The Elements of Science

Reminder: Register your Clicker

- In order to earn points for your i>clicker responses, you must register your i>clicker online (but don't worry, you will still get the points from before registration).
  - Go to www.iclicker.com/registration
  - Fill in:
    - your name
    - your PID (student ID) number
    - your clicker ID (located on the back of your clicker, below the scan code)
  - click ENTER

What Do Scientists Do?

- One proposal: Scientists observe what happens in the world
  - Mendel observed a pattern in the inheritance of traits in peas
  - Halley observed a pattern in the occurrence of a comet
- But they do much more: they attempt to **explain why** things happen
  - Mendel proposed factors which accounted for traits
  - Halley proposed an orbit for a comet

Hypotheses and Theories

- A hypothesis is a conjecture about the way some phenomenon in the world is or behaves
  - Malaria is transmitted by mosquitoes
  - Mental imagery uses the same brain processes as perception
- A theory is a systematic set of hypotheses
  - Newton's theory of motion
  - Freud's psychodynamic theory
  - Darwin's theory of evolution

It is just a theory!?

- Hypotheses and theories range from conjectures or guesses to well-substantiated proposals
  - When first proposed, most hypotheses are conjectures or proposals—guesses as to how things might be
  - What matters is whether *appropriate* evidence can be marshaled for them
- Hypotheses and theories that were once well-substantiated may turn out to be false!
  - The theory that the sun circled the earth was once very well supported
- Because hypotheses and theories go beyond the evidence, they always risk being falsified by future evidence

Clicker Question

How does a theory differ from a hypothesis?

A. A theory is true whereas a hypothesis is just a guess.
B. A hypothesis is a structured set of theories.
C. A theory is a systematic set of hypotheses.
D. A hypothesis is true whereas a theory is just a guess.

Predictions and Explanations

- We value hypotheses and theories because they give us power and satisfy our curiosity
- **Predictions**—specific detectable phenomena which we can infer from a hypothesis and to which the hypothesis is committed (false predictions count against the truth of a hypothesis)
  - From the hypothesis that mosquitoes transmit malaria, we predict that if we eliminate mosquitoes we will stop the spread of malaria
- **Explanations**—enable us to understand why something happens and often to alter it
  - From the hypothesis that a disease is produced by a vitamin deficiency, we can figure out how to treat that disease

Representations and Phenomena

- Although it is the phenomenon in nature that interest us, we understand it by re-presenting it to ourselves
- Representations are particularly important when our hypotheses and theories go beyond what we can observe to posit factors responsible for what we observe
  - Words and sentences provide one way of representing
  - Diagrams provide another
  - Sometimes physical models are used
- All representations emphasize some features of the phenomena and distort others
  - True of English as well!

Statements: Atoms of representation

- A statement is a sentence that has a truth value—it is either true or false (even if we do not know which)
  - Today is Saturday
  - A woman will be President of the US in 2020
  - DNA is found in the nucleus
- A statement has an internal structure (subject, predicate, etc.), but for our purposes we will not go inside of a statement.
  - We will treat statements as atoms (indivisible)

Combining Statements

- While we won't divide them, we can combine them using connectives such that the truth value of the compound is determined solely by the truth value of the components
  - AND: true when both components are true
  - OR: true when at least one of the components are true
  - IF, THEN: true unless the first component is true and the second false
  - NOT: true if the component is false

Clicker Question

What is the distinctive feature of a statement?

- A. It reports the facts.
- B. It has one subject and one predicate.
- C. It has a truth value.
- D. It is written on paper.

Types of statements

- Contingent statements: whether they are true or false depends upon the truth value of their components

- Contradictions: false no matter what the truth value of the component statements are

- Tautologies: true no matter what the truth value of the component statements are
  - Definitions: stipulate that the two components have the same truth value
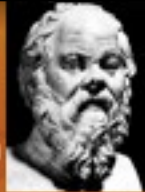
Clicker Question

The sentence

My name is Bill but Bill is not my name

is an example of

    A. A contingent statement

    B. A contradiction

    C. A command

    D. A tautology

Definitions: Important But Overrated!

- Definitions attempt to provide the necessary and sufficient conditions for being an instance of a word
- Example: an odd number is a positive integer that is not divisible by two without remainder
- A necessary condition is a condition which must be met for something to be an instance of the term
  - Being an positive integer is necessary for being an odd number
- A sufficient condition is one which suffices for being an instance.
  - Being both a positive integer and not being divisible by two is sufficient for being an odd number
- Sufficient conditions are especially interesting when there are different ways of satisfying a term: different ways that suffice to be a U.S. citizen

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Trying to define ordinary terms

- Necessary and sufficient conditions can generally only be provided for technical terms (e.g., in mathematics or in legal contracts)

- Most ordinary terms defy such definition: For any attempted definition, a counter-example can be found

- A counter example is either
  - An example that fits the definition but we would not count as an instance of a term

  Or

  - An example that does not fit the definition but we would count as an instance of a term

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Define *game*

Define *bird*

Flying: Not all birds fly (and most insects do)

Feathers: is everything with feathers a bird?
  Caudipteryx, Microraptor seem to have had feathers but are not birds

The case of color terms

- Central colors: red, blue, green, etc.

- Although many others have names, they are longer, and not well known

- Boundaries less important than focal instance

Doing without definitions

Using examples and similarity: start with typical cases

Robin   Chickadee   Blue jay   Finch

Extend to unusual cases

LEWIS CARROLL, *Through the Looking Glass*

"I don't know what you mean by 'glory'" Alice said.

Humpty Dumpty smiled contemptuously. "Of course you don't — till I tell you. I meant 'there's a nice knock-down argument for you!'"

"But glory doesn't mean 'a nice knock-down argument,'" Alice objected.

"When *I* use a word," Humpty Dumpty said, in a rather scornful tone, "it means just what I choose it to mean — neither more nor less."

"The question is," said Alice, "whether you can make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master — that's all."

Words have history
But are open-ended

"The words and phrases used by men and women throughout the ages are the loveliest flowers of humanity… the whole past from the time when the word was coined is crystallized in it; it represents not only clear ideas, but endless ambiguities."

- GEORGE SARTON (1952) *A History of Science*, Preface

Defining Argument

- While this picture may represent what we typically call an argument

- For our purposes we will offer a specific definition
  - This is common in academic fields
    - Define terms for their own purposes, leaving behind the ordinary meaning

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Arguments and justification

- Arguments serve to provide judstification
  - An argument is a set of statements, some of which are offered as support for other statements in the set
  - An argument provides reasons to believe something
  - If someone asserts something which you do not believe, you frequently ask them to justify what they say

- As we define argument, it need not involve another person—you can construct an argument to demonstrate that something is true without showing it to anyone

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Premises and Conclusions

- The statements offered in support are called premises
  - Often indicated by words such as Because, Since, Given that, On account of, etc.

- The statements that are supported are called conclusions
  - Often indicated by words such as thus, therefore, this establishes that, etc.
- Example: Today is Friday, thus, the sun will set.
- Example: Because there is water on Mars there will be life.

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Clicker Question

In the argument

We can infer from the fact that the dog has lost its hair that there will soon be a lunar eclipse

The statement "the dog has lost its hair" is

A. A premise
B. A conclusion
C. Neither a premise nor a conclusion
D. Unable to determine from the information given

Good and bad arguments

- Our concern is not just with whether the conclusion is true
  - It is with whether those reasons stated in the premises give us good logical grounds for thinking that the conclusion is true
- The goal is not actual persuasion (people can be persuaded for bad reasons),
  - but establishing the truth
- Two factors relevant to the evaluation of arguments:
  - Are the premises true?
  - Is the connection between the premises and the conclusion such that the premises, if they were true, they would establish the conclusion?

Valid Arguments

- A valid argument is an argument in which, *if the premises were true*, the conclusion *must* also be true

- A valid argument *cannot* have true premises and a false conclusion

This relationship is modal: it tells us what *would be the case* were certain conditions to be met. These conditions might not be satisfied, and the modal definition tells you nothing about what happens when they are not satisfied.

One way to assess whether an argument is valid is to use your imagination and see if you can imagine a situation in which the premises are true and the conclusion false

If it is possible to imagine such a situation, then the argument is probably not valid.

Sound arguments

- A valid argument in which the premises are true is known as a sound argument.
    - This definition of a sound argument does not say anything about the truth of the conclusion.
    - But the conclusion of a sound argument must be true

- A sound argument meets both of the desiderata of a good argument:
    - True premises
    - Valid