ROYAL INSTITUTE
OF TECHNOLOGY

MF2070

Workshop 1

An Introduction to **Theories** of Science

Pictures from Wikipedia Commons and digitalart, David Castillo Dominici, Stuart Miles / FreeDigitalPhotos.net

ROYAL INSTITUTE OF TECHNOLOGY

Outline

- **Paradigms, Scientific Theories and the Scientific Community**
- The Scientific Method

ROYAL INSTITUTE OF TECHNOLOGY

The Purpose?

What is the purpose of a **theory of science**?

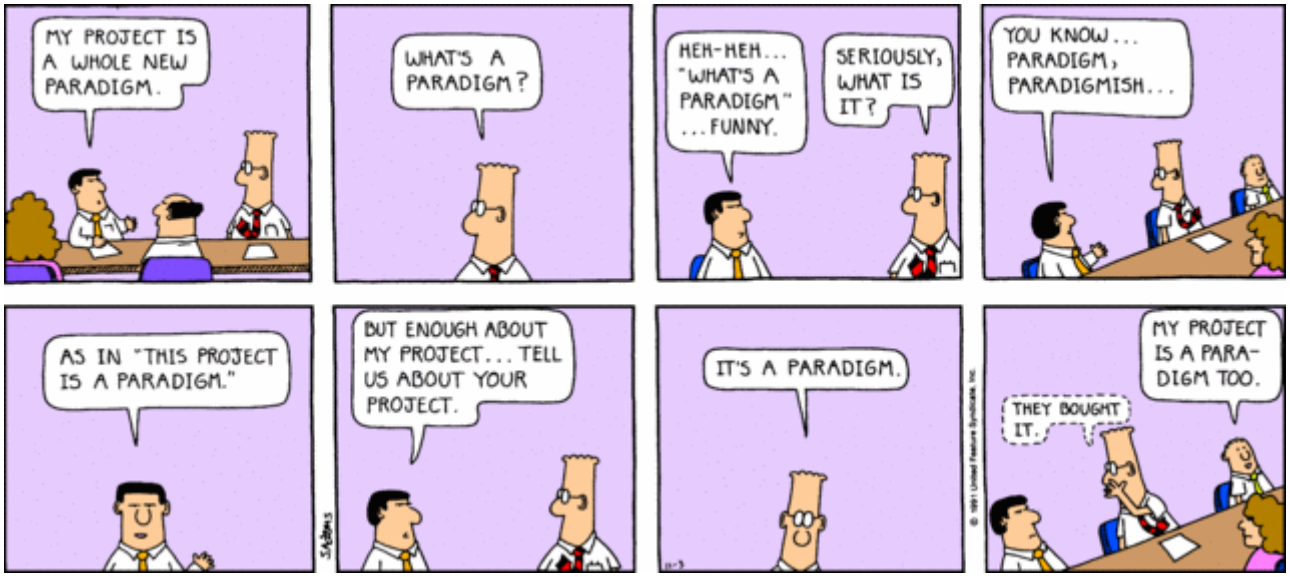
1. What is the goal of science?

2. What is the nature of scientific change?

ROYAL INSTITUTE OF TECHNOLOGY

Paradigm...

(or "Philosophical Worldview")



ROYAL INSTITUTE OF TECHNOLOGY

Contemporary Definition

- “Universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners”
  - What is to be observed and scrutinized.
  - The kind of questions to be asked and probed for answers.
  - The structure of these questions.
  - Interpretation of results.
  - Experiment setup, equipment use, etc.

ROYAL INSTITUTE OF TECHNOLOGY

A Vague Term

- Kuhn, and others, have used different definitions.
- A very vague term, but useful in that it points out that beliefs, attitudes, procedures and techniques of the scientific community are important.
- To highlight the very real influence by these we only have to look at a few different philosophical standpoints that underpin different research fields.

ROYAL INSTITUTE OF TECHNOLOGY

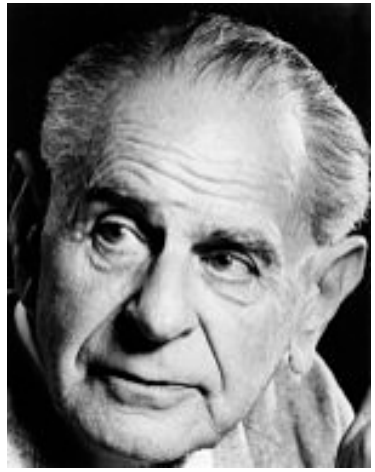
Logical Positivism

- Roots trace back to August Comte (1798-1857).

- **Ontology:** There is a single reality.
- **Epistemology:** Knower and known are independent.
- **Axiology:** Inquiry is value-free.
- **Generalizations:** Time- and Context-free generalizations are possible.
- **Causal Linkage:** There are real causes that are temporally precedent to or simultaneous with effects.
- **Deductive Logic:** Emphasis on arguing from the general to the particular.
- **“Choice” of Methods:** Quantitative

ROYAL INSTITUTE OF TECHNOLOGY

Postpositivism



- Arose during the 1950s and 1960s (Popper, Kuhn, Hanson, etc.).

- **Value-ladenness of Inquiry:** Research is influenced by the values of investigators.
- **Theory-ladenness of Facts:** Research is influenced by the theory, hypotheses or framework that an investigator uses.
- **Nature of Reality:** Our understanding of reality is constructed.
- **Choice of Methods:** Primarily quantitative
- **Focus:** Theory verification

ROYAL INSTITUTE OF TECHNOLOGY

Constructivism

- Various schools of though, here gathered under one name. Important in regard to social phenomena. Example standpoints include:

- **Ontology:** There are multiple, constructed realities.
- **Epistemology:** Knower and known are inseparable.
- **Axiology:** Inquiry is value-bound.
- **Generalizations:** Time- and Context-free generalizations are **not** possible.
- **Causal Linkage:** It is impossible to distinguish causes from effects.
- **Inductive Logic:** Emphasis on arguing from the particular to the general.
- **“Choice” of Methods:** Qualitative
- **Focus:** Theory generation

Pragmatism

- Arose after the paradigm wars between postpositivists and constructivists. Either provides more nuanced view or just compromises between paradigms (depends on who you speak to).

- **Ontology:** There is an external reality, but it can never be completely defined.
- **Epistemology:** Knower and known may be independent, it depends.
- **Axiology:** Values play a large role in interpreting results.
- **Causal Linkage:** There may be real causes that are temporally precedent to or simultaneous with effects, but we will never be able to **completely** pin them down.
- **Inductive + Deductive Logic**
- **Choice of Methods:** Quantitative + Qualitative
- **Focus:** Real-world practice

ROYAL INSTITUTE OF TECHNOLOGY

Why are Paradigms important (in practice)?

- To publish
- To get grants
- In other words, the *research community* ***enforces*** compliance to *the* paradigm

ROYAL INSTITUTE
OF TECHNOLOGY

So, how is this related to

scientific change?

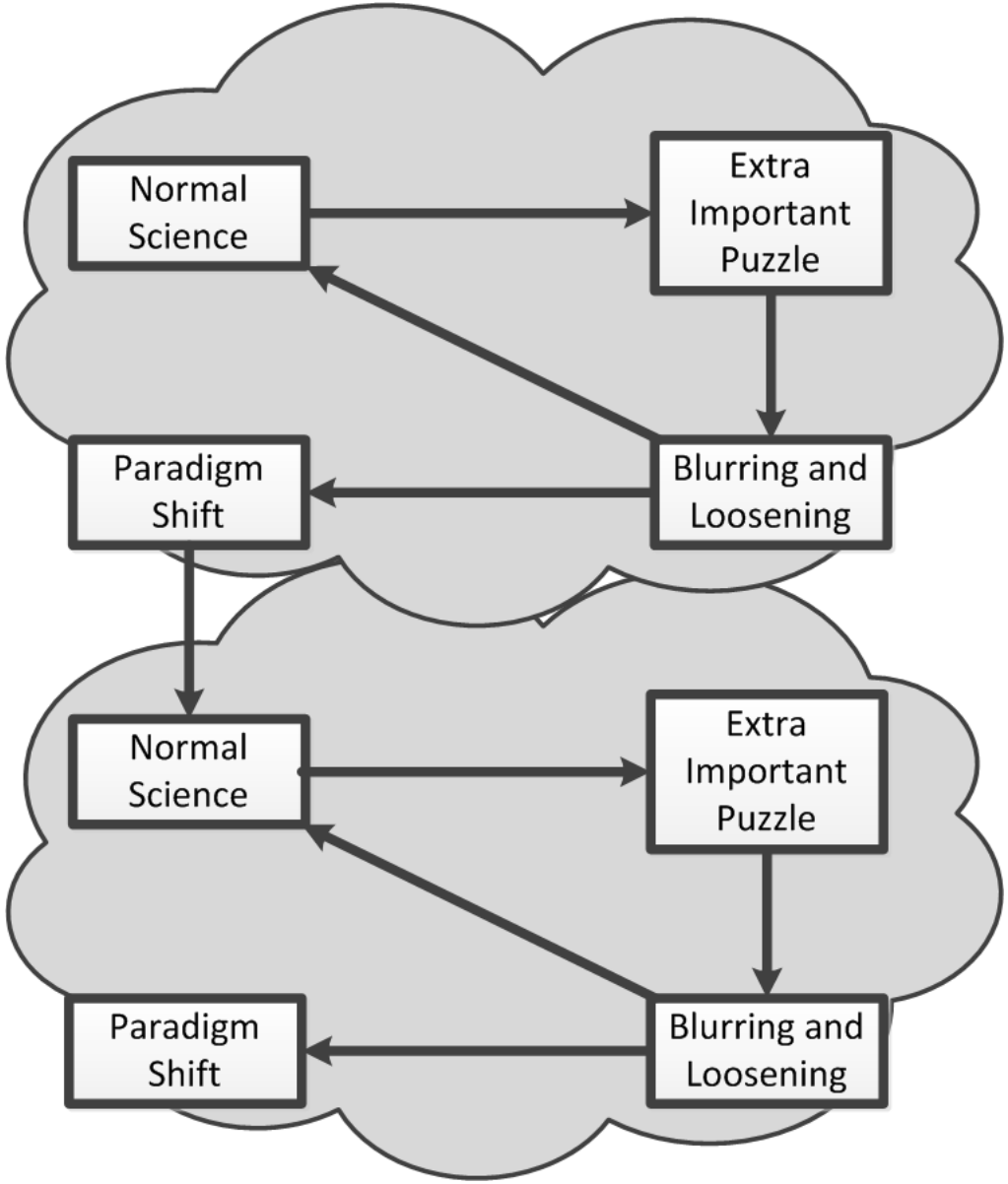
ROYAL INSTITUTE OF TECHNOLOGY

Through the anomalies...

Paradigm A

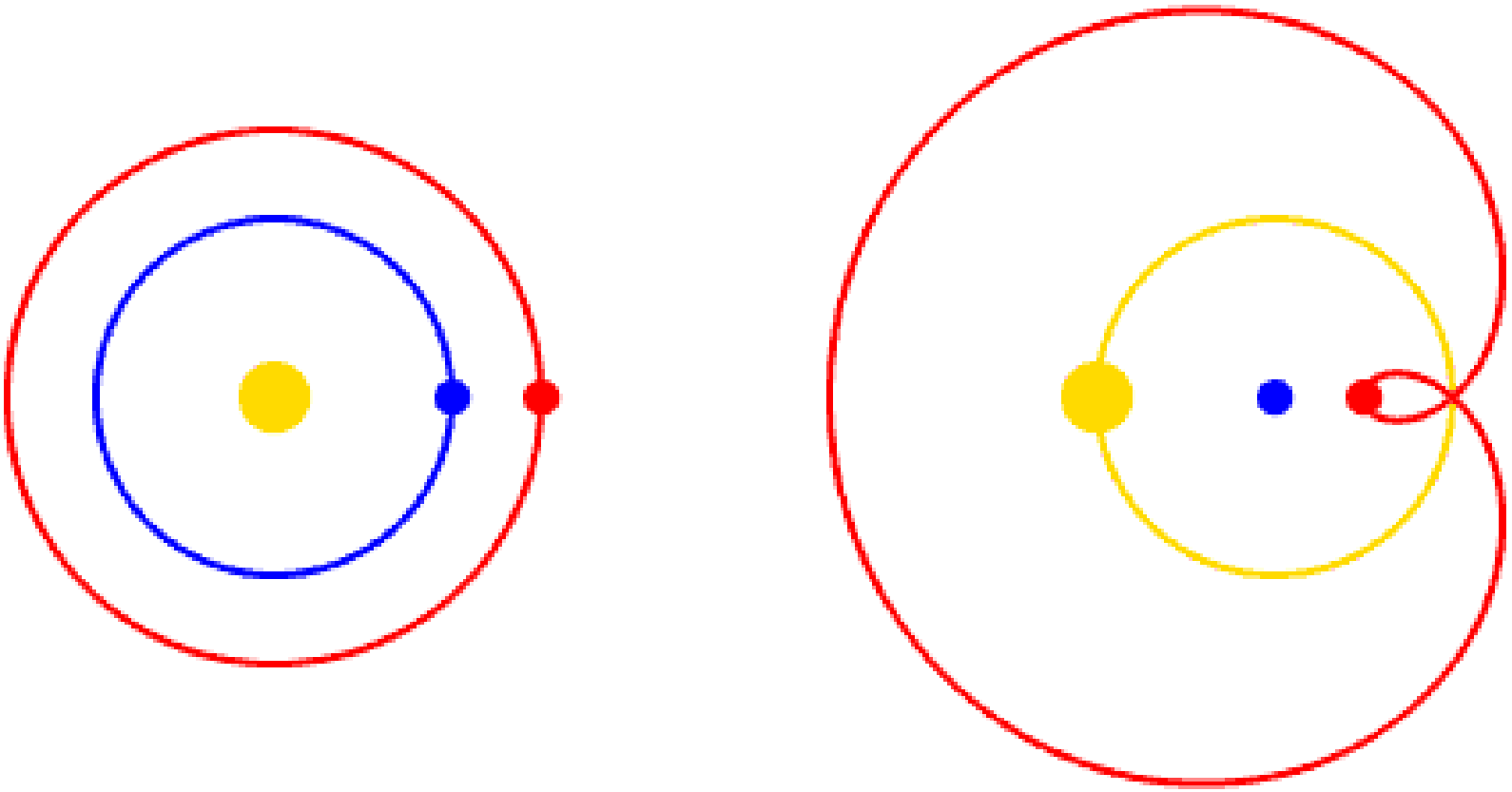
to

Paradigm B

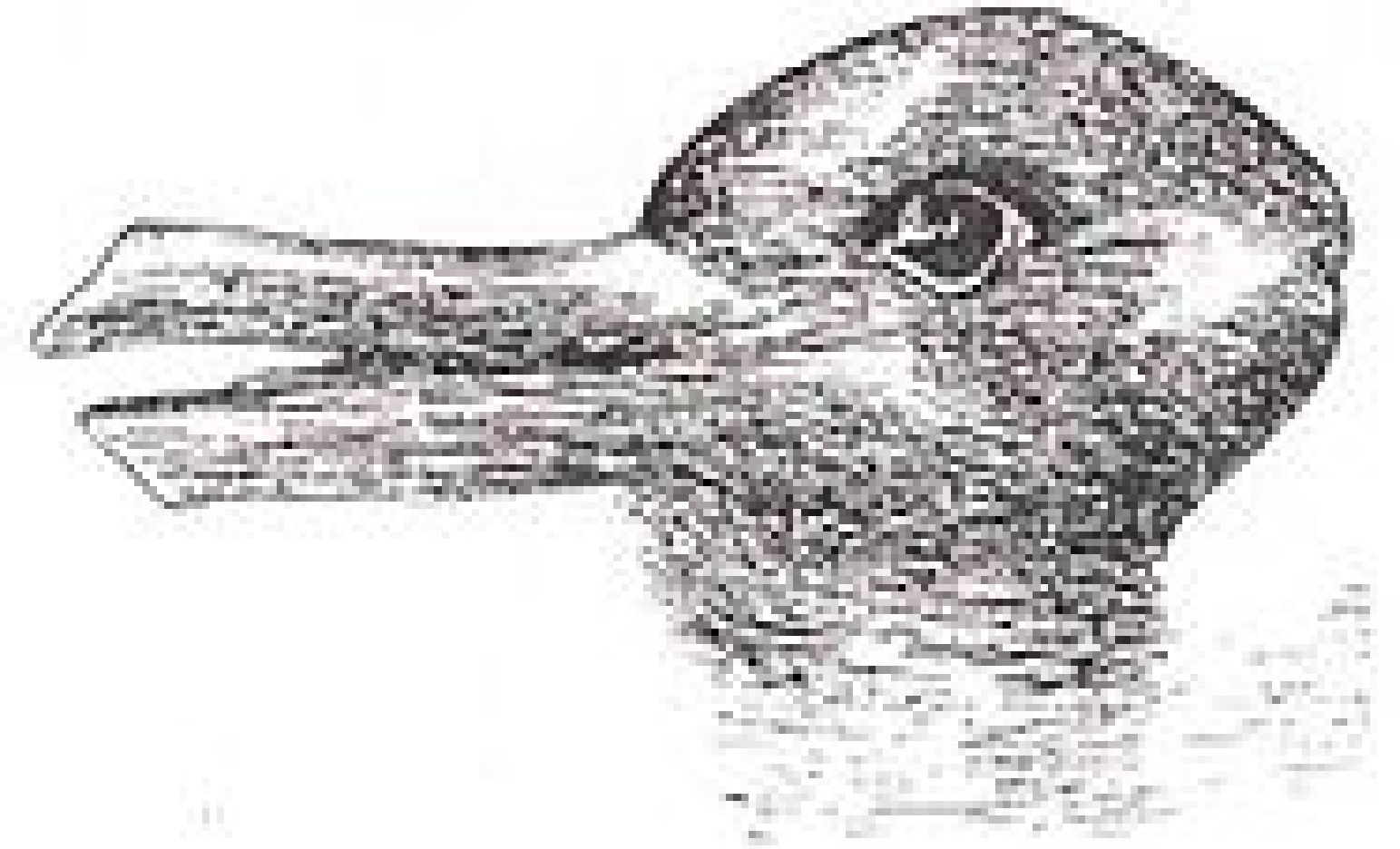


ROYAL INSTITUTE OF TECHNOLOGY

An Example of Paradigm Shifts (by Kuhn): The Copernican Revolution



ROYAL INSTITUTE
OF TECHNOLOGY



ROYAL INSTITUTE OF TECHNOLOGY

So, is "The Scientific Endeavor" relative?

Is there No Good and Bad Science?

ROYAL INSTITUTE OF TECHNOLOGY

Thomas Kuhn

A Scientific Theory:

- should provide **accurate** predictions.
- should **permit puzzle-formulation** and **solution**.
- should be **simple**.
- should be **self-consistent**.
- should be **compatible** with other theories currently deployed.

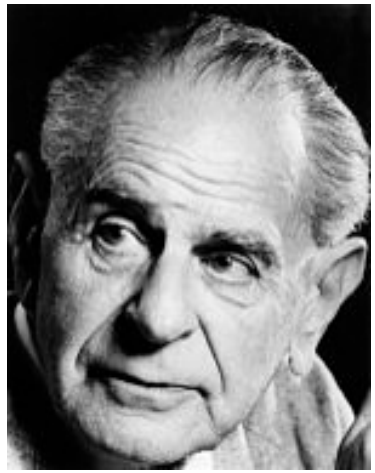
ROYAL INSTITUTE OF TECHNOLOGY

So, is "The Scientific Endeavor" non-rational?

Is there no possibility to differ objectively between Good and Bad Science?

ROYAL INSTITUTE OF TECHNOLOGY

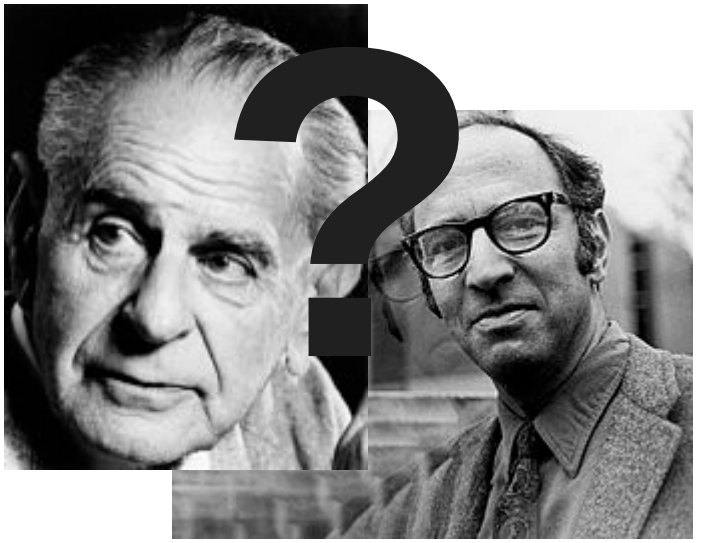
Karl Popper



- Defines another, **rational** perspective on scientific change.
- Focused on what is different between *scientific* theories and *non-scientific* theories.
- Chose *falsification* as the answer, and the *empirical method* as a way of forcing a choice between scientific systems.

ROYAL INSTITUTE OF TECHNOLOGY

Popper vs. Kuhn?



- Both Popper and Kuhn are well respected with regard to the theory of science, but…
- There is, unfortunately for the rationalist, no question regarding whose theory is closest to the history of the scientific endeavor.

ROYAL INSTITUTE OF TECHNOLOGY

Enter Imre Lakatos

ROYAL INSTITUTE OF TECHNOLOGY

Enter Imre Lakatos

ROYAL INSTITUTE OF TECHNOLOGY

Competing Theories – It is easy

"A theory (T) ought to be rejected (falsified) if and only if:

1. *Another theory T' has excess empirical content over T: that is, it predicts novel facts, that is, facts improbable in the light of, or even forbidden by, T;*
2. *T' explains the previous success of T, that is, all the unrefuted content of T is included (within the limits of observational error) in the content of T'; and*
3. *some of the excess content of T' is corroborated."*

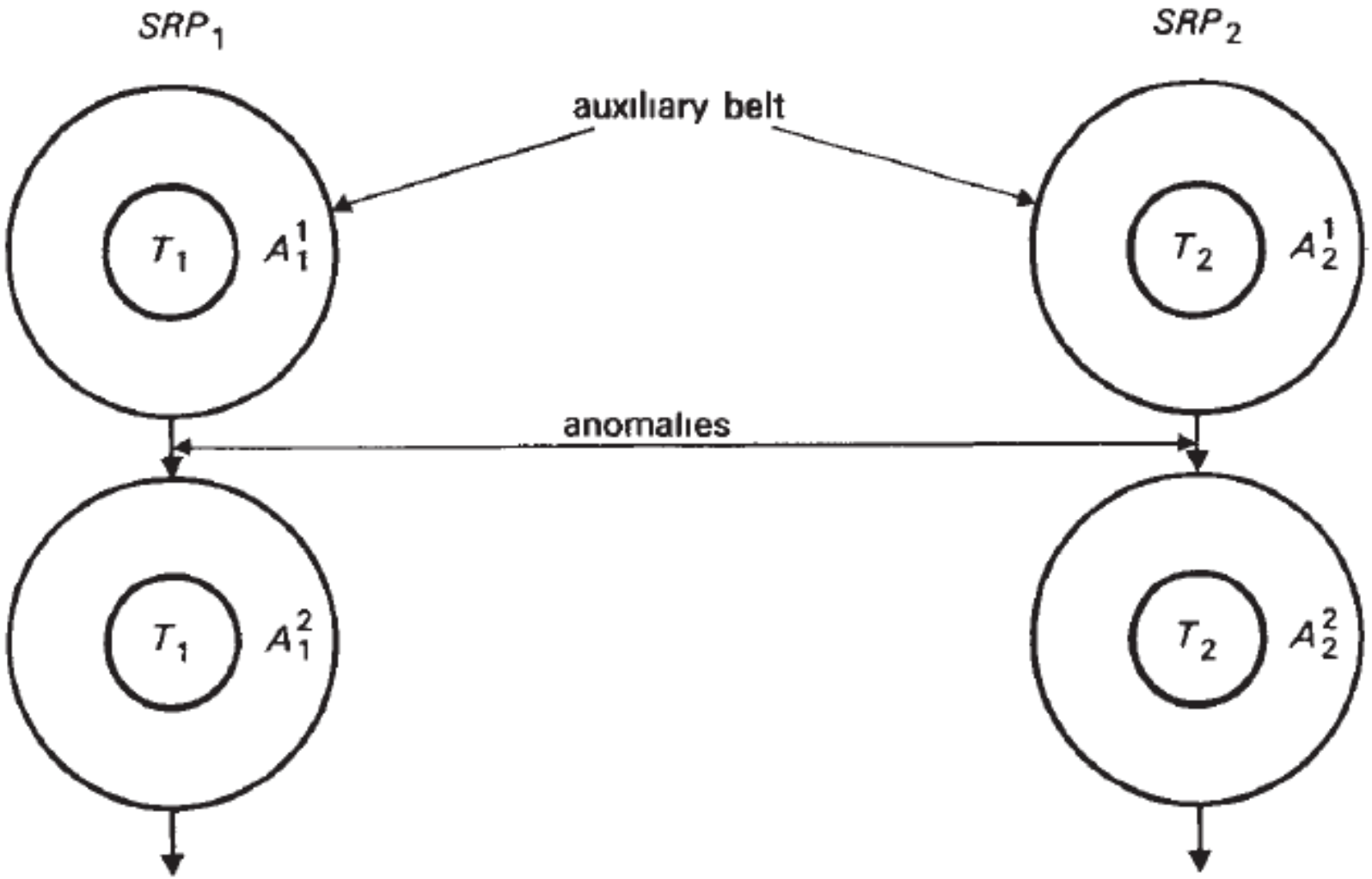
ROYAL INSTITUTE OF TECHNOLOGY

So...

- Yes, we only abandon theories in favor of better theories.
- But, we first explore modifications in theories which might make them better able to cope with anomalies.
- Hence we should not consider single theories but a sequence of theories in which each theory is generated by modifying its predecessor (a *"Scientific Research Programme"*).

ROYAL INSTITUTE OF TECHNOLOGY

The auxiliary belt



ROYAL INSTITUTE OF TECHNOLOGY

And this is an answer to
Good versus Bad...

Progressive

Versus

Degenerative

ROYAL INSTITUTE OF TECHNOLOGY

And Then What?

- Lakatos views have also been criticized by other theorists.
- Different philosophical standpoints abound.
- However, the structure of the scientific community still reflects at least a hope that scientific change is **rational** and **objective**.

ROYAL INSTITUTE OF TECHNOLOGY

The Structure of the Scientific Community?

- Science as ”Organized Scepticism”

- Everything **can** be doubted, but scientists should provide:
  - Proof of expertise within the area
  - Transparency with regard to method use and study execution
  - A consideration of alternative explanations and opinions **based on** available evidence (even scepticism does not imply that all theories are of equal value)

ROYAL INSTITUTE OF TECHNOLOGY

Outline

- Introduction to the Course
- Paradigms, Scientific Theories and the Scientific Community
- **The Scientific Method**

ROYAL INSTITUTE OF TECHNOLOGY

Good or Bad Methods?

- ~~Theory~~
- Method

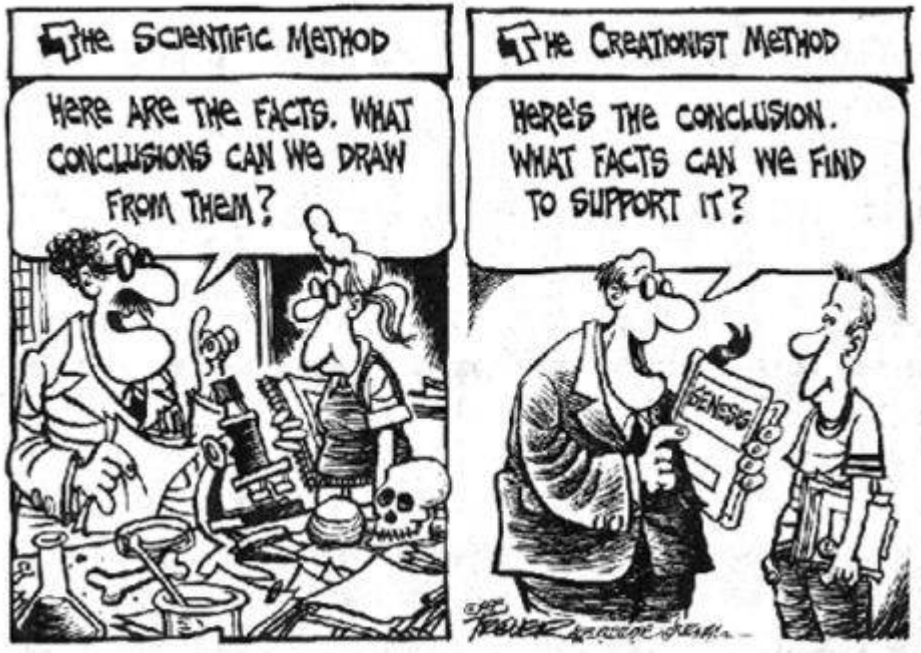
ROYAL INSTITUTE OF TECHNOLOGY

Good or Bad Methods?

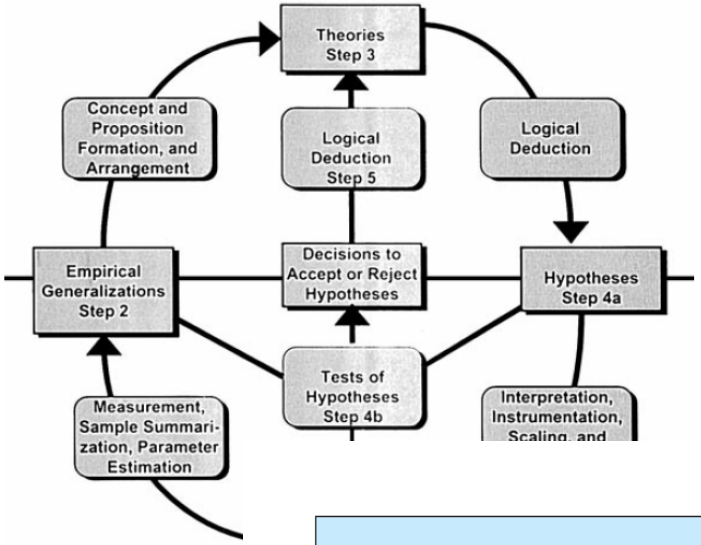
- ~~Theory~~
- Method

ROYAL INSTITUTE
OF TECHNOLOGY

Method...



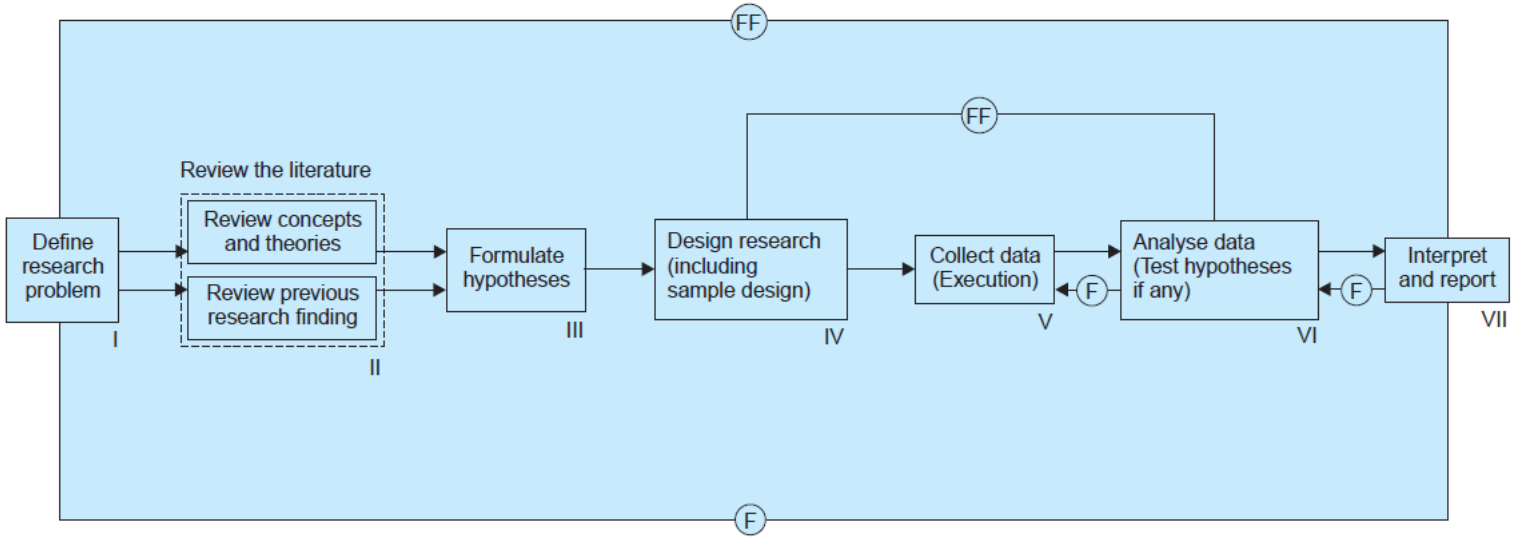
Described in many ways



An eight-stage model of the scientific method

Stage 1: Hypotheses, hunches and guesses
Stage 2: Experiment designed; samples taken; variables isolated
Stage 3: Correlations observed; patterns identified
Stage 4: Hypotheses formed to explain regularities
Stage 5: Explanations and predictions tested; falsifiability

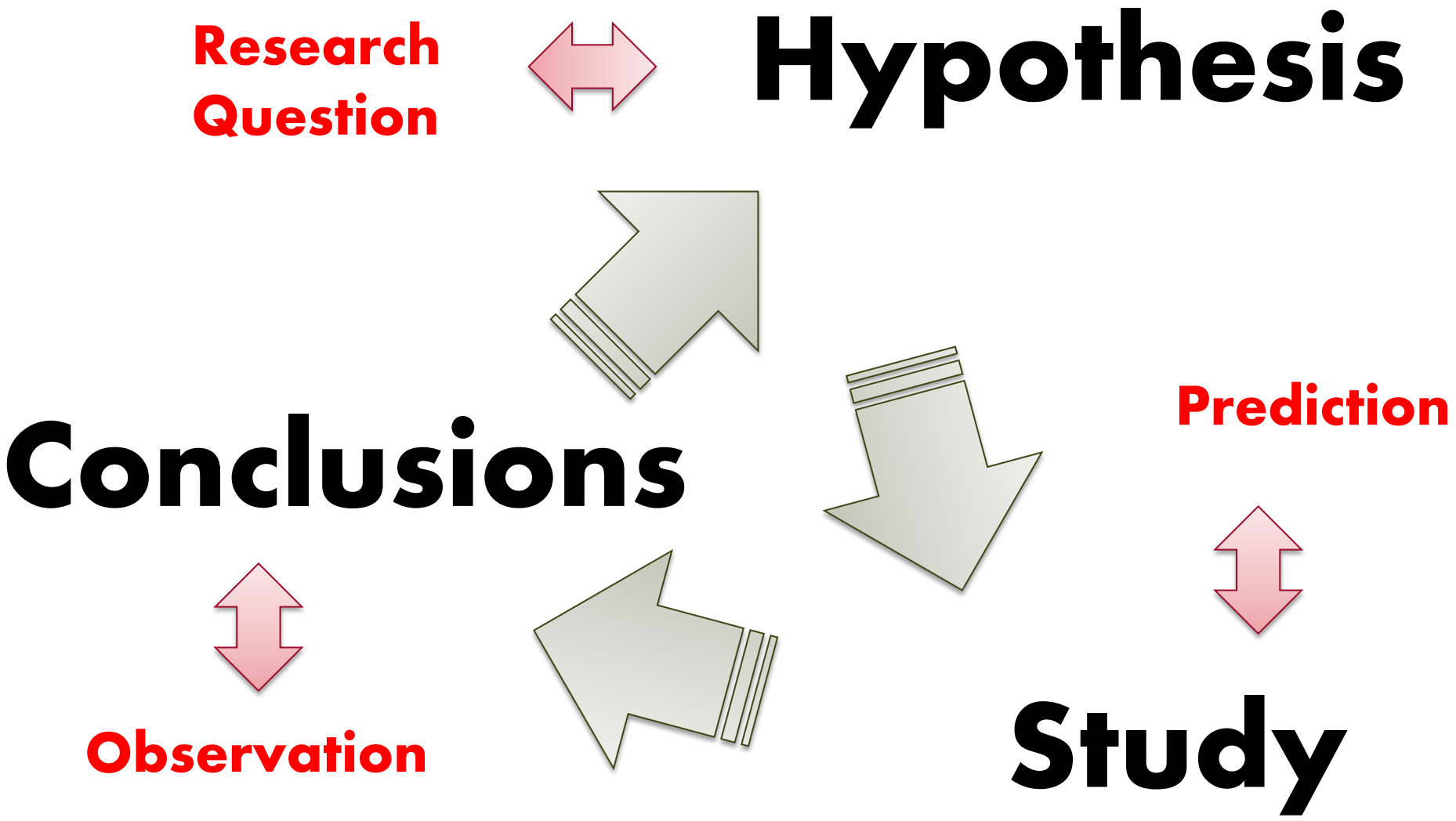
RESEARCH PROCESS IN FLOW CHART



Where (F) = feed back (Helps in controlling the sub-system to which it is transmitted)
(FF) = feed forward (Serves the vital function of providing criteria for evaluation)

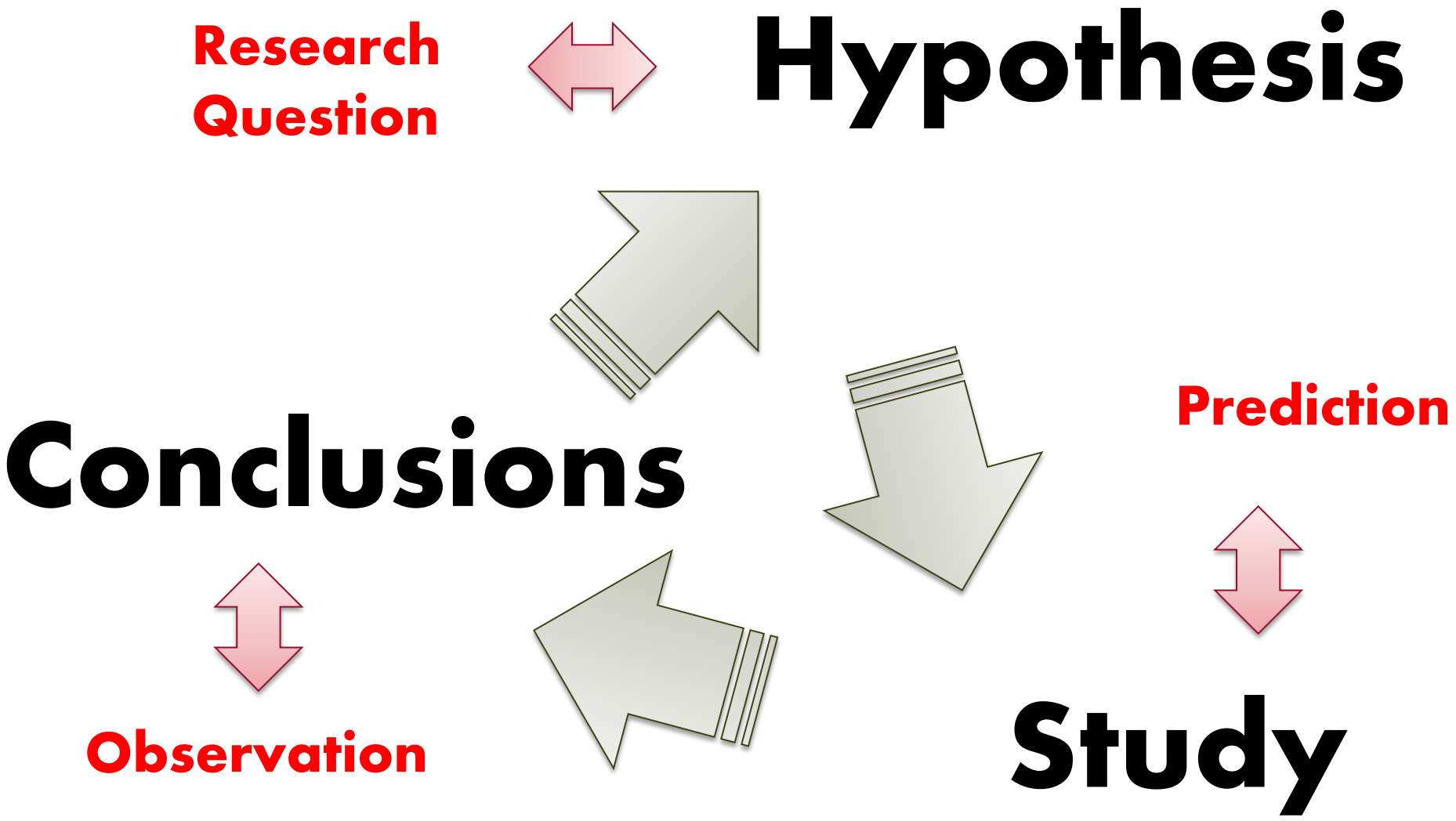
ROYAL INSTITUTE OF TECHNOLOGY

A Deceptively Straight-Forward Simplification…



ROYAL INSTITUTE OF TECHNOLOGY

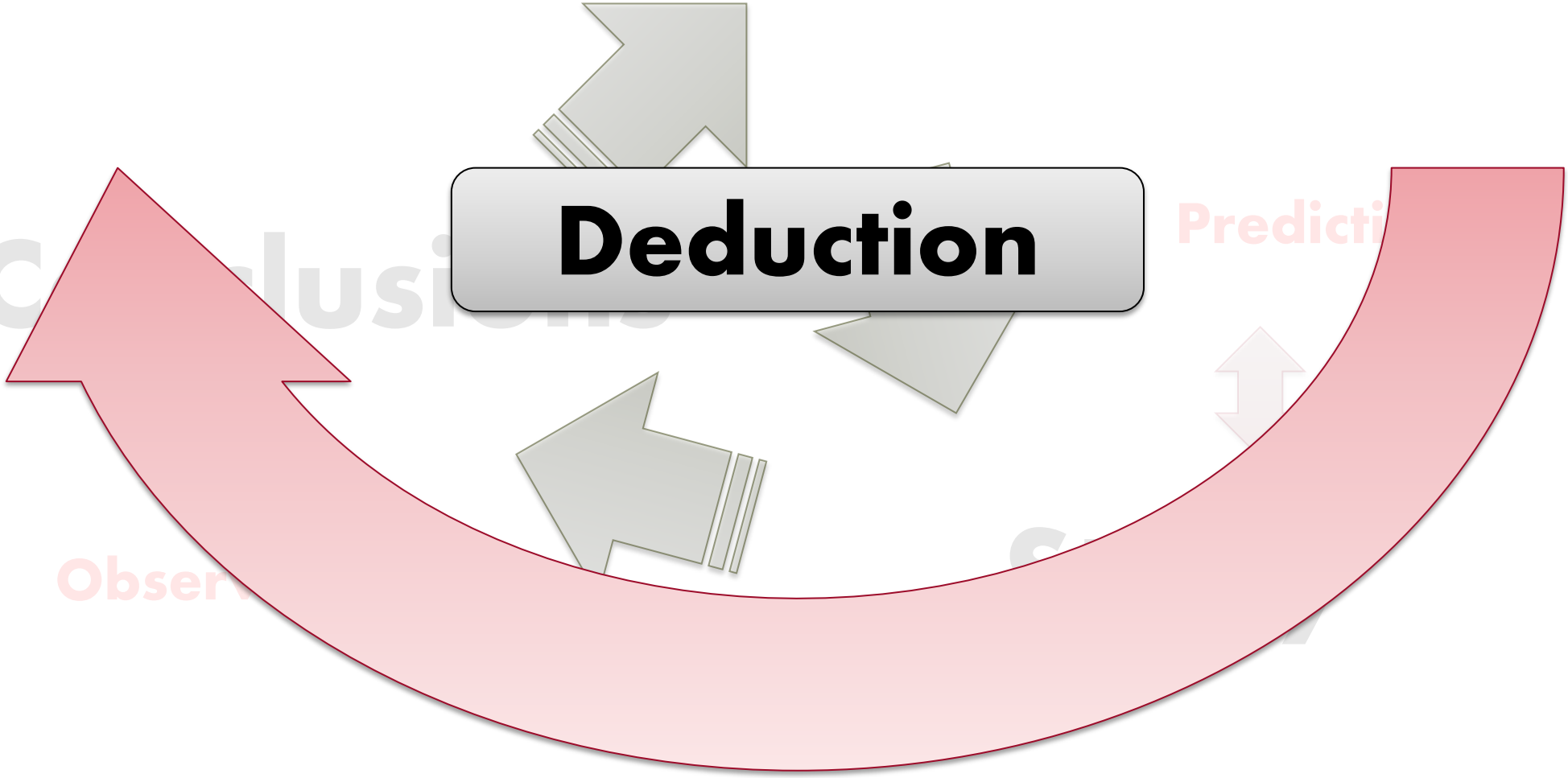
Where to Start?



ROYAL INSTITUTE OF TECHNOLOGY

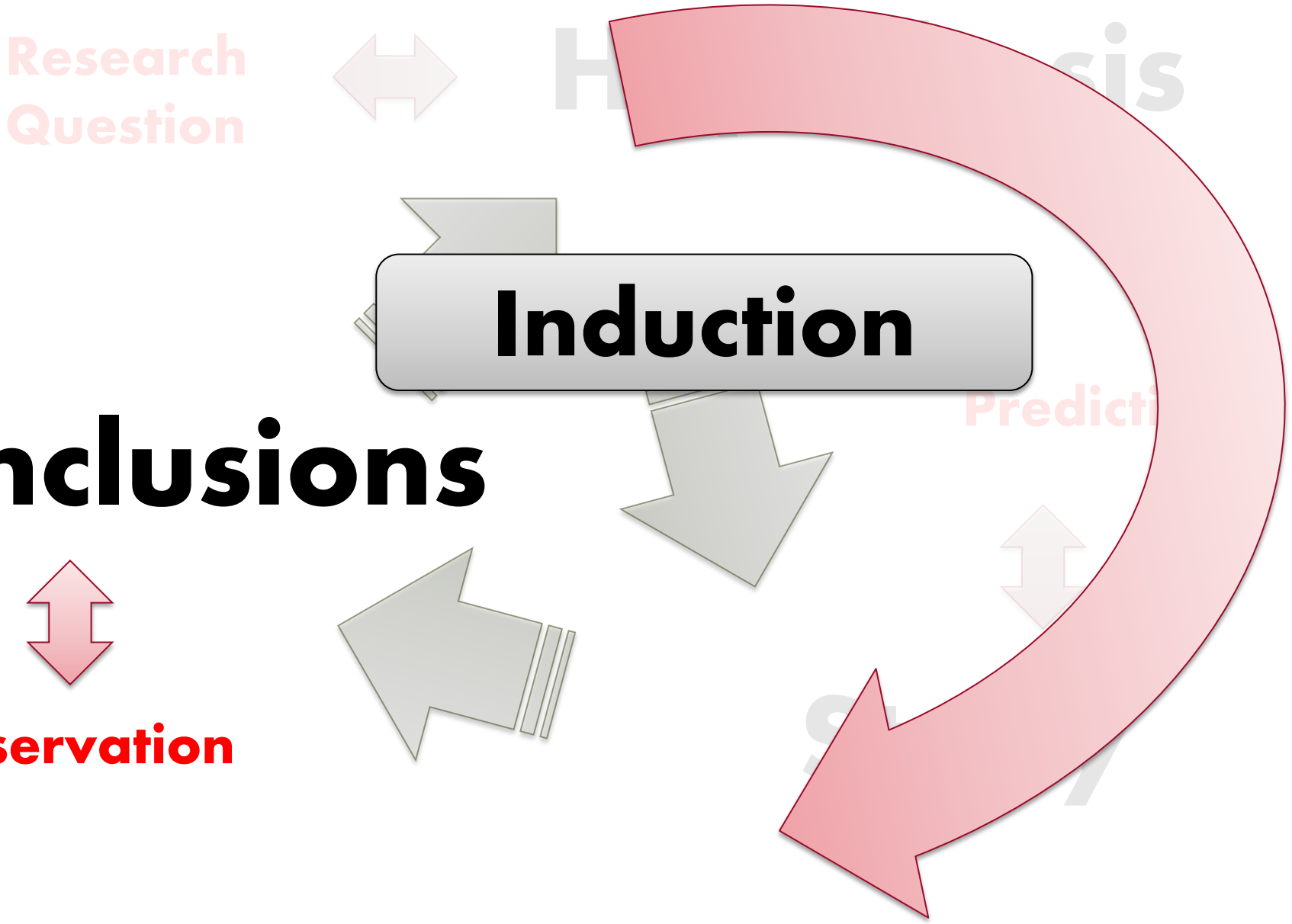
Where to Start?

Research Question ⇔ **Hypothesis**



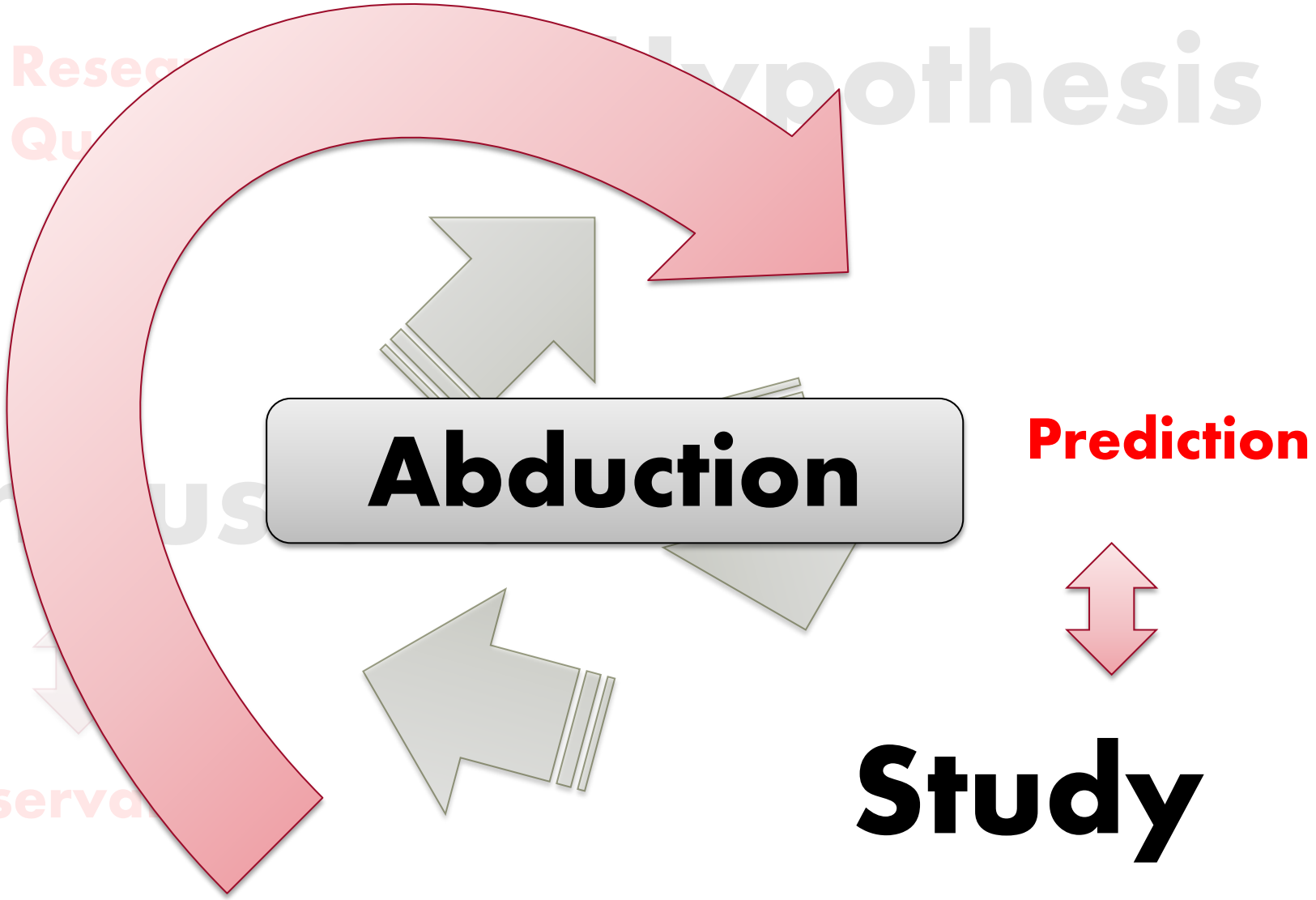
ROYAL INSTITUTE OF TECHNOLOGY

Where to Start?



ROYAL INSTITUTE OF TECHNOLOGY

Where to Start?



ROYAL INSTITUTE
OF TECHNOLOGY

So, is there a solution to this

Chicken

Or

Egg Dilemma?

ROYAL INSTITUTE OF TECHNOLOGY

Regardless – The key parts

- Research Question
- Data Gathering
- Data Analysis

ROYAL INSTITUTE OF TECHNOLOGY

Regardless – The key parts

- Research Question
- Data Gathering
- Data Analysis

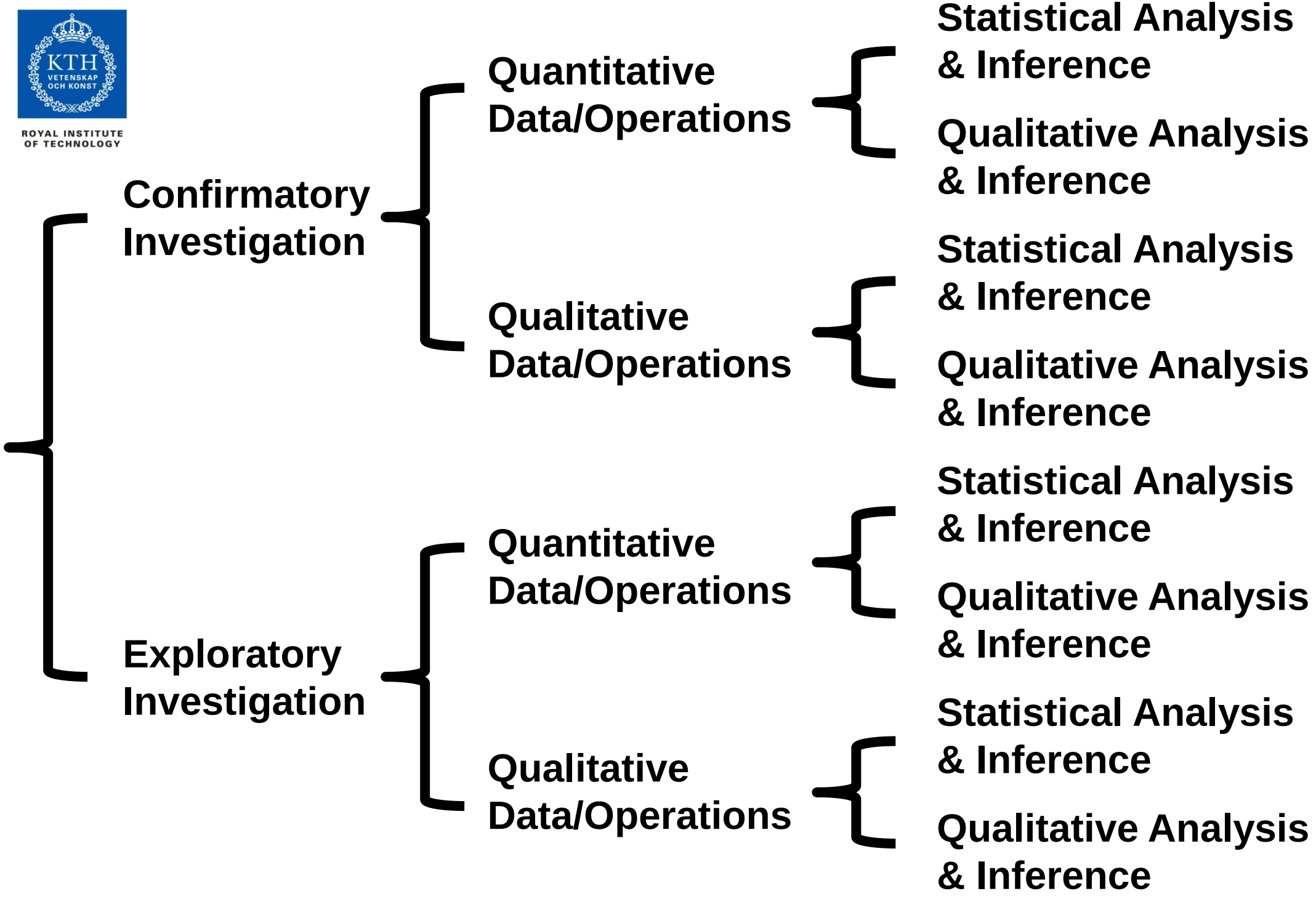
- Methods
- Methodologies (Research Designs)

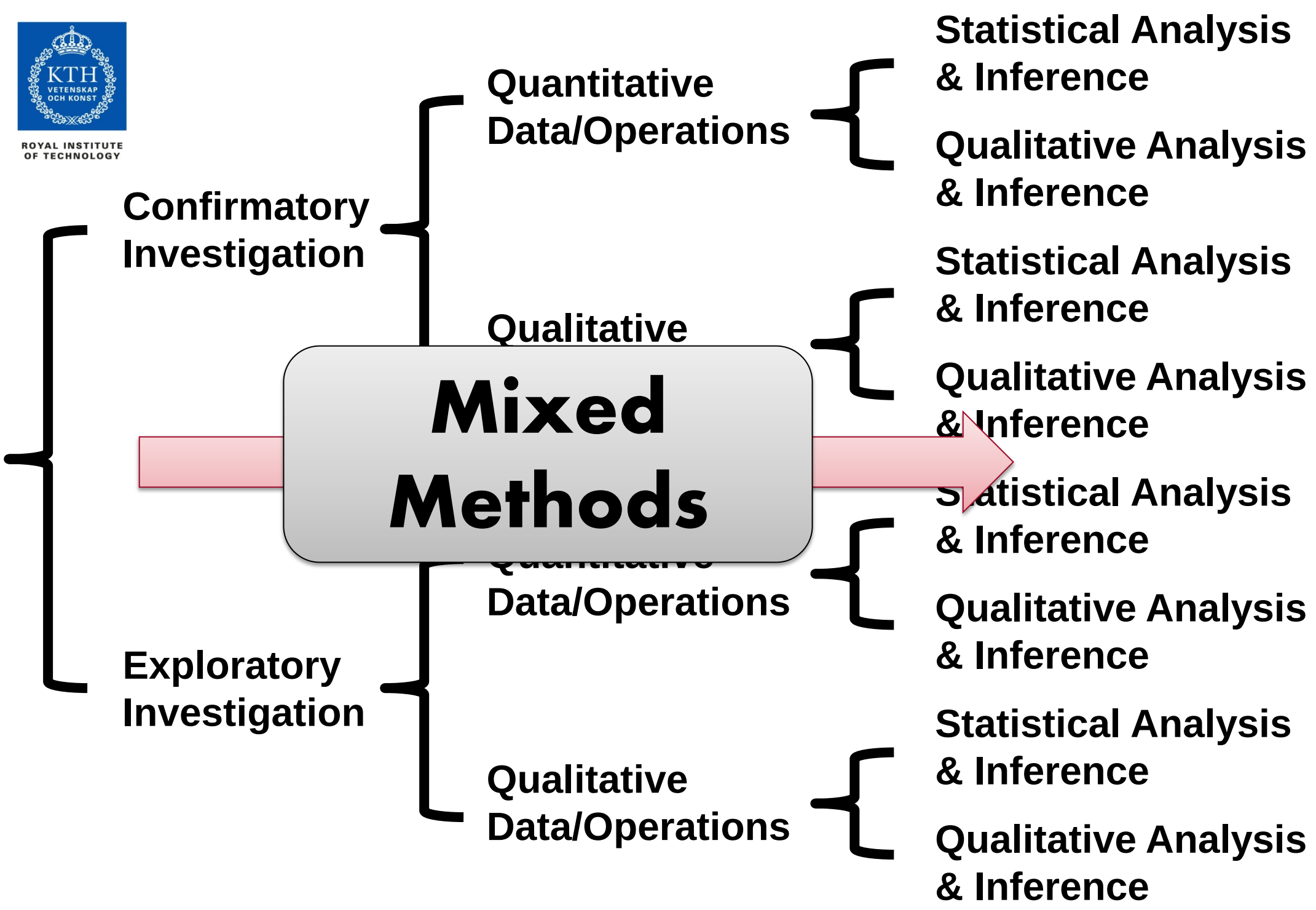
ROYAL INSTITUTE OF TECHNOLOGY

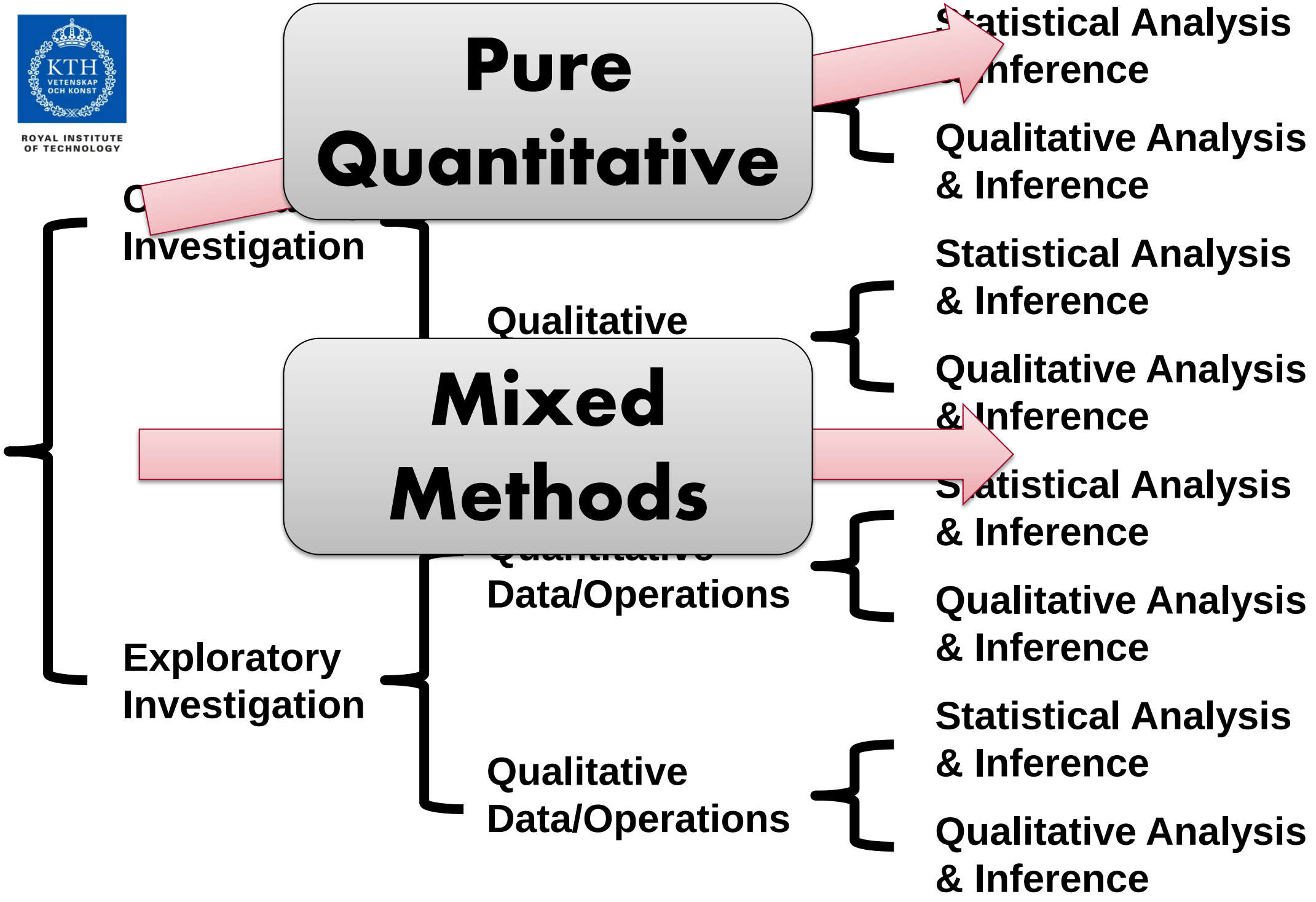
Quantitative - Qualitative

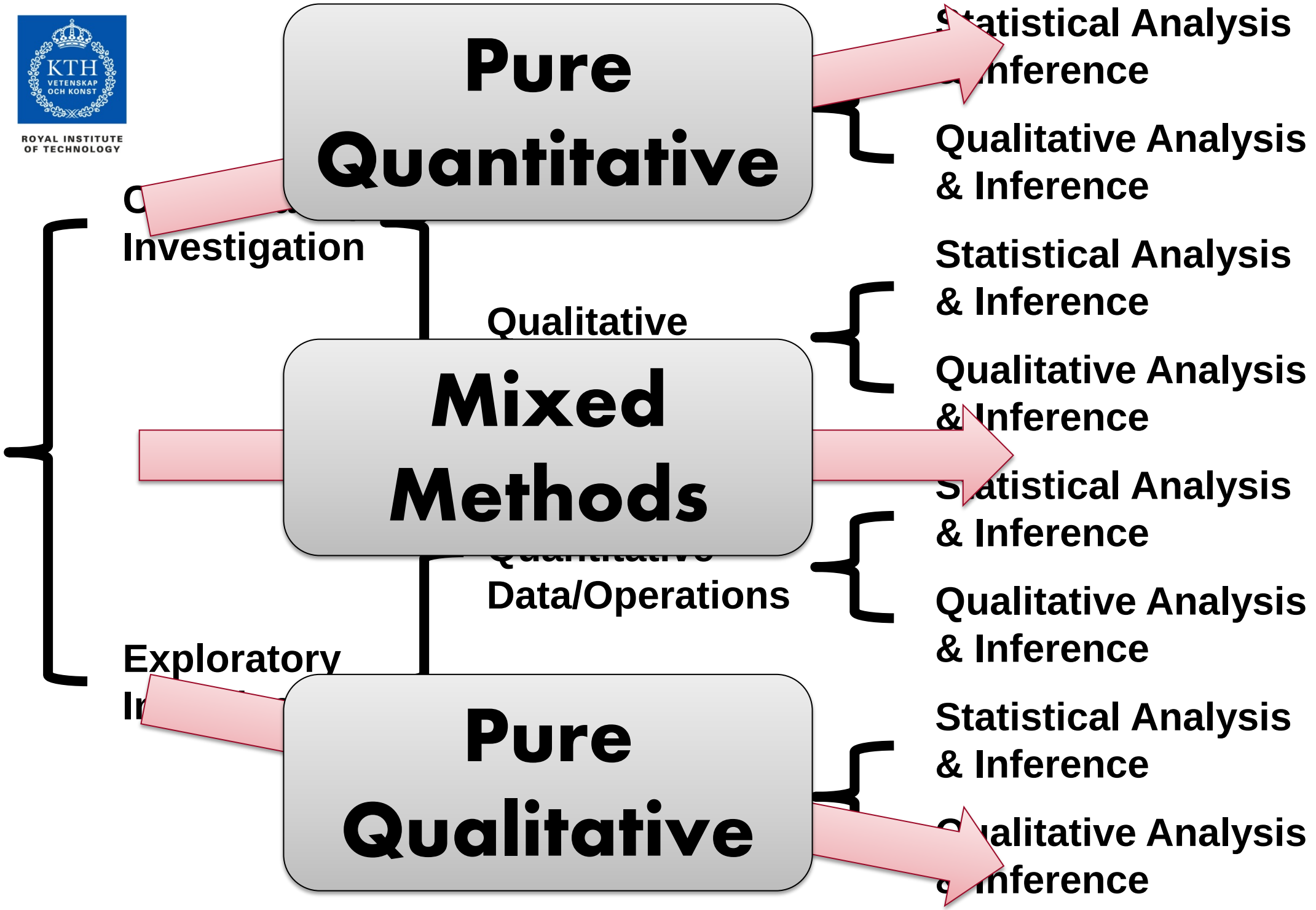
"**Quantitative methods** have been evolved within the **positivist** paradigm."

"**Qualitative methods** have been evolved within the **constructivist** paradigm."


ROYAL INSTITUTE OF TECHNOLOGY
Confirmatory Investigation
Quantitative Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference
Qualitative Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference
Exploratory Investigation
Quantitative Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference
Qualitative Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference


ROYAL INSTITUTE OF TECHNOLOGY
Mixed Methods
Confirmatory Investigation
Exploratory Investigation
Quantitative Data/Operations
Qualitative Data/Operations
Quantitative Data/Operations
Qualitative Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference
Statistical Analysis & Inference
Qualitative Analysis & Inference
Statistical Analysis & Inference
Qualitative Analysis & Inference
Statistical Analysis & Inference
Qualitative Analysis & Inference


Pure Quantitative
Statistical Analysis & Inference
Qualitative Analysis & Inference
Investigation
Mixed Methods
Qualitative
Statistical Analysis & Inference
Qualitative Analysis & Inference
Data/Operations
Exploratory Investigation
Statistical Analysis & Inference
Qualitative Analysis & Inference
Qualitative Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference


ROYAL INSTITUTE OF TECHNOLOGY
Pure Quantitative
Statistical Analysis & Inference
Qualitative Analysis & Inference
Investigation
Qualitative
Mixed Methods
Statistical Analysis & Inference
Qualitative Analysis & Inference
Data/Operations
Statistical Analysis & Inference
Qualitative Analysis & Inference
Exploratory
Pure Qualitative
Statistical Analysis & Inference
Qualitative Analysis & Inference

ROYAL INSTITUTE OF TECHNOLOGY

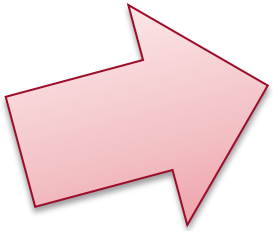
The Quantitative Extreme

- Design Quality:
  - Generalizations are possible!
    - Focus on Deductive Logic
  - There is a objectively understandable reality!
    - Results makes sense to Independent Experts
- Information/Data Quality:
  - Separate Concern

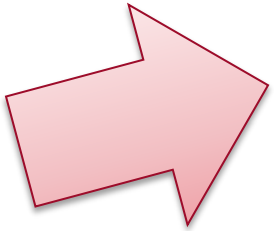
ROYAL INSTITUTE OF TECHNOLOGY

The Quantitative Extreme

Question to (try to) answer objectively



Data to (try to) evaluate objectively



Inferences to be evaluated by other experts

ROYAL INSTITUTE OF TECHNOLOGY

Surveys

- Scientific Theories arise as generalizations from observable data, specifically through studying samples of populations.
- Typical Methods, Data Gathering: Questionnaires
- Typical Methods, Data Analysis: Statistics

ROYAL INSTITUTE OF TECHNOLOGY

The Hypothetico-Deductive Model (Experiments)

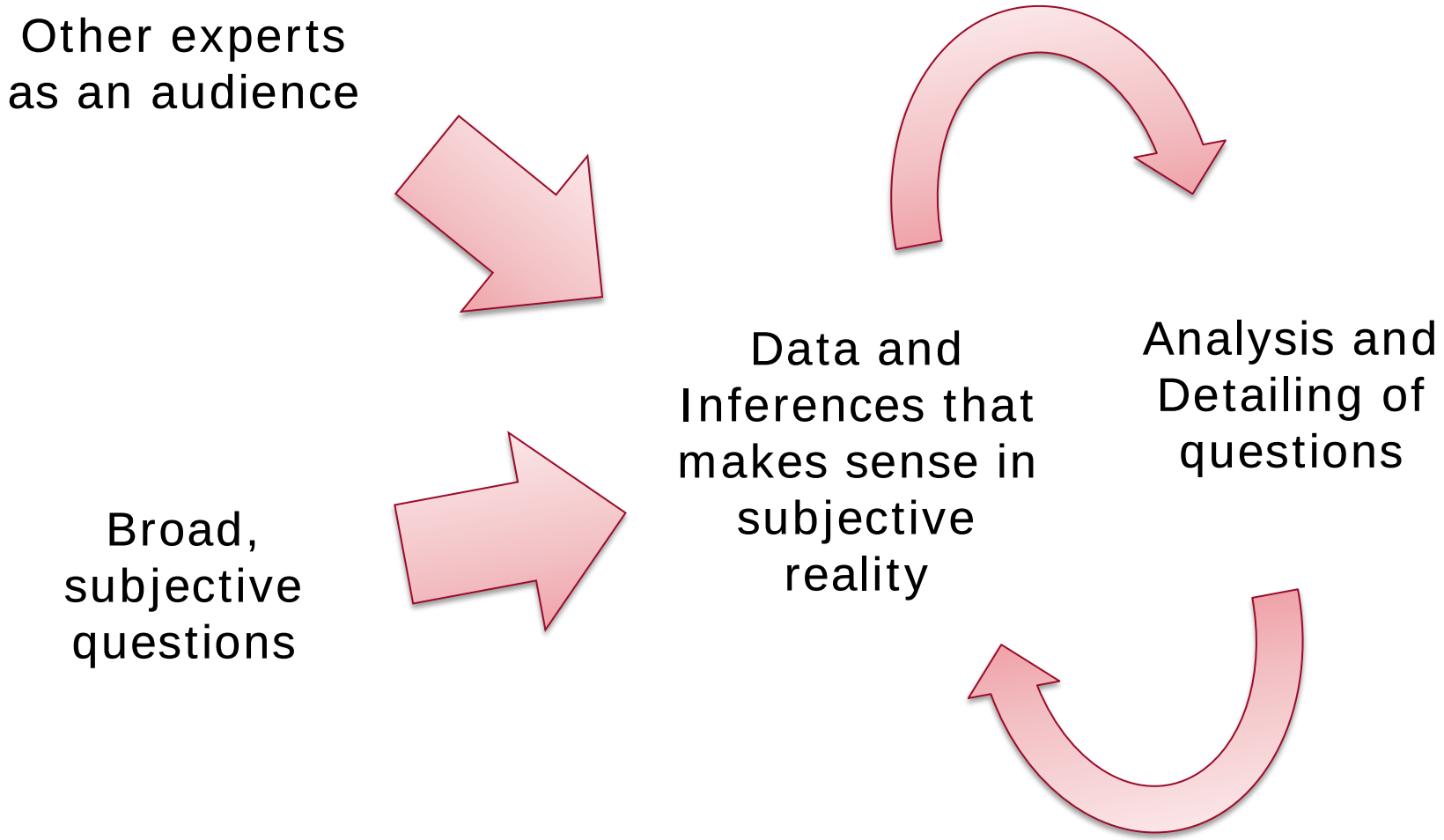
- Scientific Theories arise as generalizations from observable data, specifically through trying to falsify hypotheses.
- These generalizations remain “hypotheses” in the general sense, which are not conclusively established until all their consequences have been verified through relevant tests.
- Typical Methods, Data Gathering: Non-participant Observations
- Typical Methods, Data Analysis: Statistics

ROYAL INSTITUTE OF TECHNOLOGY

The Qualitative Extreme

- Design Quality:
  - Generalizations are not possible!
    - Focus on Inductive Logic (if any)
  - There are multiple realities!
    - Results makes sense to those whose realities are reconstructed/described
- Information/Data Quality:
  - Intrinsically linked to inferences

The Qualitative Extreme



ROYAL INSTITUTE OF TECHNOLOGY

Ethnography

- The study of an intact cultural group in a natural setting over a prolonged period of time.
- Typical Methods, Data Gathering: Observations and Interviews.
- Typical Methods, Data Analysis: Various, but tries to be ”emic”.

ROYAL INSTITUTE OF TECHNOLOGY

Grounded Theory

- The derivation of a general, abstract theory of a process, action, or interaction **grounded** in the views of participants in a study.
- Typical Methods, Data Gathering: “All is Data” (Observations, Interviews, Content Analysis…)
- Typical Methods, Data Analysis: The Constant Comparative Analytical Scheme

ROYAL INSTITUTE OF TECHNOLOGY

Case Studies

- The in-depth exploration of an individual unit (person, community, project, etc.). Difference lies in the characteristic of the individual case (generic, critical, oddity, etc.).
- Typical Methods, Data Gathering: Various.
- Typical Methods, Data Analysis: Various.

ROYAL INSTITUTE OF TECHNOLOGY

Phenomenology

- The identification of the "essence" of human experiences concerning a phenomenon, as described by participants in a study.
- Typical Methods, Data Gathering: Lengthy observation or interviews.
- Typical Methods, Data Analysis: Various.

ROYAL INSTITUTE OF TECHNOLOGY

Narrative Inquiry

- The researcher retells or “restories” data into a narrative chronology.
- Typical Methods, Data Gathering: Various.
- Typical Methods, Data Analysis: Various.