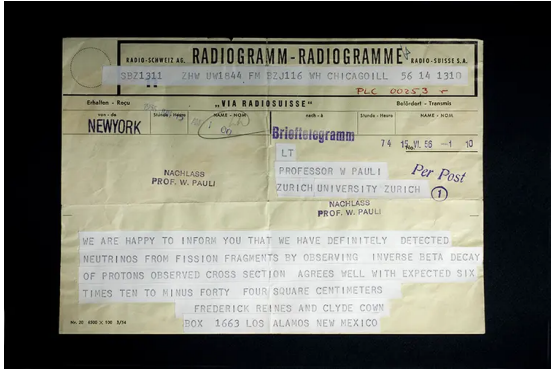

In the falsificationist account, the significance of confirmations depends very much on their historical context

Confirmation and historical context

- Heinrich Hertz (1857–1894) in 1888 confirmed James Clerk Maxwell's (1831–1879) theory when he detected the first radio waves

- We also confirm Maxwell's theory whenever we listen to the radio

The logical situation is similar in the two cases

- Nevertheless, Hertz is justly famous for the confirmation he achieved
- Our frequent confirmations are rightly ignored in a scientific context

$\rightarrow$ Hertz made a *significant* step forward.

Falsificationism, inductivism and its limitation

- The factual basis for science is fallible
- Falsificationist seeks only constant improvement in science rather than demonstrations of truth or probable truth
- Facts give significant support to theories when they constitute severe tests of that theory

If the truth of some observation statement, O, is given, then the falsity of a theory T which logically entails that O is not the case can be deduced
A clash between T and O does not have the consequence that T is false

All that logically follows from the fact that T entails a prediction inconsistent with O is that either T or O is false, but logic alone cannot tell us which

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A realistic scientific theory will consist of a complex of universal statements rather than a single statement like 'all swans are white'

Duhem-Quine thesis

- Pierre Duhem (1861–1916)
- Willard Van Orman Quine (1908–2000)

A theory cannot be conclusively falsified, because the possibility cannot be ruled out that some part of the complex test situation, other than the theory under test, is responsible for an erroneous prediction

A physicist of the pre-Einsteinian era takes Newton's law of gravitation, N, the initial conditions, I, and calculates the path of a newly discovered small planet, p. But the planet deviates from the calculated path.

Does she consider that the deviation forces her to refute N? No.

There must be a hitherto unknown planet p^1, which perturbs the path of p. [...] However the planet p^1 is too small, she cannot possibly observe it... she applies for a research grant to build a bigger telescope [...] But she cannot observe it.

Does she abandon Newton's theory and her idea of the perturbing planet? No.

She suggests that a cloud of cosmic dust hides the planet from us [...] But the cloud is not found

Is this regarded as a refutation of Newtonian science? No.

Either yet another ingenious auxiliary hypothesis is proposed or... the whole story is buried in the dusty volumes of periodicals and the story never mentioned again

I. Lakatos and A. Musgrave, (eds) *Criticism and the Growth of Knowledge*

A theory can always be protected from falsification
by deflecting the falsification to some other part of the complex web of assumption

Popper's criterion of demarcation is too easily satisfied and satisfied by many knowledge claims that Popper would wish to classify as non-science

Thomas Kuhn (1922–1996)

- The evolution and progress of major sciences exhibit a structure that is not captured by the inductivist and falsificationist accounts

1. Observation can be said to be theory-dependent
   - experiment was by no means the key to Galileo's innovations in mechanics
2. Language and definition of the concepts:
   - Newton could not define mass or force in terms of previously available concept
   - history of a concept

The Structure of Scientific Revolutions (1962)

Abandonment of one theoretical structure and its replacement by another, incompatible one sociological characteristics of scientific communities

Scientific progress

pre-science – normal science – crisis – revolution – new normal science – new crisis – ...

A mature science is governed by a single paradigm
The lack of disagreement over fundamentals that distinguishes mature, normal science from the relatively disorganised activity of immature pre-science
Normal science as a puzzle-solving activity governed by the rules of a paradigm. The puzzles will be of both a theoretical and an experimental nature

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Paradigm

Metaphysical principles
Fundamental laws and theoretical assumptions
Instrumentation

- Normal scientists must be uncritical of the paradigm in which they work
- Failure of the scientist rather than as an inadequacy of the paradigm

Crisis and revolution

- The existence of unsolved puzzles within a paradigm does not constitute a crisis:
a paradigms will always encounter difficulties, there will always be anomalies

An anomaly is particularly serious if it is striking at the very fundamentals of a paradigm, and yet persistently resists attempts by the members of the normal scientific community to remove it

$\rightarrow$ The changes important with respect to some pressing social need

- historian of science
- 'psychologist of science'

Theory of science

- Periods of normal science → opportunity for scientists to develop the esoteric details of a theory

Progress through revolutions

- No a priori reason to expect that a paradigm is perfect or the best available
- Alternative to the cumulative progress
  - inductivist accounts of science → knowledge grows continuously as more numerous and more various observations

→ enabling new concepts to be formed, old ones to be refined, and new lawful relationships between them to be discovered

paradigms in guiding observation and experiment

paradigms have pervasive influence on the science practised within them, the replacement of one by another must be a revolutionary one


I. Firmamentum fixarum Sphæra immobilis.
II. Saturnus Annis XXX. revolvitur
III. Jupiter XII. Annorum revolutis
IV. Martis vimis revolutis

Risks of Kuhn's view

- No logically compelling demonstration of the superiority of one paradigm over another
- A choice between incompatible modes of community life, no argument can be *logically or even probabilistically compelling*
- *Relativist* in terms of scientific progress

Whether a paradigm is better or not than one that is currently consider does not have a definitive, neutral answer

$\rightarrow$ Science is intrinsically sociological

It is philosophy, rather than science, that can best criticise the fundamental of a paradigm

Imre Lakatos (1922–1974)

Popper and Kuhn rival accounts of science, but their views much in common

- They both take a stand against positivist, inductivist accounts of science
- They both give priority to theory (or paradigm) over observation

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Research program

- Not all parts of a science are on a par
- Some laws or principles are more basic than others
- Scientists to solve problems by modifying the more peripheral assumptions

1. Fundamental principles as the *hard core* of a research program
2. Augmented by a range of supplementary assumptions $\rightarrow$ *protective belt*

A heuristic set of rules or hints to aid discovery or invention: *negative heuristic* and *positive heuristic*

Research programs

Merit of a research program is the extent to which it leads to novel predictions

- Offer a program of research
- Not ad hoc solutions
- Testable

Inviolability of the hard core of the program
and by the positive heuristic that accompanies it

- Degenerating program
- Progressing program

$\Rightarrow$ Novel prediction

One program is superior to another insofar as it is a more successful predictor of novel phenomena

It makes natural, as opposed to novel, predictions that are confirmed, where 'natural' stands opposed to 'contrived' or 'ad hoc'

$\rightarrow$ Quantum Mechanics

History of science

Kuhn's account of science as 'merely' descriptive

- Criticise positivist and falsificationist methodologies

Young's (1773–1829) theory was not strongly confirmed experimentally in a natural, as opposed to a contrived, way, as Fresnel's (1788-1827) was, and that Fresnel's version of the wave theory had a vastly superior positive heuristic by virtue of the mathematical tools he was able to introduce

- Theories not to be rejected after apparent falsifications
$\rightarrow$ blame might be directed at a source other than the theory
- Single successes certainly do not establish the merit of a theory for all time

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$\Rightarrow$ Research programs: which are given time to develop
and may come to progress after a degenerating period, or degenerate after early successes

Philosophy of science

- Scientists work in a coordinated way within a framework
  - However for Lakatos Kuhn is affected by unacceptable relativism

Philosophy of science $\rightarrow$ universal conditions under which a theory is scientific
closely linked with the problem of the rationality of science

Not rules for the elimination of whole research programs
$\rightarrow$ it is rational to stick to a degenerating program in the hope that it will make a comeback
No position to diagnose any contemporary theory as non-scientific *intellectual pollution*

Without argument $\rightarrow$ scientific knowledge in fundamental sense to be like the physics of the last three hundred years

Paul Karl Feyerabend (1924–1994)

Against Method: Outline of an Anarchistic Theory of Knowledge (1975)

Science does not possess features that render it superior to other forms of knowledge

There is no such method that can be called a scientific method

- Aristarchus and Copernicus were able to make reason so conquer sense that, in defiance of the latter, the former became mistress of their belief
- Necessary for Galileo to conquer sense by reason and even to replace the senses by 'a superior and better sense', namely, the telescope

1. Earth is stationary
2. Apparent sizes of Venus and Mars change appreciably

Proving 1. and 2. $\rightarrow$ Did Galileo support these arguments by appealing to the facts? That is certainly not how Galileo did it in the *Dialogue*, by *picking the brains* of the reader

Feyerabend's reading of Galieo

Galileo did not have an adequate or detailed theory of the telescope
$\rightarrow$ Terrestrial use of the telescope is aided by a range of visual cues absent in the astronomical case
- But when looking into the heavens, we are in unfamiliar territory and lack clear guidance

Galileo needed to, and did, resort to propaganda and trickery

Anarchistic theory of knowledge

- Humanitarian attitude $\rightarrow$ individual freedom

Feyerabend rejected Kuhn's appeal to the social consensus of the scientific community

- Kuhn distinguished between legitimate and illegitimate ways of achieving consensus
- consensus was capable of distinguishing between science and other activities such as theology and organised crime

P. K. Feyerabend, *Consolations for the Specialist*, in Lakatos and Musgrave (1970), 195–230

- The freedom of scientists by removing them from methodological constraints
- Leaves individuals the freedom to choose between science and other forms of knowledge

Institutionalisation of science in our society is inconsistent with the humanitarian attitude

P. K. Feyerabend, *Against Method*, p 20

There is no scientific method...

There is no scientific method...
Scientists should follow
their subjective wishes

There is no scientific method...
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There is no scientific method...
Scientists should follow
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Anything goes???

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Backup

The elementary understanding of scientific method

1. Systematic observation is undertaken of the phenomena to be explained
2. Theory is proposed which would provide an explanation of these phenomena
3. From this theory is derived a prediction of some phenomenon other than those already included in the survey
4. The prediction is tested empirically
   - if the prediction turns out false, than the theory is to be rejected
   - if it comes true, then the theory is so far confirmed

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... but for Popper

Induction does not old
Observation is guided by and presupposes theory

Science does not rest on a solid layer of rock

Structure of scientific theories as it were above a swamp, a building constructed on stilts
We desist from our attempts to drive the stilts deeper $\Rightarrow$ does not mean that we have found solid ground.

- We simply stop when we are satisfied and feel that at least for the moment the supports are stable enough to support the structure

I will certainly only admit as empirical, or scientific, a system that can be controlled by experience.

These considerations suggest that, as a demarcation criterion, one should not take the verifiability, but the falsifiability of a system. [...]

from a system I will not demand that it be capable of being evaluated in a positive sense once and for all; but I will demand that its logical form be such that it can be evaluated, by means of empirical checks, in a negative sense: an empirical system, in order to be scientific, must be capable of being refuted by experience.

K. Popper, *Logic of Scientific Discovery*, ch. I, 6

This criterion [...] is absolutely simple and intuitive. It states that the theory that asserts the most, i.e. that contains the most information or empirical content; that is logically stronger; that has the greatest power of explanation and prediction; and that can therefore be checked more rigorously, comparing predicted facts with observations.

In short, we prefer a more interesting, bold, and informative theory in a high degree, to a trivial one.

It is possible to show that all these properties, which we consider desirable in a theory, amount to one and the same characteristic: a higher degree of empirical content, or controllability

K. Popper, *Conjectures and Refutations*, ch. 10, III

Realism

- Against the *Copenhagen interpretation* of QM $\Rightarrow$ disagreed with Niels Bohr's instrumentalism and supported Albert Einstein's realist approach to scientific theories about the universe. He found that Bohr's interpretation introduced subjectivity into physics:

Bohr was a marvelous physicist, one of the greatest of all time, but he was a miserable philosopher, and one couldn't talk to him. He was talking all the time, allowing practically only one or two words to you and then at once cutting in

John Horgan, *The Paradox of Karl Popper* (22/08/2018) in Scientific American 12/03/2023

Truth and Three worlds

The search for truth as one of the strongest motives for scientific discovery
However, in *Objective Knowledge* (1972) still concerns about the much-criticised notion of *truth as correspondence*

⇒ *Semantic theory of truth* formulated by the logician Alfred Tarski (1901-1983)
→ support metaphysical realism and the regulative idea of a search for truth

1. *World One*: the physical world, or physical states
2. *World Two*: the world of mind, or mental states, ideas and perceptions
3. *World Three*: the body of human knowledge expressed in its manifold forms, or the products of the Second World made manifest in the materials of the First World

Resemblance to Descartes' mind–body dualism

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The Structure of Scientific Revolutions

The operations and measurements that a scientist undertakes in the laboratory are not "the given" of experience but rather "the collected with difficulty". They are not what the scientist sees—at least not before his research is well advanced and his attention focused. Rather, they are concrete indices to the content of more elementary perceptions, and as such they are selected for the close scrutiny of normal research only because they promise opportunity for the fruitful elaboration of an accepted paradigm. Far more clearly than the immediate experience from which they in part derive, operations and measurements are paradigm-determined. Science does not deal in all possible laboratory manipulations. Instead, it selects those relevant to the juxtaposition of a paradigm with the immediate experience that that paradigm has partially determined. As a result, scientists with different paradigms engage in different concrete laboratory manipulations.

T. S. Kuhn, *The Structure of Scientific Revolutions*, 216

Normal science according to Kuhn

Even though there is no complete, explicit characterisation, individual scientists acquire knowledge of a paradigm through their scientific education. By solving standard problems, performing standard experiments and eventually by doing a piece of research under a supervisor who is already a skilled practitioner within the paradigm

Knowledge according to Kuhn

- Knowledge is a state of mind, with objective properties

Many scientists contribute in their separate ways and with their individual skills to the growth and articulation of physics, just as many workers combine their efforts in the construction of a cathedral

- An individual scientist will be confronted by an objective situation
- Linguistic objects and objective relation between paradigms