Valid Arguments

Decision making (whether in science or elsewhere) involves reasoning based on evidence.

Question: when does some piece of information count as (good) evidence for or against a conclusion?

- When does some piece of information (evidence) serve to support (confirm) or count against (disconfirm) a hypothesis or theory?

To answer these questions we need to discuss arguments.

Brief Review

- **Statements** are sentences that have a truth value—either true or false.
- **Arguments** are sets of statements, some of which serve as premises for others, which are conclusions.
- **Valid arguments** are arguments in which, if the premises are true, the conclusion must also be true.
- **Sound arguments** are valid arguments with true premises.
Review continued

True or False:
- A valid argument cannot have a false conclusion.
- A sound argument cannot have a false conclusion.
- An argument with a true conclusion is sound.
- The conclusion of a valid argument with false premises is false.

Conditional Statements

- Conditional statements consist of two component statements linked by the logical connective IF, THEN.
- If and then are not indicator words—they are not marking premises and conclusions of an argument.
- If it rains today, there will be no picnic is not an argument!
- It simply asserts a conditional relationship between two statements.
- Compare: On account of the fact that it is raining today, there will be no picnic.

Conditional Statements - 2

IF, THEN is a truth functional connective: the truth of a compound statement depends only on the truth values of the component statements.

If you trespass, then you will be arrested

- is false if you trespass and are not arrested
- is true if you trespass and are arrested
- is true if you do not trespass and are not arrested
- is true if you do not trespass and are arrested

The last case may seem surprising, but of course there are other reasons you might be arrested.
Conditional Statements - 3

IF A, THEN B is NOT equivalent to IF B, THEN A.
IF A, THEN B is false when A is true and B is false.
IF B, THEN A is false when B is true and A is false.

IF A, THEN B is equivalent to IF not B, THEN not A.
If you trespass, then you will be arrested
is equivalent to
If you are not arrested, then you did not trespass.

Conditional Statements - 4

IF, THEN versus ONLY IF

Compare:
If you trespass, then you will be arrested
False if you trespass and are not arrested.
Only if you trespass will you be arrested.

B ONLY IF A is equivalent to If B, then A.
If you were arrested, then you trespassed.

THERE IS NO IF IN ONLY IF.

Conditional statements - 5

UNLESS can also be used to assert conditional relations.
Unless you complete the assignment, you will not get promoted.
says the same thing as
If you do not complete the assignment, you will not get promoted.
or
If you get promoted, then you completed the assignment.
Sufficient Conditions

When a conditional statement uses general terms (e.g., dog, mammal) it expresses relations between categories of things that satisfy those terms.

If something is a dog, then it is a mammal.

Presents a relation between being a dog and being a mammal.

It asserts that meeting the first condition (being a dog) suffices for meeting the second condition (being a mammal).

If _________, then _________ suffices for _________.

Necessary Conditions

Since a true conditional statement cannot have a true antecedent and a false consequent, the consequent of a conditional expresses something that is necessary if the antecedent is true.

If something is a dog, then it is a mammal.

Asserts that meeting the second condition (being a mammal) is necessary for meeting the first condition (being a dog).

If _________, then _________ is necessary for _________.

If versus Only if again

What follows the if of a conditional is a sufficient condition.

What follows only if is a necessary condition.

You can vote only if you are at least 18 years old.

Being 18 is a necessary condition for voting.

If you are able to vote, then you are at least 18 years old.

Being able to vote is sufficient (evidence) that you are at least 18 years old.
Practice with conditionals

Assume:
Sales are increasing = T
Our sales force is less effective = F
We need to build a new plant = F
We have excess production capacity = T

Whenever sales are increasing, we need to build a new plant:
If sales are increasing do we need to build a new plant
We do not need to build a new plant only if we have excess production capacity
Unless we have excess production capacity, we need to build a new plant
Only if our sales force is less effective are our sales not increasing
Unless sales are increasing we need to build a new plant

Using conditionals in inference

There are two ways to use a conditional statement in a valid inference, one obvious, one less so:

The obvious way:
From IF A, THEN B, affirm A
From this it follows that B

Why?
If B weren’t true, and A is true
IF A, then B would be rendered false

So, the following form is VALID:
IF A, then B
A
B
Modus ponens

Using conditionals in inference - 2

The less obvious way:
From IF A, THEN B, what happens if B is denied?

If B is false and A is true, then what is the truth value of
IF A, THEN B?

It is false. Thus A cannot be true when the whole conditional is true. Thus:

IF A, then B
Not B
Not A
is VALID
Modus tollens
Uses of conditional arguments in scientific reasoning

Modus ponens is most commonly invoked to make predictions from a hypothesis

If malaria is transmitted by mosquitoes and we eliminate the mosquitoes, malaria will decline.
Malaria is transmitted by mosquitoes and we are eliminating the mosquitoes.
\[ \therefore \text{Malaria will decline} \]

Modus tollens is most commonly invoked to confirm or falsify a hypothesis based on the truth of falsity of a prediction.

Invalid conditional arguments

Not all arguments that start with conditional statements are valid.

What can you conclude (validly) from:

If A, then B
Not A

Remember, to be valid, it must be that if the premises were true, the conclusion would also have to be true.

What conclusion has to be true in this case?
Both B and not B are compatible with the premises.
There is no valid argument here!

Invalid conditional arguments - 2

What about if we start with:

If A, then B
B

What conclusion has to be true in this case?
Both A and not A are compatible with these premises.
There is no valid argument here either!
Practice with Argument Forms

- I know I passed since I took the test, and if I took the test, I passed.
  - Modus ponens, valid

- Only if the dog is white is the ball blue. Indeed, the dog is white. So, the ball is blue.
  - Affirming the consequent, invalid

- Whenever the computer is broken, I have to calculate the result by hand. Today, I had to calculate the result by hand. Thus, the computer must have been broken.
  - Affirming the consequent, invalid

Reasoning with And, Or and Not

A very commonly used valid argument form is the following:

<table>
<thead>
<tr>
<th>Either A or B</th>
<th>Not A</th>
<th>or</th>
<th>Not B</th>
<th>B</th>
<th>or A</th>
<th>Alternative Syllogism</th>
<th>Valid</th>
</tr>
</thead>
</table>

Common reasoning strategy:
- start with an exhaustive set of alternatives
- eliminate all but one
- conclude that the remaining one is true

Reasoning with And, Or and Not - 2

An important but somewhat confusing type of inference involves negations operating on disjuncts (or) or conjuncts (and)

Consider the statement:
- You cannot enlist in both the Army and the Navy
  - This is not the same
  - You cannot enlist in either the Army or the Navy

If you want to make the statement using “or” you must divide the negation:
- Either you do not enlist in the Army or you do not enlist in the Navy
Reasoning with *And*, *Or* and *Not* - 3

Likewise, consider the statement:

Neither San Diego nor Los Angeles will win the World Series this year.
Which is equivalent to:
It is not the case that either San Diego or Los Angeles will win the World Series this year.
You cannot simply move the not to be with the two parts:
Either San Diego will not win the World Series this year or Los Angeles will not win.
But must switch to an and:
San Diego will not win the World Series this year and Los Angeles also will not win.

The *apparent* simplicity of showing a hypothesis to be false

The initial intuition is that a hypothesis is false if a prediction derived from it is false.
If the hypothesis is true, then the prediction is true.
The prediction is not true.
The hypothesis is not true.

Apply this to Halley:
If Halley’s comet hypothesis is correct, his comet will reappear in December, 1758.
Had his comet not appeared, people would have concluded that his hypothesis was wrong.

The challenge of confirmation

What seems to be the obvious way to confirm a hypothesis faces a serious problem:
If the hypothesis is true, then the prediction is true.
The prediction is true.
The hypothesis is true.

This is the form affirming the consequent, and is invalid.

We can also see what is intuitively wrong with it.
Make up a theory (a really bad one) from which you predict that sunlight feels warm.
Check the prediction.
Sure enough, it is true.
That doesn’t make your bad theory true.
The strategy for overcoming the problem of confirmation

Focus not on any prediction of a theory, but one that, if one did not accept the hypothesis, one would not expect to be true.

That is, one connected to the hypothesis in the following conditional:
If the hypothesis were not true, then the prediction would not be true.

Now you can invoke modus tollens in the confirmation:
If the hypothesis were not true, then the prediction would not be true.
The prediction is true.
The hypothesis is true.