Lecture 2:]
The Research Process
Scientific Reasoning and Paradigms

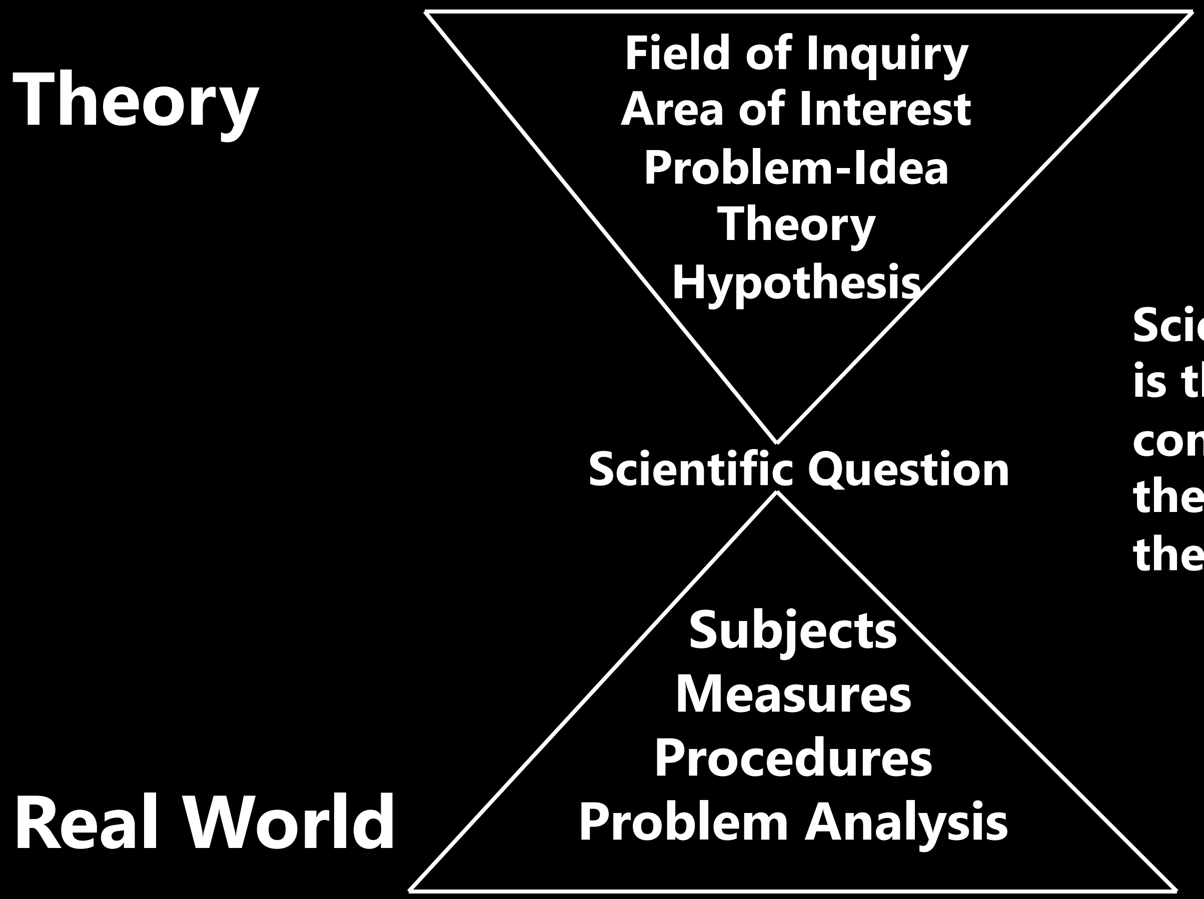
What is science?

Science (from Latin scientia, meaning "knowledge”) is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe.

What is research?

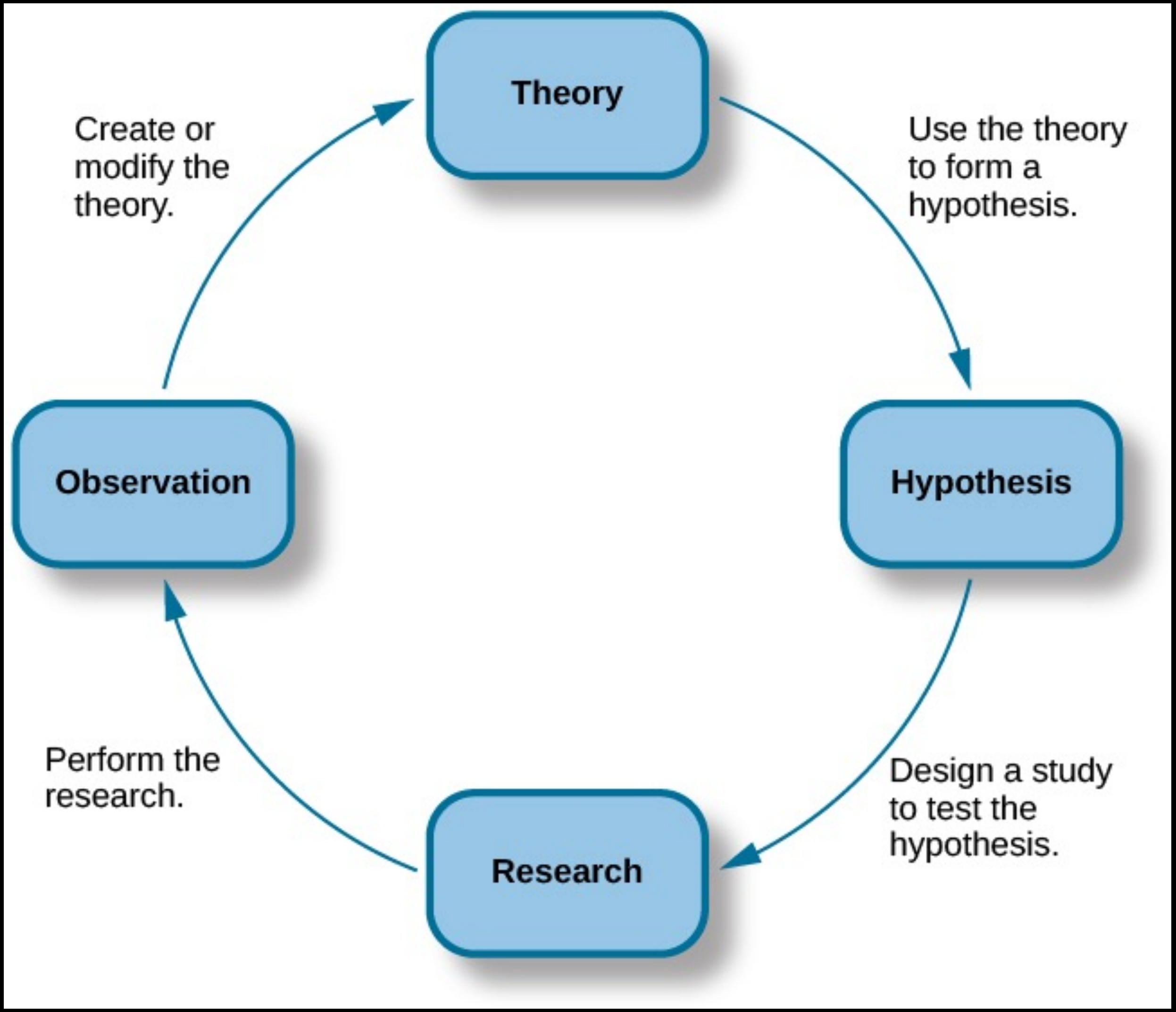
Research is a process to discover new knowledge. It is the systematic investigation to establish facts and reach new conclusions.

Research is a Dynamic Tension Between Theory and Real World



Scientific Question is the point of contact that links theories to the real world.

Research Process

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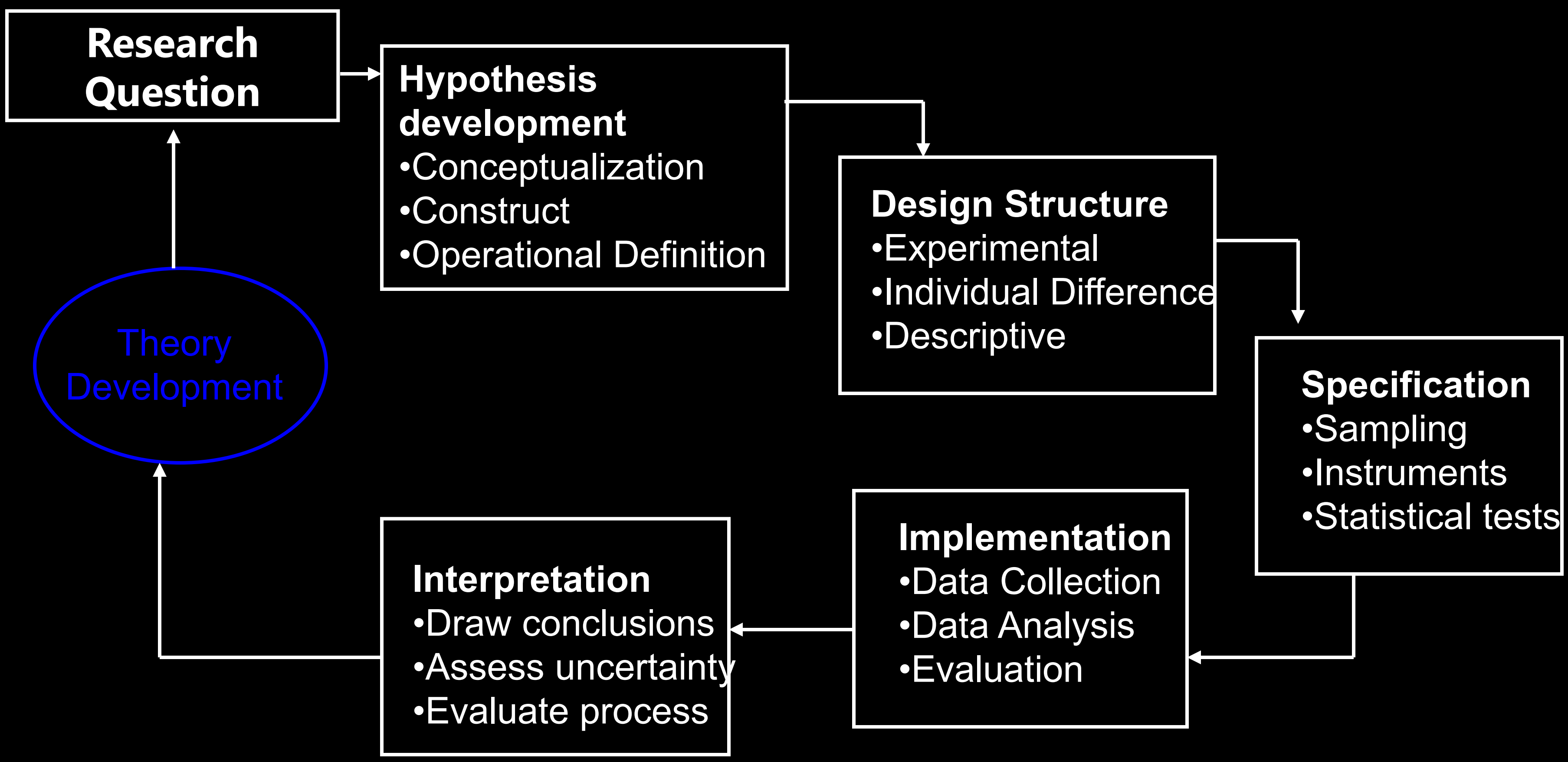
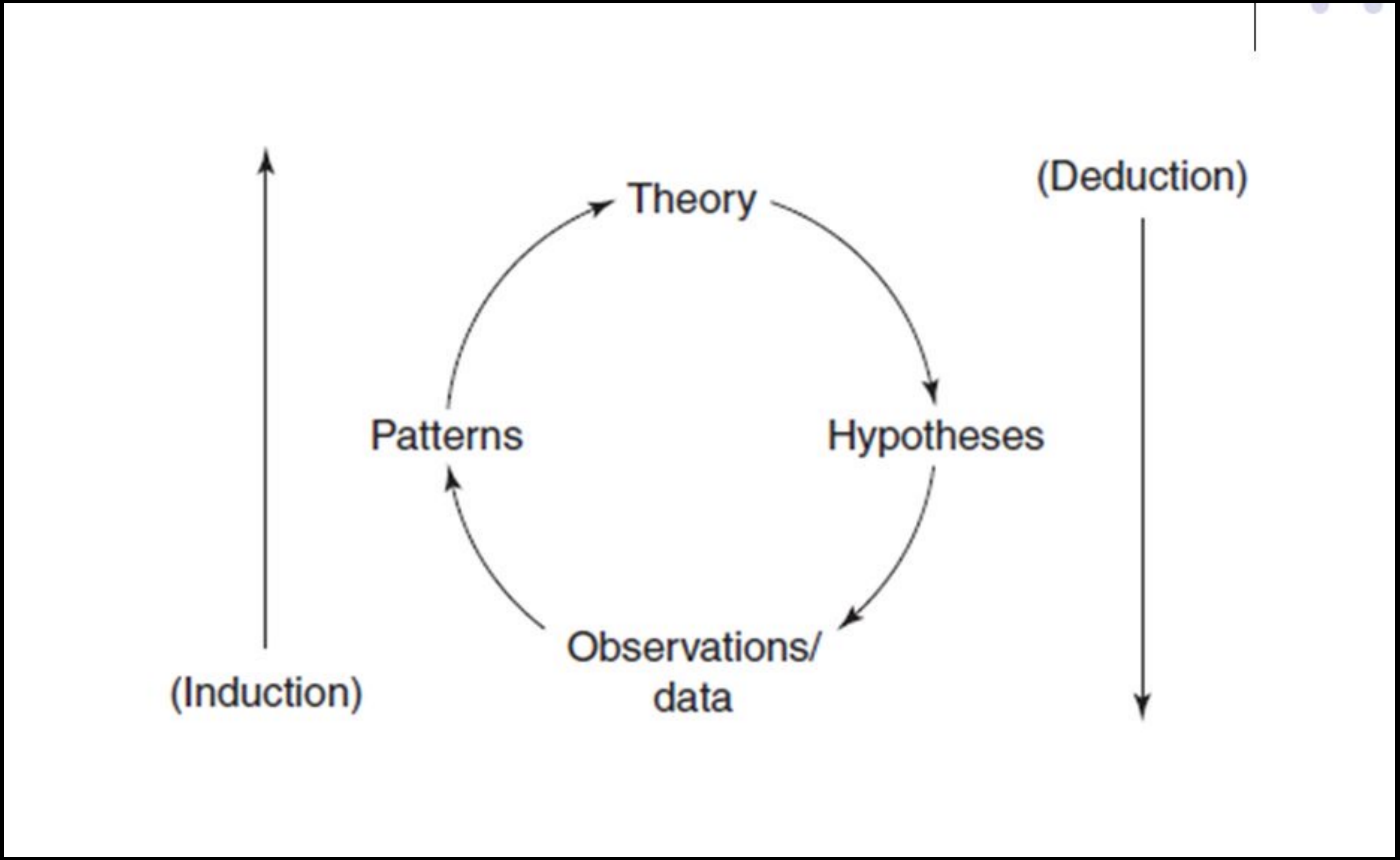
Research Process



Scientific Reasoning



Deduction and induction

- Deduction proceeds from the general case to the specific case: “certain inference”

- Induction proceeds from the specific case to the general case: “probable inference”

Both induction and deduction are used in all models of scientific reasoning, but they receive different emphasis

Statistics

- It is an *inductive process*: we are trying to draw general conclusions based on a specific, limited sample

Advantages of the inductive method

- It emphasizes the link between data and theory
- Explicitly builds and modifies the hypothesis based on previous knowledge
- It is confirmatory (we seek data that support the hypothesis)

Disadvantages of the inductive method

- Considers only a single starting hypothesis
- Derives theory exclusively from empirical observations; “some important hypotheses have emerged well in advance of the critical data that are needed to test them”
- Places emphasis on a single correct hypothesis, making it difficult to evaluate cases in which multiple factors are at work.

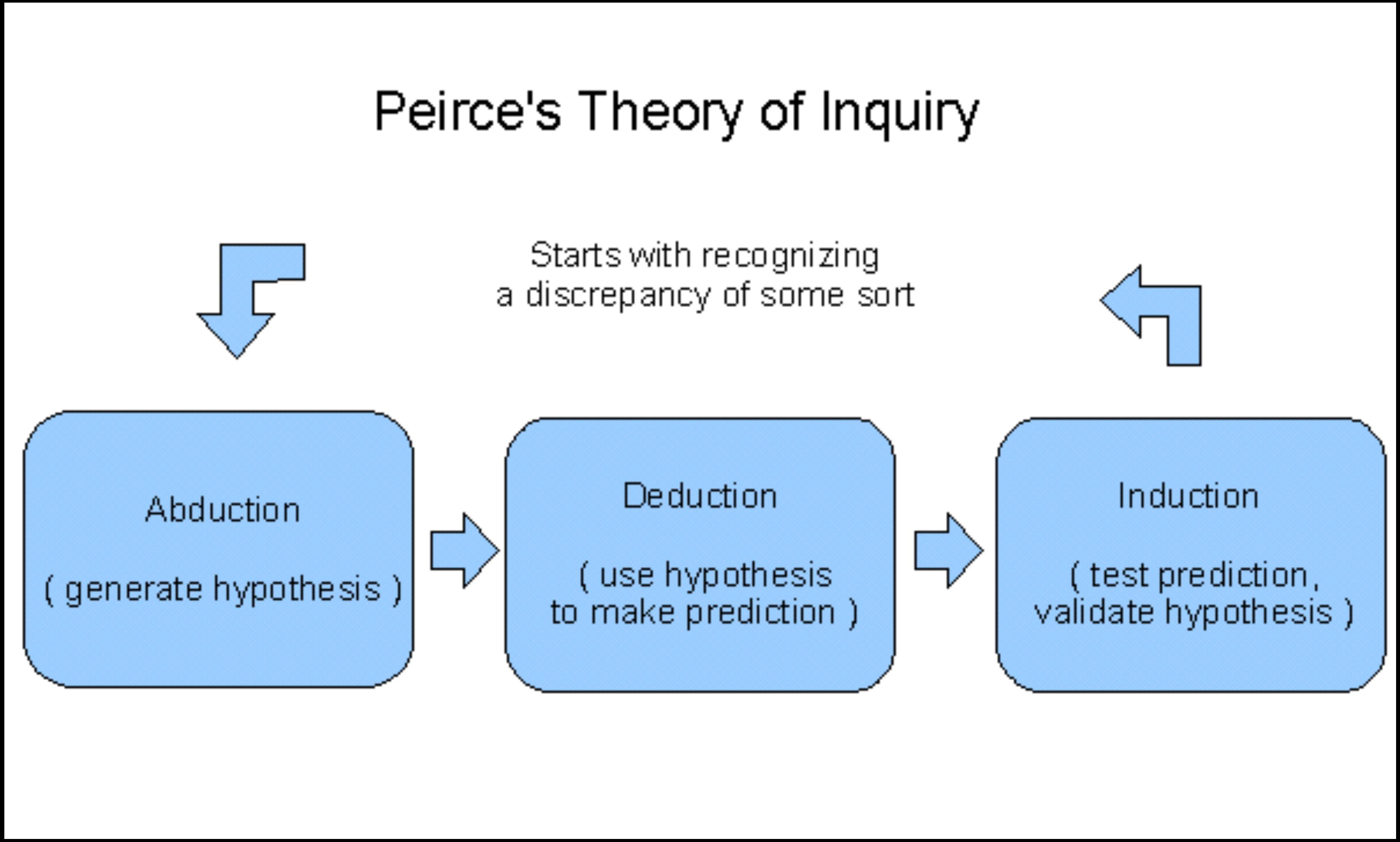
The Hypothetico-Deductive Method

- Championed by the philosopher of science Karl Popper (1902-1994)
- The goal of testing a hypothesis is not to confirm, but to falsify, the hypothesis
- The accepted scientific explanation is the hypothesis that successfully withstands repeated attempts to falsify it

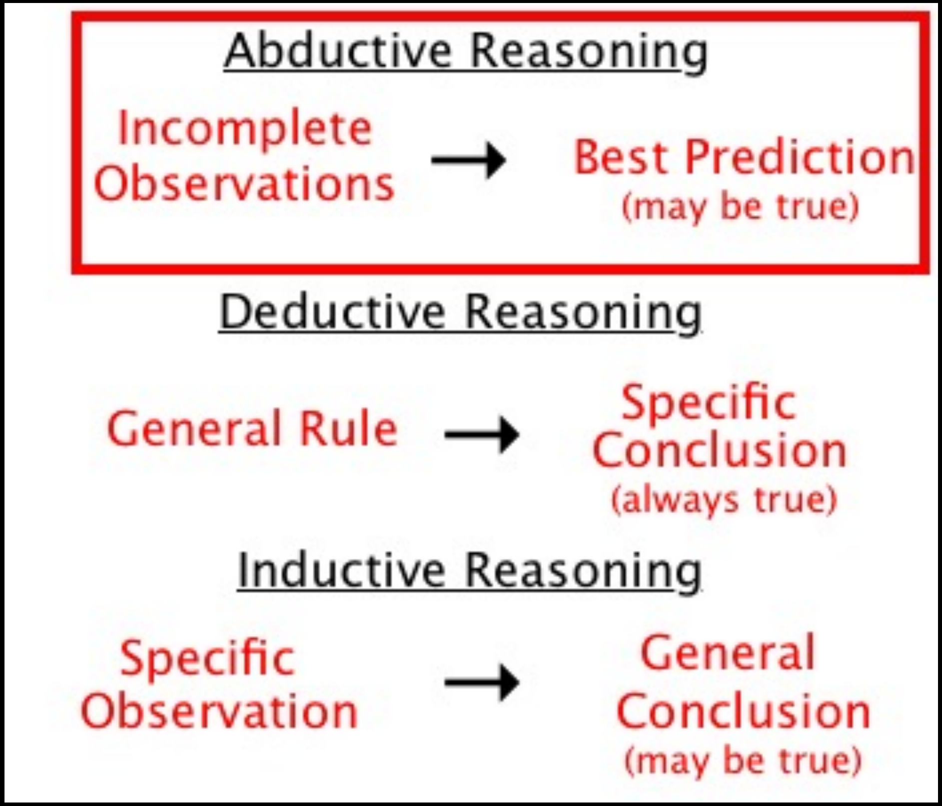
Disadvantages of the Hypothetico-Deductive Method

- Multiple working hypotheses may not always be available, particularly in the early stages of investigation
- Even if multiple hypotheses are available, this approach will not work unless the “correct” hypothesis is among the alternatives
- Places emphasis on a single correct hypothesis, making it difficult to evaluate cases in which multiple factors are at work.

Abductive Reasoning



Abductive Reasoning



Logic	Reasoning	Example
Deductive	Deductive reasoning moves from the general rule to the specific application: In deductive reasoning, if the original assertions are true, then the conclusion must also be true.	Low density cities have relatively higher CO2 emissions. Houston is a low density city. Houston has relatively high CO2 emissions.
Inductive	Inductive reasoning begins with observations that are specific and limited in scope, and proceeds to a generalized conclusion that is likely, but not certain, in light of accumulated evidence. Inductive reasoning moves from the specific to the general.	Houston is a relatively low density city. Houston has relatively high CO2 emissions. Low density cities have relatively high CO2 emissions.
Abductive	Abductive reasoning (also called abduction, abductive inference, or retroduction is a form of logical inference which starts with an observation then seeks to find the simplest and most likely explanation	Low density cities have relatively high CO2 emissions. Houston has relatively high CO2 emissions. Houston is a low density city.

Paradigms in Science

Reality

Reality is merely an illusion, albeit a very persistent one. [Einstein]

Evolution of science

Thomas Kuhn introduced a new conception of the way scientific knowledge evolves

- scientific research not only leads us to revise our conceptions about the world but also radically transforms our methodological and epistemological orientations to nature.

- by historicizing the conception of scientific method he also rendered relative all attempts to logically reconstruct the practice of science and codify it as definitive.

Evolution of science

A number of factors influenced Kuhn's attempt to reorient our understanding of how scientific knowledge evolves

1) what we consider scientific data are crucially shaped by our theoretical conceptions of the world.

2) standards that scientists deploy to compare theories also evolve over time

3) changes in scientific theories often involve radical revisions in the meanings of the terms that scientists deploy

4) there are deep ontological and metaphysical presuppositions that are built into the practice of science

Scientific method

Reason-based theory construction tested by empirical research

The scientific method is often characterized as a cycle:

1. Generate/elaborate a theory
2. Derive a hypothesis (a specific testable statement from the theory)
3. Test the hypothesis against empirical data
4. Feed the results back into the theory (*e.g.*, abandon theory if hypothesis rejected)

Karl Popper *The Logic of Scientific Discovery*, 1959:

- Multiple theories consistent with a given set of information > can't prove a theory right
- We can only prove theories wrong *(falsify*)
- Cycle:
  1. Generate theory
  2. Derive falsifiable statement from the theory
  3. Test the statement
  4. If true, accept the theory **(for now**!)
  5. If false, abandon the theory
- 'Falsification' is critically important: a theory that can't generate falsfiable statements cannot be tested, is not scientific

Paradigms

- Framework for characterizing phenomena that a particular discipline takes as its subject matter
- General (meta) theory that instructs how scientific theories or models are to be developed and applied in further research

Paradigms (Thomas Kuhn, 1962)

- Paradigms: higher level bodies of theory within which substantive theories are situated
- Individual theories are tested against data, results feed back into the paradigm
- Theories which don't fit the paradigm are suspect even before testing
- As new information becomes available, a paradigm may still be used until it is superseded by a competing paradigm

Paradigms (Thomas Kuhn, 1969)

1. Paradigms as Exemplars

   Among the numerous examples of paradigms Kuhn gives are Newton's mechanics and theory of gravitation, Franklin's theory of electricity, and Copernicus' treatise on his heliocentric theory of the solar system.

2. Paradigms as Disciplinary Matrices

   A disciplinary matrix is an entire theoretical, methodological, and evaluative framework within which scientists conduct their research. This framework constitutes the basic assumptions of the discipline about how research should be conducted and what constitutes a good scientific explanation.

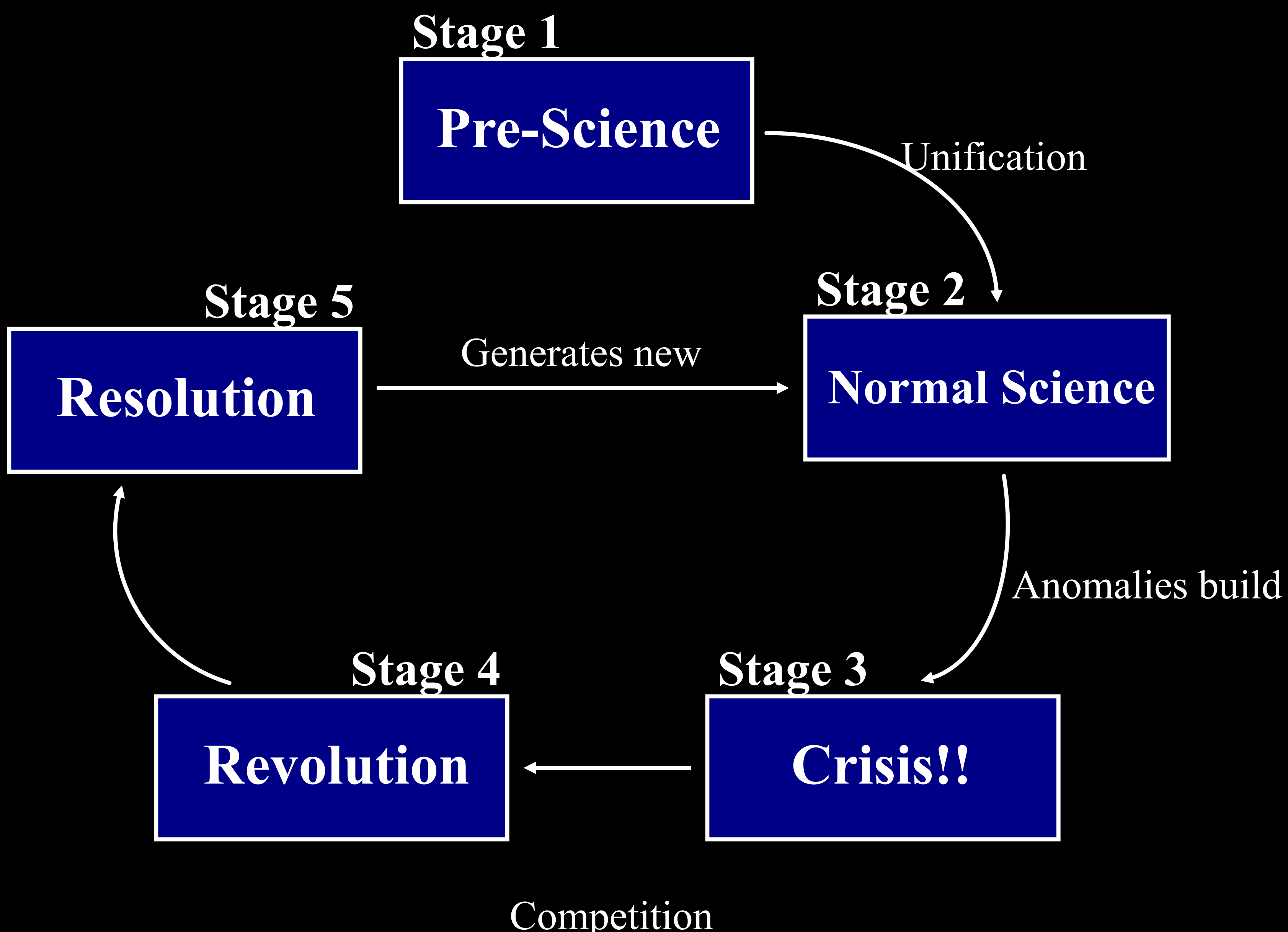
How do paradigms contribute to scientific inquiry?

- General theoretical assumptions
-
- Methodological techniques
- Standards for research
- Unresolved problems

Advantages of paradigms

- First they preclude the need for each researcher to work in isolation and build anew from new principles, data, instrumentation etc.
- Secondly the paradigm guides researchers in the identification of the relevant facts for the discipline - there is no danger of being overwhelmed by a morass of data as often happens in the case of craft knowledge like that of medicine
- Finally paradigms also allow for long term esoteric commitments in research. Fact collection and theory articulation could become directed activities.

Development of a paradigm



1. Pre-science or Immature Science

- Scientific activities not guided by generally accepted paradigm
- Number of competing schools of thought
- Disagree about theory and what constitutes observational phenomena

2. Normal Science

- One school of thought adopted
- Unites scientific community into one research program
- Extension of theory and method to other problems or content areas

3. Crisis of a paradigm

- Unsolved problems or anomalies build up over course of application

- Increasing number of anomalies and reduced rate of progress builds concern of effectiveness of paradigm

- Scientists begin to doubt future potential of paradigm = relaxation of rules

4. Revolutionary Science

- Active struggle between defenders of old paradigm and proponents of new paradigm

- Each one tries to solve the greatest number of anomalies

- Incommensurability = inability to directly compare theories\methods because of different paradigms

5. Resolution

- One paradigm becomes dominant
- Generates new period of Normal Science (Stage 2)
- Because of incommensurability, choice between paradigms is fundamentally not rational, but matter of subjective preference

Main Components of a Paradigm

- Ontology – concerned with being or reality
- Epistemology – The branch of philosophy concerned with the origin, nature, methods & limits of knowledge
- Methodology refers to general principleswhich underline how we investigate thesocial world and how we demonstrate thatthe knowledge generated is valid.

Comparing paradigms

- Ontology: the nature of the "reality.” What is real?
- Epistemology: validation of knowledge claims: the relationship of the "knower" to what is "knowable." How do we know what we know about the world around us?
- Methodology: how we know what we know; what ways we think are legitimate for generating knowledge
- Causality: the possibility of causal linkages, distinction between cause and effects
- Neutrality: the role of value, degree of subjectivity

Elements	Positivism	Post Positivism	Critical Theory	Constructivism
Ontology	Naïve realism—“real” reality but apprehend able	Critical realism—“real” reality but only imperfectly and probabilistically apprehend able	Historical realism—virtual reality shaped by social, political, cultural, economic, ethnic, and gender values; crystallized over time	Relativism—local and specific constructed realities
Epistemology	Dualist/ objectivist; findings true	Modified dualist/ objectivist; critical tradition/community; findings probably true	Transactional/ subjectivist; valuemediated findings	Transactional/ subjectivist; created findings
Methodology	Experimental/ manipulative; verification of hypotheses; chiefly quantitative methods methods	Modified experimental/ manipulative; critical multiplism; falsification of hypotheses; may include qualitative	Dialogic/dialectical	Hermeneutical/ dialectical

Elements	Positivism	Post Positivism	Critical Theory	Constructivism
Nature of knowledge	Verified hypotheses established as facts or laws	Non falsified hypotheses that are probable facts or laws	Structural/historical insights	Individual reconstructions coalescing around consensus
Inquiry aim	Explanation	Prediction and control	Critique and transformation, restitution and emancipation	Understanding; reconstruction
Knowledge Accumulation	Accretion – "building blocks" adding to "edifice of knowledge"; generalizations and cause-effect linkages		Historical situatedness; generalization by similarity	More informed and sophisticated reconstructions, vicarious experience
Goodness or quality criteria	Conventional benchmarks of "rigor" internal and external validity, reliability and objectivity		Historical situatenedness; erosion of ignorance and misapprehensions, action stimulus	Trustworthiness and authenticity
Values	Excluded – influence denied		Values Included	

Pragmatism

- Pragmatism as a philosophical movement began in the United States in the 1870s. Its direction was determined by The Metaphysical Club members Charles Sanders Peirce

- Theory and practice are not separate spheres; rather, theories and distinctions are tools or maps for finding our way in the world. John Dewey: “there is no question of theory versus practice but rather of intelligent practice versus uninformed practice.”

Pragmatism and Science

- The method of science is an experimental method, and the application of the pragmatist maxim reveals how hypotheses can be subject to experimental test

- A knower is an agent, who obtains empirical support for her beliefs by making experimental interventions in her surroundings and learning from the experiences that her actions elicit.

Theory and Practice

- All the pragmatists, but most of all Dewey, challenge the sharp dichotomy that other philosophers draw between theoretical beliefs and practical deliberations.
- All inquiry is practical, concerned with transforming and evaluating the features of the situations in which we find ourselves.

Pragmatic-Strategic View

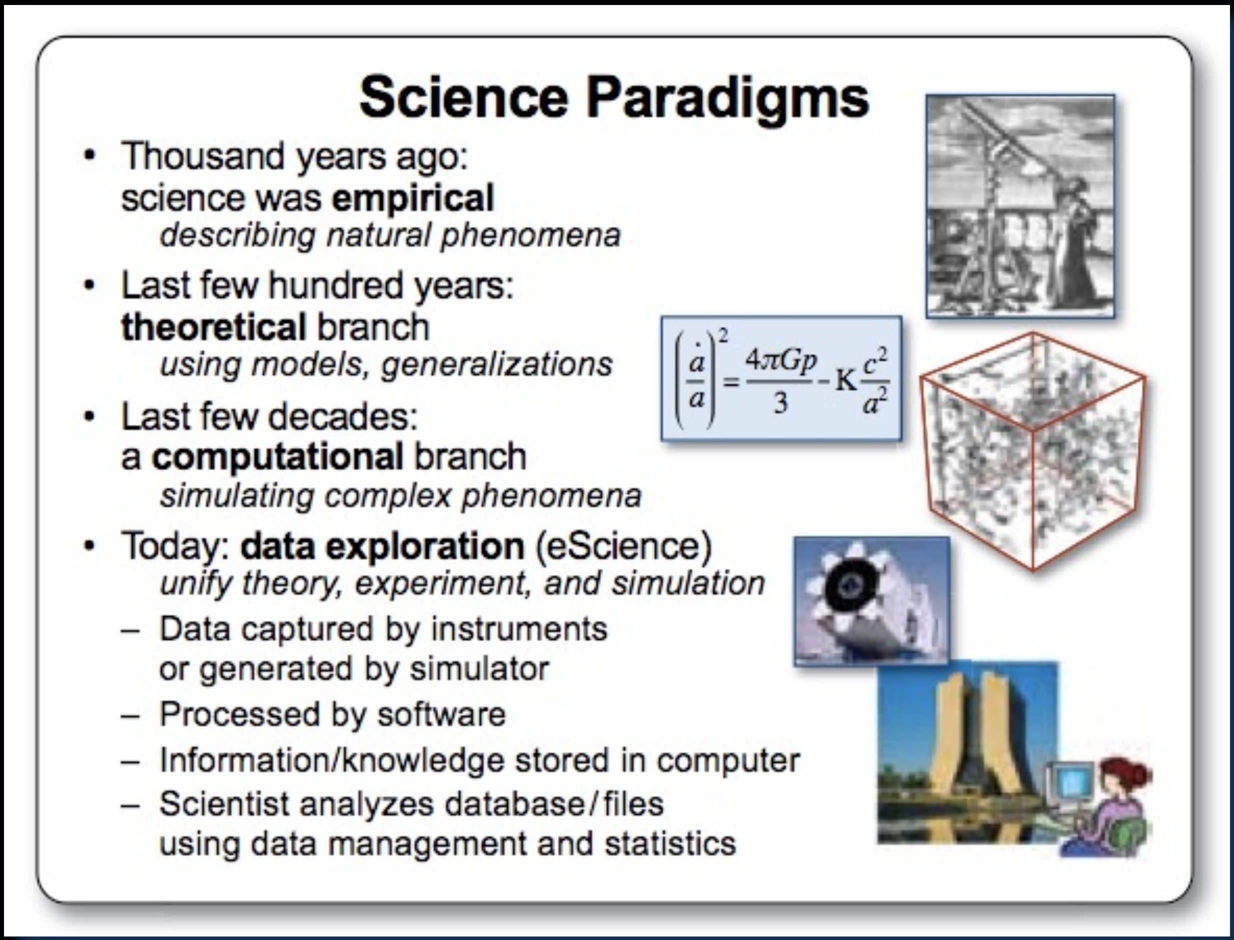
- A broad range of theoretical and methodological choices and their integration in a dialectic manner produces the riches results of inquiry.

- Alternative paradigms are useful to understand different aspects and objectives of research and accordingly select appropriate methodologies.

- Postmodern critique is an indispensable starting point for critical evaluation of our assumptions about the production of knowledge, but offer few clues about how to do work.

- The usefulness of a positivist epistemology lies in the pragmatic assumption that there is a world out there that can be observed and measured in a way that approximate the truth.

Jim Gray's four scientific paradigms / branches



 Jim Gray's The Fourth Paradigm: Data-Intensive Scientific Discovery.

1. empiricism
observe phenomenon and attempt to classify
Ptolemy's universe of concentric spheres

2. theory
describe above classifications with mathematical models
Newtonian/Einsteinian gravity

3. computation
build `virtual' physical systems via solution of math models
Cosmic structure formation

4. data-driven synthesis (?)
unite empirical, theoretical and computational branches with data (X-info and Comp-X)
Matter/energy content of the universe

Does Big Data means the end of “Theory”?

This is a world where massive amounts of data and applied mathematics replace every other tool that might be brought to bear. With enough data, the numbers speak for themselves.

(C. Anderson, 2008)

Scientists no longer have to make educated guesses, construct hypotheses and models, and test them with data-based experiments and examples. Instead, they can mine the complete set of data for patterns that reveal effects, producing scientific conclusions without further experimentation.

(M. Prensky, 2009

The illusion of a new empiricism?

- big data can capture a whole domain and provide full resolution;
- there is no need for a priori theory, models or hypotheses;
- through the application of agnostic data analytics the data can speak for themselves free of human bias or framing, and any patterns and relationships within big data are inherently meaningful and truthful;
- meaning transcends context or domain-specific knowledge, thus can be interpreted by be interpreted by anyone who can decode a statistic or data visualization.

(R. Kitchin, 2014)

An Alternative Approach

- A view of big data and analytics as a positive contribution to scientific practice without considering them as a oracle or a conclusive solution.
- Data-driven science as a hybrid combination of abductive, inductive and deductive approaches to advance the understanding of a phenomenon.
- It forms a new mode of hypothesis generation before a deductive approach is employed.
- The epistemological strategy adopted within data-driven science is to use guided knowledge discovery techniques to identify potential question (hypotheses) worthy of further examination and testing.

(R. Kitchin, 2014)

Relating paradigms to types of research

The choice of research format (exploration/formulative, description/descriptive, and explanation/experimental) depends upon three general factors:

1) the type of research question proposed

2) the extent of control a researcher has/desires over the actual behavior or events under study, and

3) the degree of focus on contemporary as opposed to historical phenomenon.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