Logical Basis of Hypothesis Testing in Scientific Research

A logic primer to accompany Giere 1984, chapter 6

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1. LOGIC: THE STUDY OF ARGUMENTS

Logic: the study of methods and principles used to distinguish good (correct) from bad (incorrect) reasoning.

Argument: a set of statements (propositions) divided into two parts, (1) the **premises**, and (2) the **conclusion**, in which the premises are the statements from which the conclusion follows.

An **argument** must meet 2 conditions to **justify** believing the conclusion:

(1) the premises themselves must be justified

(2) their must be sufficient connection between the premises and conclusion

Inductive vs deductive arguments

deductive arguments:	truth preserving; conclusions contain less information than premises
inductive arguments:	knowledge expanding; conclusions contain more information than premises

2. DEDUCTIVE ARGUMENTS (TRUTH PRESERVING)

Deductive Argument: an argument in which the premises claim to support the conclusion in such a way that, if the premises are assumed to be true, then it is impossible for the conclusion to be false.

Take general principles and determine what would happen under specific conditions
Premises provide conclusive grounds for the truth of the conclusion.

Valid / Invalid

Valid argument: a deductive argument in which the premises support the conclusion in such a way that, if the premises are assumed to be true, then it is impossible for the conclusion to be false.

Invalid argument: a deductive argument such that, if the premises are assumed to be true, then it is possible for the conclusion to be false.

Sound / Unsound

Sound argument: a deductive argument that: (1) is valid **and** (2) has all true premises.

Deductively Valid (DV) Argument:

Truth preserving: If the premises are true the conclusion **must** be true. Impossible for the premises to be true and the conclusion false. Deductively valid arguments can have false premises (but conclusion will be false).

Erosion proof: if new premises are added to a valid deductive argument and none of the original premises are changed or deleted the argument remains valid.

All or nothing: deductive validity is all or nothing; it does not come in varying degrees.

Examples of DV arguments:

All humans are mortal	Insects always have 6 legs
I'm human	Maggots don't have 6 legs
Therefore, I'm mortal	Therefore, maggots are not insects

3. INDUCTIVE ARGUMENTS (KNOWLEDGE EXPANDING):

Inductive argument: an argument in which the premises claim to support the conclusion in such a way that, if the premises are assumed to be true, then (based on that assumption) it is probable that the conclusion is true.

Characteristics of inductive arguments:

Not necessarily truth preserving
Use specific cases to arrive at general principles.
Premises provide some support for the conclusion.
Inductive arguments are neither "valid" or "invalid," but rather "strong" or "weak" (a matter of degree).
Not erosion proof: new premises may completely undermine a strong inductive argument

Strong / Weak Inductive Argument:

Strong Inductive Argument: The premises support the conclusion in such a way that, if the premises are assumed to be true, then (based on that assumption) it is probable that the conclusion is true (it is, however, possible for the premises to be true and conclusion false).

Weak Inductive Argument: An inductive argument such that, if the premises are assumed to be true, then (based on that assumption) is <u>not</u> probable that the conclusion is true.

Cogent / Uncogent Argument:

Cogent argument: an inductive argument that: (1) is strong **and** (2) has all true premises.

Example of Strong Inductive Argument:

All known planets are round.
Therefore, all planets are **probably** round.

4. EXAMPLES OF DEDUCTIVE AND INDUCTIVE ARGUMENTS

Deductive Arguments

All acoustic neuromas are benign.
John's tumor is an acoustic neuroma.
So, John's tumor is benign.

Either the battery is dead or there is an electrical short.
The battery is not dead.
Therefore, there is an electrical short.

All wapiti are ungulates.
All ungulates have hooves.
Thus, wapiti have hooves.

If I were Harrison Ford, then I would be rich and famous.
I am not rich and famous.
Therefore, I am not Harrison Ford.

Inductive Arguments

Most politicians are extroverts.
Bill Clinton is a politician.
Thus, Bill Clinton is an extrovert
(premises claim to provide strong but not necessary support for the conclusion)

All swans I have seen in the past have been white.
It follows that the next swan I see will be white.
(inductive prediction)

All floppy disks I have examined in this shipment are defective.
So, it is likely that the entire shipment is defective.
(inductive generalization)

Neon has unstable isotopes.
Argon is similar to neon in many ways.
Therefore, argon probably has unstable isotopes also.
(inductive: argument by analogy).

5. THE LOGICAL BASIS OF HYPOTHESIS TESTING (GIERE, CHAPTER 6)

Scientific Inquiry: attempts to provide good justification for believing a hypothesis is true or false.

Theoretical Model: a generalized explanation of observed phenomena.

Theoretical Hypothesis: a contingent statement asserting that some real system corresponds to the theoretical model.

Hypothesis: contingent statement that is treated as the object of research

Hypotheses are logically justified by exhibiting them as conclusions of appropriate arguments.

premises: **B**ackground
Initial conditions (**IC**)
Outcome of experiment (**P**rediction or its negation)

conclusion: the **H**ypothesis

If(Not **H** and **IC** and **B**), then very probably Not **P**
P and **IC** and **B**
Thus (inductively), **H**

An **argument** must meet 2 conditions to **justify** believing the conclusion (hypothesis):

(1) the premises (assumptions, experimental/initial conditions must themselves be justified.

(2) there must be sufficient connection between the premises and conclusion

Giere's 3 criteria of **good test** provides the basis for judging this connection.

1) prediction is deducible from the hypothesis together with the initial conditions.
2) prediction is improbable when considered out of context from hypothesis
3) prediction is verifiable

The **experiment** determines the truth and falsity of the **prediction**.

If the prediction is successful the hypothesis is justified.
If the prediction fails the hypothesis is refuted.

6. THE JUSTIFYING ARGUMENT (INDUCTIVE; USED IF THE PREDICTION IS FOUND TO BE TRUE)

If **I**nitial **C**onditions (are true) but not **H**ypothesis, then **very probably** not **P**rediction
Initial Conditions (are true) and Prediction (is true)
Thus, very probably Hypothesis (is true)

Example of justifying argument:

Theoretical hypothesis: Insects always have 6 legs

Premise:	All creatures with 3 body parts are insects (assumption)
Prediction:	Each individual captured will have 6 legs
Premise:	They all have 6 legs (prediction true)
Conclusion:	Insects probably always have six legs

Induction is the weak link in science.

Science can not prove anything to be true with absolute certainty (just ask any tobacco company).

The strength of justification is directly proportional to the **improbability** of the prediction.

For science to be advanced by the **justifying argument** requires that hypotheses make and stand up to "bold conjectures."

The ideal prediction is not consistent with any other conceivable explanation.

Dare to put your hypothesis on the line!

7. THE REFUTING ARGUMENT (DEDUCTIVE LOGIC; USED IF PREDICTION IS FOUND TO BE FALSE)

If **H**ypothesis and **I**nitial **C**onditions (are true), then the **P**rediction (is true).
Initial **C**onditions (are true) but not **P**rediction.
Thus, hypothesis not true.

If(**H** and **IC**), then **P**.
Not **P** and **IC.**
Thus, Not **H**.

If the premises are true, and the prediction is false, then the hypothesis must be false.

Example of refuting argument:

Theoretical hypothesis: insects always have 6 legs

Premise:	Insects beget other insects (assumption)
Prediction:	Fly larvae will have six legs
Premise:	Maggots don't have 6 legs (prediction false)
Conclusion:	Insects don't always have six legs (conclusion: reject hypothesis)

The Power of Falsification:

It takes only one case to falsify a theoretical hypothesis.

Based on the result of this experiment, we modify, restrict the domain of, or replace the hypothesis, and test again (e.g. All insects have 6 legs in at least one life stage).

By falsifying alternative explanations, science moves closer to truth.