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## Scientific Writing

Theory of Science

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# Lernziele

- Forschungsprobleme in die Wissenschaftliche Methodik formulieren

# Basics of Scientific Work

**Everyday knowledge** is based on routine experiences of daily life and personal experiences.

- subjective (different people may reach different conclusions about the same fact)
- can be subject to uncontrolled changes

**Science** claims to produce knowledge systematically and methodically, which is

- objectively formulated
- free of contradictions
- intersubjective, and
- verifiable

# Basics of Scientific Work

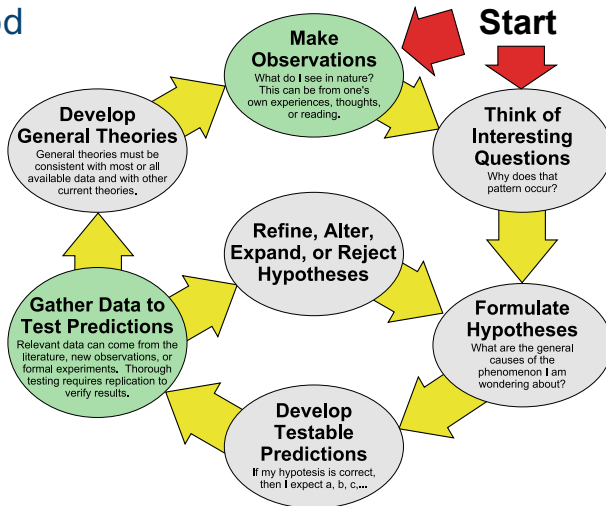
## General working definition for theories (theory in the broader sense)

- a set of interconnected statements, of which at least one non-empty subset refers to empirically testable relationships between variables
- a theory must include at least one empirically testable hypothesis

## Theory in the narrower sense

- more elaborated theories contain (1) **basic assumptions** (assumptions about empirically hard-to-test relationships and definitions of key concepts)
- (2) hypotheses derived from the basic assumptions, as well as rules for measuring variables
- a mathematically formalized theory is called a **model**

# Scientific Method



**Figure:** Based on “The Scientific Method as an Ongoing Process”, ArchonMagnus  
[https://en.wikipedia.org/wiki/Scientific\\_method](https://en.wikipedia.org/wiki/Scientific_method)

# Theory Formation According to Critical Rationalism

## Example in Computer Science

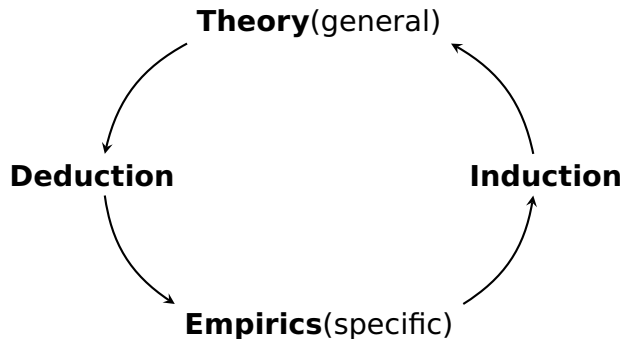
| Step                              | Example (Computer Science)                                   |
|-----------------------------------|--------------------------------------------------------------|
| 0. Question                       | Is Code review beneficial for software quality?              |
| 1. Hypothesis about reality       | “Code reviews improve software quality.”                     |
| 2. Testable hypothesis            | The number of code reviews is correlated to number of bugs.  |
| 3. Testing with data              | Analysis of projects with different review frequencies.      |
| 4. Methodological critique        | Other factors (e.g., team size) might influence the results. |
| 5. Comparison with other theories | Perhaps automated tests are more important for quality.      |

# Exercise: Scientific Method to a CS Problem

## **Group Task** ⌚ 15 Min

- 1 Give an example (e.g. use your thesis) for a CS problem

# Two Central Ways of Scientific Reasoning



## Deduction

- From general to specific

## Induction

- From specific to general

# Deduction and Induction

## Deduction

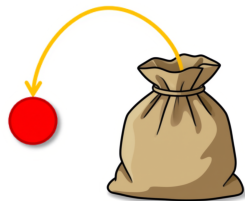
All balls from the bag are red.  
→ The ball is from the bag



**Result:** The ball is red.  
→ **Deduction**

## Induction

The ball is from the bag.  
→ The ball is red.



**Result:** All balls from the bag are red.  
→ **Induction**

# Deduction and Induction

- From the truth of the premises ("It is raining") logically follows the truth of the conclusion ("The ground will be wet").
- Besides deductive inferences, inductive inferences are often drawn.
- Example: From the empirical finding "The ground is wet" it is concluded: If the ground is wet, rain is always responsible.

**Inductive inferences** from individual cases to general cases can be correct but can also be false. Inductive inferences are not truth-transferring.

# Counterexample in Science

- A **counterexample** occurs when an **empirical observation** or an **experiment** contradicts an existing theory.
- This shows that the underlying **assumption** or **theory** is **not universally valid**.
- A single contradictory observation can be sufficient to **falsify** a theory.

## Consequence

If a counterexample is found, then:

→ **The theory or assumption is refuted.**

# What is a paradigm?

# What is a Paradigm?

- Paradigm = Research approaches, ways of thinking
- For example:
  - ▶ Hermeneutics
  - ▶ Empirical and critical rationalism
  - ▶ ...

# Research Paradigms – Hermeneutics

- Focuses on grasping comprehensive contexts
- **Interpretive understanding:**  
Meaning of a word from the sentence → meaning of the sentence from the paragraph → meaning of the paragraph from the chapter → meaning of the chapter from the book (or an era)
- *Knowledge gain* through uncovering meaningful connections

## Hermeneutics – Example “Romeo and Juliet”

- **First impression:** You understand the plot: two young lovers from feuding families, whose love ends tragically.
- **Analysis of individual scenes:** You discuss individual dialogues, for example, the balcony scene. You pay attention to language, style, and emotions.
- **Expansion of understanding:** Through context (e.g., Elizabethan society, family honor, religion), you realize the play is not just a love story but also a critique of societal constraints.
- **Back-reference:** You reread earlier passages and recognize new meanings—such as how Juliet’s language already hints at the tragic ending early on.
- → **Hermeneutic Circle:** Your understanding of the *whole* (the play) changes your understanding of the *parts* (scenes, quotes)—and vice versa.

# Empiricism and Critical Rationalism

## Logical Empiricism

- Only statements that are **empirically verifiable** are considered meaningful
- Knowledge arises through **induction** (from the particular to the general)
- A statement is meaningful only if it is **verifiable**
- **Induction problem:** General statements can never be fully certain, as they refer to future observations

## Critical Rationalism

- Rejection of pure induction as a principle of knowledge
- Knowledge arises through **falsification**: theories must be falsifiable
- Statements can never be finally proven, only **provisionally confirmed**
- Criticism: Makes theory comparison difficult and promotes reduction to measurable variables

## Exercise: Induction and Deduction

### **Group Task** ⌚ 15 Min

- 1 Clarify the differences between the two types of reasoning.
- 2 Provide examples of induction and deduction in small groups.

### **Group Task** ⌚ 15 Min

- 1 Explain the concept of the hermeneutic circle in your own words.
- 2 Apply the hermeneutic circle to an example from your everyday life.

# Discussion

## **Group Task** ⌚ 20 Min

- Share findings from group discussions.
  - ▶ Induction and Deduction
  - ▶ Hermeneutic Circle

# Literature

- [https://de.wikipedia.org/wiki/Hermeneutik\\_\(Methode\)](https://de.wikipedia.org/wiki/Hermeneutik_(Methode))
- [https://de.wikipedia.org/wiki/Kategorie:Wissenschaftliche\\_Methode](https://de.wikipedia.org/wiki/Kategorie:Wissenschaftliche_Methode)