What is Science?

What do the following statements all have in common?

- Science is a collection of facts that tell us what we know about the world.
- A scientific theory is one that has been proven.
- "The sun revolves around the earth" is not a scientific statement.
- If my theory is correct, then I should observe that rich countries are more likely to be democracies. I do observe that rich countries are more likely to be democracies. Therefore, my theory is correct.
- Politics cannot be studied in a scientific manner.

They are all wrong.

- Science is NOT a collection of facts that tell us what we know about the world.

- A scientific theory is NOT one that has been proven.

- "The sun revolves around the earth" IS a scientific statement.

- If my theory is correct, then I should observe that rich countries are more likely to be democracies. I do observe that rich countries are more likely to be democracies. IT DOES NOT FOLLOW that my theory is, therefore, correct.

- Politics CAN be studied in a scientific manner.

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- No – if this were the case, then Newtonian physics would have to be called unscientific because it's been replaced by more recent theories.

- No – if this were the case, then we couldn't make appeals to science in order to determine the veracity of that knowledge. We would be engaging in circular reasoning.

The body of knowledge we call 'scientific' may well be a product of science, but it isn't science itself.

Science is a method for *provisionally* understanding the world.

Science is a quest for knowledge.

But is science any quest for knowledge? Are meditation, religion, or introspection science?

Science is a quest for knowledge that relies on criticism.

The thing that allows for criticism is the possibility that our theories or claims might be wrong.

The thing that distinguishes science from ‘non-science’ is that scientific statements must be falsifiable.

- There must be some imaginable observation that could falsify or refute them.
- All scientific statements must be potentially testable.
- This doesn’t mean that our theories will ever be falsified, just that there’s a possibility they could be falsified.

There are two types of non-falsifiable statements:

1. Tautologies.

2. Statements about unobservable phenomena.

A tautology is a statement that's true by definition.

- “Triangles have three sides.”

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- "Strong states are able to implement policies."

A tautology is a statement that's true by definition.

- "Triangles have three sides."
- "Strong states are able to implement policies."
    - Unless we can think of a way of identifying a strong state without reference to its ability to implement policies, then this statement can't be falsified and is, therefore, not scientific.

Statements about unobservable phenomena.

- "God exists" or "God created the world" are claims that can't be falsified and therefore aren't scientific.

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- "God exists" or "God created the world" are claims that can't be falsified and therefore aren't scientific.

This does not mean that non-science is nonsense or that these claims are necessarily false.

Scientific Method

The scientific method describes the process by which scientists learn about the world.

1. Question
2. Theory or Model
3. Implications (Hypotheses)
4. Observe the World (Test Hypotheses)
5. Evaluation

Question

"Why did that occur?"

Surprise implies a prior expectation or theory.

Without a pre-existing theory, there can be no surprises or puzzles.

Theory/Models

A theory is a set of logically consistent statements that tell us why the things we observe occur.

- It is an abstraction that offers an explanation as to ‘why’ something happens.
- An explanation identifies for us a ‘cause’ or a causal process.

Theory is often referred to as a ‘model.’

A model is a simplification of the world.

- What a model needs to contain depends on the question.
- Models are useful or not useful, not right or wrong.
- Models are like maps.

A model can be informal or formal.

- Though they don't have to be, informal models tend to be long and imprecise.

When generating a theory it's useful to think of the starting puzzle as the end result of some previously unknown process.

We then speculate about what (hidden) process might have produced our starting puzzle.

In other words, we try to imagine a prior world that, if it existed, would produce this otherwise puzzling observation.

This becomes our model explaining the observation.

Deriving Implications

Once we have our model, we must deduce implications from our theory other than those we set out to explain in the first place.

"If the prior world we created to explain the phenomenon we originally found puzzling really did exist, what else ought we to observe?"

Good models are pregnant with many different implications.

Observe the World

The next step is to examine whether the implications of the model are consistent with observation.

We should conduct *difficult* tests and not seek to dogmatically confirm the implications.

A critical test allows us to use observation to distinguish between two or more competing explanations of the same phenomenon.

Evaluation

If we observe the implications deduced from our theory, then we say that our theory is corroborated. We do **not** say that our theory is proven. We then continue to look for evidence that would contradict our theory.

If we fail to observe the implications deduced from our theory, then our theory is probably wrong and so we return to theory construction.

Evaluation

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- Possible measurement error.
- Probabilistic vs deterministic.
- "It takes a theory to kill a theory."

The Case of Smart Female Athletes

A professor has noticed that women who engage in athletic activities frequently outperform the average student in their classes.

This is surprising because female athletes often have to miss class for competitions.

Can you think of a model – a process – that might produce this puzzling observation?

You might start with the following conjecture:

- Female athletes are smart.

While this is an explanation, it's not a particularly good one.

One thing you might think to do to improve your explanation is to make it more general.

- Athletes are smart.

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- Athletes are smart.

But there are at least two problems with this model:

1. There's no sense of process.
2. The model is close to being a tautology.

This might lead you to look for a new explanation that includes some sort of process that makes female athletes appear smart.

- Being a good athlete requires a lot of hard work. Performing well academically in college ralso equires a lot of hard work. Students who develop a strong work ethic in athletics are able to translate this to their studies.

Work Ethic Theory: Some activities provide a reward for hard work. Individuals who engage in these activities develop a habit of working hard and so will be successful in other areas of life as well.

This model provides a process explaining why female athletes might be more academically successful than other students.

An appealing feature of the model is that it applies to any person involved in an activity that rewards hard work.

Can you think of any alternative explanations for why female athletes appear smart?

Excellence Theory: Everyone wants to feel successful, but some people go long periods without success and become discouraged. Those individuals who experience success in one area of their life (perhaps based on talent, rather than hard work) develop a taste for it and devise strategies to be successful in other parts of their life. Anyone who achieves success in nonacademic areas, such as athletics, will be more motivated to succeed in class.

Gender Theory: In many settings, women are treated differently from men. This differential treatment often leads women to draw inferences that certain activities are ‘not for them.’ Because many athletic endeavors are gender specific, they provide an environment for women to develop their potential free from the stultifying effects of gender bias. The resulting sense of efficacy and autonomy encourages success when these women return to gendered environments like the classroom.

But how can we evaluate which model is correct or best?

One way is to test some of the implications that can be derived from these theories. In particular, we'd like to find some new question(s) to which the three models give different answers.

In other words, we'd like to conduct a critical test that would allow us to choose among the alternative reasonable models.

Three Critical Tests

	Theory		
Question	**Gender**	**Excellence**	**Work ethic**
Will athletics help women more than men?	Yes	No	No
Is academic success associated with success in other areas of life?	No	Yes	Yes
Are female athletes more successful at board games than women who are not athletes?	Yes	Yes	No

An Introduction to Logic

Science involves constructing logically consistent theories.

There are two reasons why you should care about logic:

1. If you can't distinguish between a valid and an invalid argument, then it's easy for someone to manipulate and exploit you!

2. Logic tells us quite a lot about the way scientists should test their theories.

An argument is a set of logically connected statements, typically in the form of a set of premises and a conclusion.

A premise is a statement that's presumed to be true within the context of an argument leading to a conclusion.

A conclusion in an argument is a claim that's thought to be supported by the premises.

An argument is valid when accepting the premises compels us to accept its conclusion.

An argument is invalid if, when we accept the premises, we're free to accept or reject its conclusions.

A categorical syllogism consists of a major premise, a minor premise, and a conclusion.

The major premise is typically a conditional statement such as "If P, then Q."

- If . . . is the antecedent.
- then . . . is the consequent.

"If a country is wealthy, then it will be a democracy."

The minor premise consists of a claim about either the antecedent or the consequent of the conditional statement.

The conclusion is a claim that's thought to be supported by the premises.

	Antecedent	Consequent
Affirm	?	?
Deny	?	?

Which of these arguments are valid?

Affirming the Antecedent: Valid

	General Form	Specific Example
Major Premise	If P, then Q.	If a country is wealthy, then it will be a democracy.
Minor Premise	P.	The country is wealthy.
Conclusion	Therefore, Q.	Therefore, the country will be a democracy.

Affirming the Antecedent: Valid

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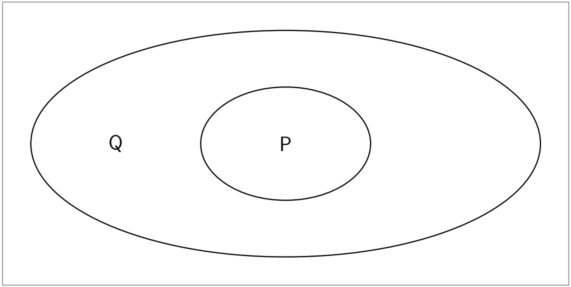
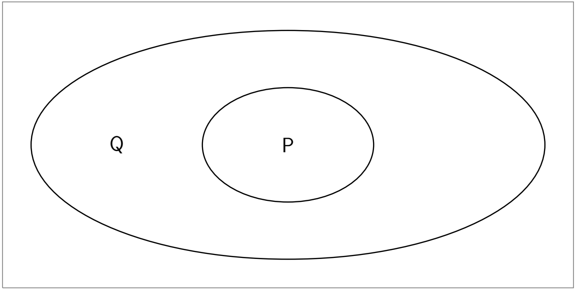


Denying the Antecedent: Invalid

	General Form	Specific Example
Major Premise	If P, then Q.	If a country is wealthy, then it will be a democracy.
Minor Premise	Not P.	The country is not wealthy.
Conclusion	Therefore, not Q.	Therefore, the country will not be a democracy.

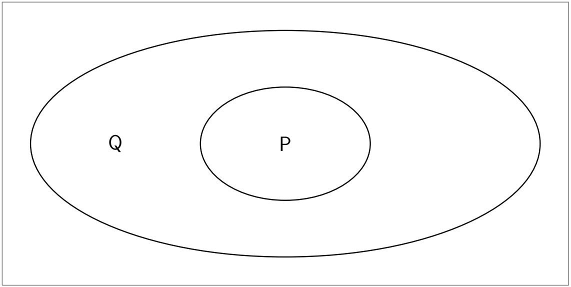


Affirming the Consequent: Invalid

	General Form	Specific Example
Major Premise	If P, then Q.	If a country is wealthy, then it will be a democracy.
Minor Premise	Q.	The country is a democracy.
Conclusion	Therefore, P.	Therefore, the country is wealthy.

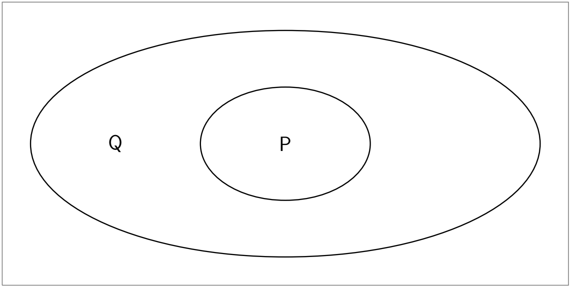
Affirming the Consequent: Invalid

	General Form	Specific Example
Major Premise	If P, then Q.	If a country is wealthy, then it will be a democracy.
Minor Premise	Q.	The country is a democracy.
Conclusion	Therefore, P.	Therefore, the country is wealthy.



Denying the Consequent: Valid

	General Form	Specific Example
Major Premise	If P, then Q.	If a country is wealthy, then it will be a democracy.
Minor Premise	Not Q.	The country is not a democracy.
Conclusion	Therefore, not P.	Therefore, the country is not wealthy.



	Antecedent	Consequent
Affirm	Valid	Invalid
Deny	Invalid	Valid

This brief foray into logic tells us something about how scientists test their theories.

Scientists typically evaluate their theories by examining the real world to see if the implications of their theories are true, based on the premise "If a theory is true, then its implications will be true."

Puzzle: Rich countries are much more likely to be democracies than poor countries.

Theory:

- Living in a dictatorship is risky. Living in a democracy is less risky.
- Rich people are less likely to take risks than poor people because they have more to lose.
- Countries with lots of rich people are, therefore, more likely to be democracies than dictatorships.

Implication: Rich democracies live longer than poor democracies.

Say we went out into the real world and observed that wealthy democracies do in fact live longer than poor democracies.

Can we conclude from this that our theory is correct?

Say we went out into the real world and observed that wealthy democracies do in fact live longer than poor democracies.

Can we conclude from this that our theory is correct?

The answer is NO, because this would be affirming the consequent.

Affirming the Consequent: Invalid

General Form	Example	Specific Example
If P, then Q.	If our theory T is correct, then we should observe implication I.	If our theory is correct, then we should observe that rich democracies live longer than poor ones.
Q	We observe implication I.	Rich democracies live longer than poor democracies.
Therefore, P.	Therefore, theory T is correct.	Therefore, our theory is correct.

Now, say we went out into the real world and observed that wealthy democracies do NOT live longer than poor democracies.

Can we conclude from this that our theory is wrong?

Now, say we went out into the real world and observed that wealthy democracies do NOT live longer than poor democracies.

Can we conclude from this that our theory is wrong?

The answer is YES, because this would be denying the consequent.

Denying the Consequent: Valid

General Form	Example	Specific Example
If P, then Q.	If our theory T is correct, then we should observe implication I.	If our theory is correct, then we should observe that rich democracies live longer than poor ones.
Not Q	We do not observe implication I.	Rich democracies do not live longer than poor democracies.
Therefore, not P.	Therefore, theory T is wrong.	Therefore, our theory is wrong.

There is an asymmetry in the logical claims that can be made on the basis of ‘confirming’ and ‘disconfirming’ cases.

- When an implication of our theory is confirmed, the most we can say is that the theory may be correct.

- When an implication of our theory is disconfirmed, we are compelled to conclude that our theory is wrong.

Think about what this means!

Think about what this means!

We're logically justified in having more confidence when we reject a theory than when we don't.

All of our knowledge remains tentative and can't ever be proven.

"The old scientific ideal of *episteme* – of absolutely certain, demonstrable knowledge – has proved to be an idol. The demand for scientific objectivity makes it inevitable that every scientific statement must remain *tentative* for ever ... With the idol of certainty ... there falls one of the defences of obscurantism which bar the way to scientific advance. For the worship of this idol hampers not only the boldness of our questions, but also the rigour and integrity of our tests. The wrong view of science betrays itself in the craving to be right; for it is not his *possession* of knowledge, of irrefutable truth, that makes the man of science, but his persistent and recklessly critical *quest* for truth."

Sir Karl Popper, [1959] 2003: 280-281

If confirming observations don't prove that a theory is correct, does this mean they're of no use whatsoever?

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No

Suppose we start with a set of implications derived from a theory.

If our observations are consistent with our theory, then we can have a greater measure of confidence in our theory *because it withstood the very real chance of being falsified.*

Falsificationism is an approach to science in which scientists generate or "deduce" testable hypotheses from theories designed to explain phenomena of interest.

It emphasizes that scientific theories are constantly called into question and that their merit lies only in how well they stand up to rigorous testing.

Falsificationism takes a clear stance in the debate between deductive and inductive approaches to learning.

The deductive approach to learning involves formulating an expectation about what we ought to observe in light of a particular theory about the world and then sets out to see if observation is consistent with theory.

- With deduction, theory precedes observation.

The inductive approach to learning starts with a set of observations and then tries to ascertain a pattern in the observations that can be used to generate an explanation for the observations.

- With induction, observation precedes theory.

Induction is problematic because to be successful it must rest at some point on the fallacy of affirming the consequent.

The fact that observation precedes theory construction means that it's never exposed to potential falsification.

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Popper: Induction isn't so much wrong, as impossible. We're all deductivists.

Myths about Science

Myths about Science

1. Science proves things and leads to certain and verifiable truth.
2. Science can be done only when experimental manipulation is possible.
3. Politics cannot be studied in a scientific manner.
4. Scientists are value neutral.

Science is value neutral.

Scientists may not be value neutral, and so the body of knowledge we call scientific may not be value neutral and unbiased.

Diversity and Science

Debates about diversity often focus on issues of representation, fairness, equity, or social justice.

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But does diversity bring substantive benefits? In terms of science, does it help us to better understand and predict things?

The answer, in short, is that it can do, *at least under certain conditions*.

Cognitive (toolbox) diversity has to do with the way that people think about, interpret, and interact with the world.

1. Perspectives
2. Heuristics
3. Interpretations
4. Predictive models

Each of us brings our own cognitive toolbox to bear when we attempt to understand the world. A diverse group is a group that contains people with different cognitive toolboxes.

Identity diversity has to do with the different components of our identity such as gender, sex, race, ethnicity, sexual orientation, class, religion, age, nationality, and physical qualities.

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Cognitive diversity and identity diversity are distinct concepts and don't have to go together.

But empirical evidence suggests that identity diversity is often associated with cognitive diversity in practice.

Cognitive diversity is important for problem solving.

- Cognitively diverse groups outperform groups of high-ability problem solvers in many settings.

- The ‘diversity trumps ability theorem’ requires certain conditions to be met.

Cognitive diversity is important for making good predictions.

- Predictions from diverse groups are always better than predictions from similarly capable groups that are less diverse.

Diversity may create communication or coordination problems.

People with drastically different perspectives, heuristics, interpretations, and predictive models may find it difficult to trust or communicate effectively with one another, thereby making problem solving more difficult.

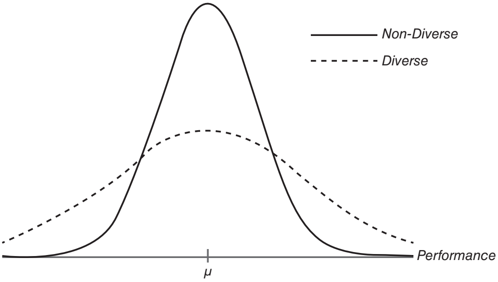
Value or preference diversity has to do with whether individuals hold conflicting preferences or values.

- Many problems don't have objective answers.
- When people hold diverse preferences and values, conflict can occur and group decisions, along with the process by which those decisions are made, can become contested.

While cognitive diversity is almost always helpful, value or preference diversity often isn't.

Identity diversity helps performance to the extent that it produces (relevant) cognitive diversity. It hinders performance to the extent that it produces (relevant) value or preference diversity.

Figure: Probability Distribution of Performance for Non-Diverse and Diverse Groups



Why Science?

Science is tentative, objective, and public.

- Its tentative nature invites criticism and hence improvement.
- Its objective nature means that incorrect ideas can't be protected based on the authority (or sheer power) of the person articulating the idea. This helps avoid conflict.
- Its public nature means that anyone can challenge and evaluate claims. This makes it faster to find errors.