

Elements of Disciplines: Natural Sciences

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- Basic Concepts/Phenomena
- Biology
    - Species taxonomies; nature, interrelationships and evolution of organisms, health, nutrition
  - Chemistry
    - Periodic table of elements
  - Mathematics
    - Logic of numbers, stats, computer simulation
  - Physics
    - Subatomic particles, nature of matter & energy and their interactions

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- Problem Solving Approach
- Describe the problem
    - Context, conditions, facts, assumptions, goal
  - Select relevant information
    - Usually objective, empirical, observable
  - Problem representation
    - Math, symbols, diagrams...
  - Inferring
    - Hypothesis based on available information
  - Synthesizing
    - Combining observations, insights to form a coherent whole
  - Verifying
    - Through experimentation, modeling, etc.

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### Modes of Inquiry

- Biology
  - Experiments (laboratory and field) using experimental design and data analysis either under controlled (laboratory) or naturalistic (field) environments
- Chemistry
  - Lab experiments, data collection in the field, computer simulations - understand macroscopic properties in terms of atomic and molecular behavior
- Mathematics
  - Rationalism (truth via logic and reasoning)
- Physics
  - Empirical, rational, experimental (observation and experimentation). Theoretical – use mathematical modeling. Experimental – experiments and computer simulation

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### Categories of Empirical Research

- Descriptive
  - Qualitative Research
    - Carefully describe behavior
    - Explanation of behavior is not a goal
- Relational
- Explanatory
- Basic / Applied
- Field / Laboratory

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### Relational Research

- Two or more variables are measured and related to each other
  - Causal-comparative, correlational
- Relationship
  - Existence
  - Pattern
  - Strength
- Observation
  - “Increases in air pollution are associated with increases in air temperature”

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### Explanatory Research

- Focuses on identifying the causes of phenomenon
- Manipulating/ modeling conditions believed to be responsible for behavior
- “What is the difference between the thermal properties of carbon dioxide compared to air?”

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### Basic vs. Applied Research

- Basic research
  - Generates knowledge about phenomenon
  - “How do gecko feet stick to walls?”
- Applied Research
  - Solves practical problems in the real world
  - Builds on basic research
  - “How can I make a robot that can climb walls?”

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### Basic and Applied Research

- Geckos
  - How do they run up walls?
- Researchers
  - Examined foot structure
    - Thousands of microhairs
  - Examined footprints
    - Presence of phospholipids
- Application
  - Wall climbing robots
  - Adhesives

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### Field vs. Laboratory Research

- Laboratory research
  - Occurs in the laboratory
  - More control
    - Greater ability to examine cause-effect relationships
- Field research
  - Occurs in naturalistic settings
  - Observe phenomena in natural context

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### Assumptions Across Sciences

- Biology
  - **Deductive reasoning + falsification** is superior to **description** and **inductive reasoning**
- Chemistry
  - Function of whole is reducible to properties of its constituents and their interactions
- Mathematics
  - Assumptions (axioms) form starting points for **logical proofs** of theorems.
- Physics
  - Finite set of laws that governs the behavior of the universe. Can be discovered **objectively**

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### Fundamental Assumptions of Science

- Determinism
- Inductive & Deductive Reasoning
- Empiricism/Operationalism
- Falsifiability

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## Determinism

- Assumption that all events have causes
  - Understanding causes allows us to predict events
- Critical assumption when engaging in science
- Does not require abandoning belief in free will
  - Free will is actually meaningless without determinism

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Empiricist



Rationalist

- **Empiricism:** phenomena investigated by careful, objective observation
- **Rationalism:** phenomena understood by careful thought, and logical proof

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## Rationalism

- Use individual powers of pure reason and logic
- Deductive reasoning
  - Beliefs are deducted from prior assumptions according to rules of logic
    - Main method in math
  - Can take the form of a syllogism

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## Logical Syllogism

- True Premises
  - Premise: All humans are mortal;
  - Premise: I am a human;
  - Conclusion: Therefore, I must be mortal



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## Inductive Reasoning

- Use observations or information
  - Draw inferences or conclusions
- Possible to create new knowledge
- Often takes the form of an analogy
  - Powerful reasoning tool



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## Empiricism

- Learning through direct observation and experience
- Can use other's observations if trustworthy
- Empirical evidence
  - Often the cornerstone of solid argument

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### Asking Empirical Questions

- What is an empirical question?
  - Answered through systematic observations
  - Precise
    - Allow specific predictions
- Operationalize terms
  - Defined in terms of a set of operations to be performed
    - Strict definition

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### Operationalizing Terms

- Strict definition
  - Based on set of operations/procedures
- Works well for basic sciences
  - [Weight](#)
- Causes problems for social sciences
  - Creates arbitrary limitations on concept
    - “Creativity”

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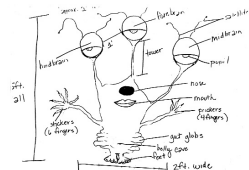
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### Operational Definitions: Social Science Example

- Links concepts to measurable, observable events
- Creativity
  - # Ps drawing animals with the same features
  - Rating scale
  - # Features shared by earth animals




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## Theories

- Theory
  - **Set of logically consistent statements about a behavioral phenomena**
- Can be derived from observation
  - **Tentative first step**
- Can be derived from experimental data
  - **Many experiments**
  - **Theory explains the whole set of data**

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## Characteristics of Theories

- Summarize empirical knowledge about a phenomena
- Organizes the knowledge
- Provides a tentative explanation for phenomena
- Serves as a basis for making predictions about behavior

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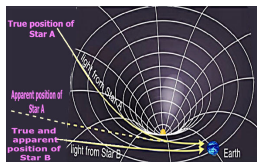
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## Falsifiability

- Theory must make falsifiable predictions
- Predictions must be specific
  - **Predict what should happen**
  - **Predict what should not happen**



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## The Freedom to Make Mistakes

- Falsifiability allows mistakes
- Falsification of predictions is progress
  - **Used to adjust theories**
  - **Theories accord more closely with data**
    - **Better reflect the nature of the world**
- Driving force in the evolution of a theory

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