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Why does reasoning matter (and how can you spot an argument)?

How do you spell out the reasoning behind an argument?

How do you draw out a logical conclusion from your premises?

How do you draw out a probable conclusion from your premises?

How can you select and test the best explanation of something?

How should you assess evidence and plan your reading strategy?
“I am convinced that the act of thinking logically cannot possibly be natural to the human mind.”

Neil Degrasse Tyson
#talkCriticalThinking
This is the first of three chapters engaging with three different types of reasoning: deduction, induction and abduction. These correspond approximately to logic, probability and explanations in the flow diagram for this half of the book. Although each has a chapter of its own, these differing types of reasoning are not opposed or exclusive ways of thinking. One does not trump the other, and it's a mistake to ask which is ‘better’. Between them, they describe a range of different ways in which we can seek, reasonably, to think about the world.

In this chapter, we will begin by exploring deductive reasoning, and the related concept of deductive proof. Deduction is all about the structure of arguments: what it means to correctly put together the information in front of you. If you spot a flaw in deduction, it means that someone has structured their argument incorrectly and drawn conclusions that their premises do not support. In terms of an essay or a research project, it’s all about carefully structuring your reasoning so that you don’t arrive at incorrect or unsupported conclusions.

Deductive proof is a matter of logical certainty. If it is true that every healthy baby has an innate capacity for language, and if it is true you have a healthy baby, then it must also be true that your baby has an innate capacity for language.

When it comes to the logical structure of arguments, correctly using deductive reasoning guarantees something special: that the truth of your premises will be preserved in your conclusions. For this reason, deductive reason is sometimes called truth-preserving.

**INTRODUCING DEDUCTIVE REASONING**

Here is an example of deductive reasoning in action:

- **Premise 1:** All fish live in water.
- **Premise 2:** I am a fish.
- **Conclusion:** I live in water.

This may sound like nonsense, but the conclusion follows perfectly logically from its two premises. If it is true that all fish live in water, and if it is true that I am a fish, it is inevitably true that I must live in water. The conclusion is already implicit in the premises, ready for us to deduce it – hence the term deduction.
PART I: THE ART AND SCIENCE OF BEING REASONABLE

When we engage in deductive reasoning, we are not bringing any additional information to bear on a situation: we are simply drawing out a conclusion that is already implicit in our initial assumptions. For this reason, assessing someone’s deductive reasoning doesn’t tell us anything about whether what they claim is true or not. It just tells us whether the logical structure of their argument makes sense, or whether something has gone wrong on this structural level.

Deduction sounds a bit like detective work, and for good reason: it entails looking very closely at the information in front of you and then teasing out exactly what it implies. Here are a few examples. In each case, use your powers of deduction to spell out the logical conclusion that the information leads to:

1. I can’t stand any kind of physical activity. Sailing is a physical activity, so..........................
2. There is no such thing as a magnetic plastic. My plate is plastic, so....................................
3. Anyone ignoring me while speaking on their phone is irritating. You are ignoring me while speaking on your phone, so.........................................................................................

The logical conclusion of each of these is that: (1) I can’t stand sailing (because it’s a physical activity); (2) My plate is not magnetic (because there is no such thing as magnetic plastic); and (3) You are irritating me (because you are ignoring me while speaking on your phone).

How did you do? Here’s a more complex example:

A combination of poor diet and inactivity in elderly patients leads to memory loss. George (not his real name) is inactive and eats a poor diet. Barbara (not her real name) is inactive but eats well. Thus, we predict that

..................................................................................................................................................
..................................................................................................................................................
..................................................................................................................................................

The correct conclusion is that ‘George will suffer from memory loss owing to his poor diet and inactivity’. Notice that there is no mention of Barbara. This is because we don’t have enough information to predict what will happen to her. All that our premises tell us is that both poor diet and inactivity lead to memory loss. Someone who is inactive but eats well doesn’t fit into this category, and so we have nothing further to say about them. If you mentioned Barbara when completing the example, you were introducing an assumption that isn’t actually contained in the premises – a common error in deductive reasoning.
VALID AND INVALID ARGUMENTS

Logic and truth are two distinct things. In the first example in this chapter, the fact that one of the premises is obviously false – I am definitely not a fish – makes no difference to the structure of the argument being a perfectly logical piece of deductive reasoning. If all fish live in water, and I am a fish, then it logically follows that I must live in water. Here’s another perfectly structured deductive argument:

Premise 1: All Blahs live in Bloop.
Premise 2: I am a Blah.
Conclusion: I live in Bloop.

There is no such thing as a Blah or a place to live known as Bloop, but this makes no difference to the deductive force of the argument. Deductive reasoning is not directly concerned with truth: it is simply concerned with validity, which means the question of whether a particular conclusion inevitably follows from its premises. If the structure of an argument is such that its conclusion must follow from its premises, then that argument is valid. If, by contrast, its conclusion does not follow from its premises, then the argument is invalid.

Here is another perfectly valid piece of deductive reasoning, expressed in ordinary prose:

All men who wear glasses are attractive. I wear glasses. Therefore, I am attractive.

The conclusion – that I am attractive – follows logically and inevitably from the premises. If all men who wear glasses are attractive, and I wear glasses, then it must follow that I am indeed attractive. My argument is valid, even if the truth of my premises is open to debate. By contrast, here is a piece of invalid reasoning based on the same premises:

All men who wear glasses are attractive. I wear glasses. Therefore, I am a man.

This conclusion – that I am a man – does not follow logically and inevitably from my premises. It may happen to be true that I am a man, but this is neither here nor there so far as deduction is concerned. I have failed to correctly deduce what my premises imply, instead leaping to an unwarranted conclusion.

Much of the time, you can use a combination of common sense and close reading to work out whether the form of an argument is valid or invalid. Here are a few examples. Are the arguments below deductively valid or invalid?

Valid reasoning: correctly applying deductive reasoning in drawing out the logical conclusion of your premises
Invalid reasoning: incorrectly applying deductive reasoning, so that your conclusion does not logically follow from your premises
Unwarranted conclusion: a conclusion that is not supported by the argument
PART I: THE ART AND SCIENCE OF BEING REASONABLE

1. All students must register if they wish to attend the workshop. I wish to attend the workshop. Therefore, I must register.  
   Valid  Invalid

2. There is no such thing as a purple monkey. This creature is purple, so it can’t be a monkey.  
   Valid  Invalid

3. Purple monkeys are difficult to spot. This creature is difficult to spot, so it must be a purple monkey.  
   Valid  Invalid

4. We always need the permission of human volunteers if our experiments on them are to be ethical. We do not yet have permission from these subjects, so we cannot yet experiment on them in an ethical manner.  
   Valid  Invalid

5. We always need the permission of human volunteers if our experiments on them are to be ethical. We do not yet have permission from these subjects, so we can only experiment on them if they don’t know what we are doing.  
   Valid  Invalid

Number (1) is clearly valid. Number (2) is also valid, although it takes a little more thought to see why: if there is no such thing as a monkey that is purple, it logically follows that anything which is purple cannot be a monkey. Number (3) is invalid, because saying that purple monkeys are difficult to spot does not imply that ‘anything that is difficult to spot must be a purple monkey’. There may be countless other things that are also hard to spot (chameleons, tiny objects that are very far away, brown monkeys sitting on brown trees).

Number (4) is a valid argument. Its premises are lengthier than our first examples, but its form is straightforward: if we always need someone’s permission to do something, then we cannot do that thing if we do not have their permission.

Finally, number (5) is invalid. It involves the kind of slippery thinking that people often use in order to justify a course of action, but this shifting of meanings has no place in valid reasoning. If we always need someone’s permission to do something ethically, then we cannot do that thing ethically without their permission – full stop. The conclusion is unwarranted: the premises do not support it.

SMART STUDY 3.1

How evasion creates invalid arguments

One of the most useful practical reasons for thinking about validity is that it allows us to spot situations in which someone is trying to get away with drawing an unwarranted conclusion from their premises, often via a hidden assumption that they would rather not spell out.

In the final example above - ‘We always need the permission of human volunteers if our experiments on them are to be ethical. We do not yet have permission from these subjects, so we can only
TEACHING IS ONLY SUCCESSFUL AS IT CAUSES PEOPLE TO THINK FOR THEMSELVES

WHAT THE TEACHER THINKS MATTERS LITTLE.

ALICE MOORE HUBBARD

#TalkCriticalThinking
PART I: THE ART AND SCIENCE OF BEING REASONABLE

experiment on them if they don’t know what we are doing. Thinking rigorously about validity exposes the fact that the author is concealing an alarming assumption: that, so long as someone doesn’t know what we are doing, we can get away with acting unethically towards them.

Assessing sources closely for validity entails insisting that people cannot pull off this kind of evasion. If someone wishes to present a claim as the logical outcome of their argument, it’s our job to insist that their argument is honest and explicit. Don’t be afraid to challenge invalid claims wherever you find them: it’s an integral part of honest thought and research.

NECESSARY AND SUFFICIENT CONDITIONS

One of the most fundamental ways in which concepts can be logically connected is through necessary and sufficient conditions. Here is an example of each:

In order for me to be a successful student, it is necessary for me to work hard.

This exam has a pass mark of 50, so my score of 52 is sufficient to pass.

A necessary condition for X must be true in order for X to be true – but its truth does not guarantee that X is the case. My first example, above, features a necessary condition. Working hard is necessary if I want to succeed; but it can’t by itself guarantee success. A sufficient condition, by contrast, does indeed guarantee that something is true. This is the case in my second example. If I score 52 in an exam with a pass mark of 50, this guarantees that I have passed. Here are a number of conditions that are necessary (but not sufficient) for me to be able to stream a movie on my iPhone:

- My iPhone needs to have a sufficiently fast data connection.
- I need to have access to some kind of streaming service.
- My iPhone needs to be sufficiently charged.
- My iPhone needs to be switched on and unlocked.

These conditions are necessary because, if even one of them is not met, I cannot stream a movie. Yet they are not sufficient because, even if all four things are true, I am not guaranteed to be able to stream a movie. All of the above could be true, yet my screen could be smashed and broken; or my phone could be paralysed by malware; and so on. In general:

Failing to meet a necessary condition means that THING X cannot be true. But...

...meeting any number of necessary conditions doesn’t guarantee THING X is true. But...

...the moment any sufficient condition is met, this does guarantee that THING X is true.
Here's a concrete example of this general point:

Being alive is a necessary condition for being a parent. But...
...just because you are alive does not guarantee that you are a parent. But...
...having one or more children is sufficient to guarantee that you are a parent. So...
...if you have one or more children, you are guaranteed to be a parent.

Here is another example in the same form. What words should go in the gaps?

Not eating any dairy products is a necessary condition for being a vegan. But... just
because you do not__________________ does not guarantee that you are___________. But...
not eating or using any animal products whatsoever is sufficient to guarantee that you
are__________________. So,... if you________________________ then you are guaranteed to
be__________________.

How did you do? Here's what it should say:

Just because you do not eat any dairy products does not guarantee that you are a vegan. But not eating or using any animal products whatsoever is sufficient to guarantee that you are a vegan. So, if you do not eat or use any animal products whatsoever, then you are guaranteed to be a vegan.

As we'll see in the next section, our ability to connect ideas in terms of ‘if’ and ‘then’ is the foundation of our ability to structure an argument logically – while it’s our tendency to confuse necessary with sufficient conditions that produces many of the most common errors in everyday logic. When it comes to logical certainties, a necessary condition is most significant in terms of the formulation ‘if... not’ – because we know that, logically if speaking, if a necessary condition for X is not met then X definitely is not the case. By contrast, a sufficient condition allows an ‘if... is’ statement – because, logically speaking, if a sufficient condition for X is met then X definitely is the case.

As we’ll also see, defining sufficient conditions in real life is extremely tricky. The Vegan Society defines veganism as ‘a way of living which seeks to exclude, as far as is possible and practicable, all forms of exploitation of, and cruelty to, animals for food, clothing or any other purpose’. This is a definition that is deliberately left open to some interpretation, given the great difficulty of tracking the ingredients and production process of every single product you use. Deduction may look neat, but pinning down the truth of every component part in its logic is an extraordinarily tricky business.
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THINK ABOUT THIS 3.1

Try to think of some necessary conditions for performing everyday tasks: preparing food, travelling, shopping, communicating with others. Can you think of any sufficient conditions for performing tasks in everyday life?

TWO TYPES OF VALID AND INVALID REASONING

Common sense and close reading go a long way when you’re assessing arguments, but it’s also important to understand things on a more fundamental level – and to have in the back of your mind a sense of the general logical forms that valid arguments take.

I’ve been using the word logic and logically a lot in this chapter, and you probably have a decent sense of what they mean. We use the word ‘logical’ informally to describe something that makes sense, and ‘illogical’ to describe something that doesn’t. These everyday senses come pretty close to the formal definition of logic: the principles and methods used to distinguish between correct and incorrect reasoning.

Logic can also be thought of as the science of validity. By correctly structuring a deductive argument, we are spelling out the logical implications of our premises. We do not add any additional information: we simply make logical (that is, correct) deductions on the basis of what we already know. Valid arguments are logical; invalid arguments are defective in their logic.7

Understanding the logic of valid arguments means looking at their form rather than their content. This isn’t a logic textbook, so I have restricted myself in this chapter to introducing the two most basic forms of valid argument, alongside the forms of invalid argument that correspond to them. If you’re interested, you’ll find a fuller range of logical arguments covered in the Appendix at the end of the book.8

Affirming the antecedent versus affirming the consequent

Affirming the antecedent is a valid logical argument that has the following general form – meaning that any argument which correctly follows this form must be valid:

Premise 1: If A, then B.

Premise 2: A.

Conclusion: Therefore, B.
What does this mean? First, it asserts that one thing always follows from another (i.e. that thing A is sufficient to guarantee thing B). Second, it affirms that, because the first thing has happened, the second thing must therefore be true. This becomes clear when we give A and B something specific:

Premise 1: If it is raining, then I will use my umbrella.
Premise 2: It is raining.
Conclusion: Therefore, I will use my umbrella.

To reiterate: any argument that has this form must be valid. If B follows from A, then whenever A is the case, we can say with certainty that B must also be the case.

Affirming the antecedent needs to be carefully distinguished from a similar but invalid form of argument – something we call a formal fallacy, because the form of the argument is itself false and illogical. This is the fallacy of affirming the consequent and it looks like this:

Premise 1: If A, then B.
Premise 2: B.
Conclusion: Therefore, A.

Here is the fallacy in concrete form:

Premise 1: If it is raining, then I will use my umbrella.
Premise 2: I am using my umbrella.
Conclusion: Therefore, it is raining.

This is an invalid argument because its conclusion does not inevitably follow from its premises. It may or may not be true that, if I am using my umbrella, it is raining – but my stated premises do not allow us to deduce this. B is necessarily true if A is true, but B is not sufficient to guarantee A. Here’s a further example of what is going wrong in this fallacy:

If I were conducting a secret affair with the president of the United States, the president would not mention my name publicly. The president has never mentioned my name publicly; therefore, I am conducting a secret affair with the president.

Clearly, there are many more likely explanations for the fact that the president has never mentioned my name. In making this mistake, I have confused necessary and sufficient conditions: I have mistaken something that would necessarily be true in the event of a certain conclusion with something that guarantees the same conclusion. My name not being mentioned might necessarily be true if I were having an affair with the president, but it is far from being sufficient to guarantee this conclusion.
PART I: THE ART AND SCIENCE OF BEING REASONABLE

Denying the consequent versus denying the antecedent

Denying the consequent is a valid argument in the following general form:

Premise 1: If A, then B.
Premise: Not B.
Conclusion: Therefore, not A.

Once again, we start off by saying that one thing will always follow from another. Next, however, we affirm that the second of these things has not happened, and thus that the first thing cannot have happened either. A is sufficient to guarantee B, which means that the absence of B is sufficient to guarantee the absence of A.

Premise 1: If it is raining, then I will use my umbrella.
Premise 2: I am not using my umbrella.
Conclusion: Therefore, it is not raining.

Any argument with this form must be valid, for reasons that mirror our initial ‘affirming’ form of argument. If B inevitably follows from A, and if we know that B is not the case, then A cannot be the case either. If I use my umbrella every single time it rains, and I tell you that I am not using my umbrella, you can validly conclude that it cannot be raining.

There is another invalid form of argument that corresponds to denying the consequent: a formal fallacy known as denying the antecedent. It takes this form:

Premise 1: If A, then B.
Premise 2: Not A.
Conclusion: Therefore, not B.

Here is the fallacy in concrete form:

Premise 1: If it is raining, then there will be clouds in the sky.
Premise 2: It is not raining.
Conclusion: Therefore, there cannot be clouds in the sky.

The problem with this particular example is that, while the absence of clouds does logically mean that it cannot be raining – because we have said that there will inevitably be clouds if it is raining – the absence of rain does not logically imply the absence of clouds. Clouds are a necessary condition for rain, but not a sufficient one. Once again, it is the confusion of necessary for sufficient conditions that creates the fallacy.
Both types of fallacious argument I’ve listed are based on the same kind of confusion: the idea that these two sentences mean the same thing:

The subject’s leg will move upwards if we hit the reflex spot.

The subject’s leg will move upwards if, and only if, we hit the reflex spot.

Put like this, the error seems ridiculous: there are obviously thousands of reasons why someone’s leg might jerk upwards in addition to being hit in the reflex spot. At other times, however, it is dangerously easy to act as though ‘if’ means ‘if, and only if’. For example:

Our research suggests that, if someone is highly intelligent, they are also likely to be of above-average wealth. This supports the theory of wealth denoting high natural ability.

Some people might find the above argument forceful, but its form is fallacious: there are many things other than high intelligence that are associated with wealth.

If we were to say that ‘research suggests that if, and only if, someone is highly intelligent then they are also likely to be of above-average wealth’, then it would make sense to say that wealth denotes intelligence – but this is no longer a convincing description of reality. Instead, it shows the kind of confusion associated with logical fallacies: failing to realize that describing a tendency (‘the highly intelligent are more likely to be wealthy’) is very different indeed from discovering a rule (‘all of the wealthy are intelligent’).

THINK ABOUT THIS 3.2

Under what circumstances do you think valid arguments are most important, and under what circumstances might making a valid argument miss the point or not fit the facts?

SOUND AND UNSOUND ARGUMENTS

We have said that validity is separate from truth: an argument can be perfectly valid while being based on lies or made-up nonsense. However, validity has an important relationship
THREE

IF IN DOUBT, WAIT. LEAVE THOSE DIFFICULT MESSAGES FOR A FEW DAYS, EVEN A WEEK, AND SUDDENLY WHAT YOU NEED TO SAY WILL FEEL MUCH CLEARER. DOING SOMETHING IS NOT NECESSARILY BETTER THAN DOING NOTHING.
with truth, because every valid deductive argument is truth-preserving. Its validity means that it will successfully preserve the truth of its premises, thus allowing us to draw true conclusions – so long as our premises are also true. If the premises of a valid deductive argument are true, then its conclusion must also be true.

We call a deductive argument that is both valid and has true premises a sound argument. By contrast, an unsound argument is one that does not satisfy these conditions: either because it is invalid (all invalid arguments are automatically also unsound), or because it is valid but its premises are untrue, meaning its conclusion cannot be relied upon.

Let’s look at an everyday example. Consider the following two premises:

If you want to conduct a literature review for your research, you must only make use of completely unbiased sources. But all sources are biased in one way or another.

Both of these statements may seem perfectly reasonable. Yet, when we apply deductive reasoning to them, they lead us to a conclusion that makes little sense. Here are the premises set out in standard form, followed by the underlying form of the argument in brackets:

Premise 1: If you want to write a literature review, then you should only make use of completely unbiased sources. (If A, then B)

Premise 2: There are no unbiased sources for you to use. (Not B)

Conclusion: You cannot write a literature review. (Therefore, not A)

This conclusion is logically implicit in the premises: it is a valid argument, conforming to the second form we looked at, ‘denying the consequent’. Once we spell it out, however, we need to decide whether we believe this to be a sound argument. Here, the conclusion which our premises lead us to think twice about the truthfulness of our premises; or, at least, about how best to express the thinking behind these premises. After all, charitably engaging with a line of argument shouldn’t entail dismissing it out of hand via a needlessly literal-minded reading of its claims.

In this particular case, the problem lies with the assertion that ‘you should only make use of completely unbiased sources’. You can reasonably claim that all sources are biased in some sense, but this doesn’t mean that you cannot use them. It simply means that you need to be sensitive to their different potential biases. In the light of this insight, we might rewrite the initial argument along these lines in order to better capture what it has to offer:

If you want to conduct a literature review for your research, you must be aware of any bias in your sources. All sources are potentially biased in one way or another. Therefore, when conducting a literature review, you must consider the potential biases in every source.

This is more likely to be a sound argument: it has a valid form and its premises are true. At least, its premises feel pretty convincing. Now that we are in the realm of truth as well as logical
PART I: THE ART AND SCIENCE OF BEING REASONABLE

validity, however, we face questions of judgement and likelihood as well as those of logical correctness. Are you 100 per cent convinced of the truth of the statement 'you must be aware of any bias in your sources'? Are there some sources of bias that you don’t need to be aware of, or some circumstances in which this doesn’t apply? Does being published in a leading scientific journal count as a kind of bias?

These are questions that point us towards the uncertainties of the world beyond our descriptions, and our inability to know many things for sure. They are not questions that can be resolved simply by looking at the form of our arguments – and addressing them entails the second type of reasoning at play in critical thinking, and the topic of the next chapter: induction.

THINK ABOUT THIS 3.3

Can you think of a deductive argument in common use that is valid but unsound? What kind of premises can we be certain are true? What kinds of deductive argument may never be sound, because their premises can’t be proven as true?

SUMMARY

Deductive proof means demonstrating that a particular conclusion logically follows from certain premises, and that this conclusion must be true if these premises are true.

When applying deductive reasoning, you are looking at the structure of an argument and drawing out a logical conclusion that is implicit in your premises.

Logic is the study of the principles distinguishing correct from incorrect reasoning, and its building blocks are the ideas of necessary and sufficient conditions:

- **Necessary** conditions need to be met in order for something to be true, but they cannot guarantee its truth. However, if any of the necessary conditions are not met, then something is guaranteed not to be true.
- **Sufficient** conditions do guarantee the truth of something. If the sufficient conditions for something are met, then it is guaranteed to be true.

We have looked in detail at two general valid forms of deductive reasoning:

- Affirming the antecedent – If A then B. A. So, B.
- If it is sunny, I get hot. It is sunny. So I am hot.
Denying the consequent – If A then B. Not B. So, not A.
If it is sunny, I get hot. I am not hot. So it cannot be sunny.

We have also looked at **two fallacious (logically invalid) forms** of argument, both of which result from the confusion of one thing being true ‘if’ another is true with one thing being true ‘if, and only’ if it is true (i.e. they confuse necessary with sufficient conditions):

- **Affirming the antecedent** – If A then B. B. So, A.
- If it is sunny, I feel happy. I feel happy. So it must be sunny.
- **Denying the antecedent** – If A then B. Not A. So, not B.
- If it is sunny, I feel happy. It is not sunny. So I cannot feel happy.

Overall, we have established that:

- **Valid reasoning** correctly draws out a logical conclusion from its premises.
- **Invalid reasoning** means a conclusion does not logically follow from its premises.
- A **sound argument** is both valid and has true premises, meaning its conclusion must also be true.
- An **unsound** argument does not meet the standard of soundness, either because it is invalid, or because one or more of its premises is untrue, or both. Thus, you cannot rely on its conclusion being true.

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**Go Online**

Now watch the video ‘Why logic is a really great thing, until it isn’t’. It’s on YouTube. Tell me what you think via #TalkCriticalThinking
FOUR

REASONING WITH OBSERVATION AND UNCERTAINTY

Why does reasoning matter (and how can you spot an argument)?
↓
How do you spell out the reasoning behind an argument?
↓
How do you draw out a logical conclusion from your premises?
↓
How do you draw out a probable conclusion from your premises?
↓
How can you select and test the best explanation of something?
↓
How should you assess evidence and plan your reading strategy?
To be prepared against surprise is to be trained.

To be prepared for surprise is to be educated.

James P. Carse

#TalkCriticalThinking
REASONING WITH OBSERVATION AND UNCERTAINTY

FIVE THINGS YOU’LL LEARN IN THIS CHAPTER

1. How inductive reasoning applies to evidence and research
2. How to assess the strength of an inductive argument
3. How to understand probability and rational expectation
4. How to make good use of samples in your work
5. The significance of black swan events and falsification

In the previous chapter, we looked at rigorously examining the form of an argument through deductive reasoning. We were interested in drawing out the conclusions implicit in our premises. So far, so logical. If a deductive argument has both true premises and a valid form, it is sound: its conclusion must also be true.

As soon as we start looking for patterns, causes and consequences within everyday experience and evidence, however, we run up against a problem. In real life, there is very little that we can be 100 per cent certain about. Deduction is all very well but, before we can apply its logic, we first need to make assertions about the world. And this brings us to a second, equally important form of reasoning: one based on observation and extrapolation rather than pure logic.

Although we rarely acknowledge it, small leaps of faith occur every time we assume that tomorrow will be like today, that one thing will follow the same pattern as another, or that the same observation will be true of different people or places. This brings us to inductive reasoning – the business of seeking good reasons to believe something in the absence of logical certainty.

ARGUMENT BY INDUCTION

The word induction comes from the Latin verb induerre, meaning ‘to lead into’. When we reason inductively, we are looking to see where our premises might lead us. We are making generalizations, inferring future events from past ones and asking what is most likely to be true, rather than dealing in absolutes.

Some people don’t like the phrase ‘inductive reasoning’ and prefer to talk about ampliative reasoning, because this offers an explicit reminder that it is a form of reasoning where your conclusion is an ‘amplification’ of your premises. The two phrases, however, mean exactly the same thing – and, because induction is a more commonly used term, I’m going to stick with it.⁹ Here is a simple example of an inductive argument:

There has never been a female president of the United States. So, the next president of the United States will almost certainly be a man as well.

Do you find this argument convincing? The first premise is certainly true – at least at the time of writing, in 2022, there had never yet been a female US president – which means that whether
you are convinced or not depends on how far you agree that the conclusion is a reasonable
generalization based on this observation.

Notice that the key question here is \textit{how far} you agree with the idea that the past is a
good guide to the future in this particular case. When deploying inductive reasoning, we are
always dealing with degrees of confidence rather than certainty. An inductive argument can-
not be valid in the way that a deductive argument is logically valid. When someone makes an
inductive argument, they are trying to persuade us to accept their particular account is highly
plausible. But they are not, and cannot be, proving something beyond all doubt.

\textbf{SMART STUDY 4.1}

Induction is a form of reasoning we apply hundreds of times each day without noticing. We do so every
time we try to work out what is going to happen next, based on what has happened before. Induction
comes so naturally that it can be difficult to think about critically. Here are four questions to help focus
your thinking:

- Inductive reasoning is at its strongest when we have good reason to believe that we are seeing
  a well-established pattern with plenty of evidence in its favour.
- Inductive reasoning is at its weakest when there is little evidence, no clear pattern or a high
degree of unpredictability, complexity or uncertainty.
- A more general scenario is always more likely than a more specific scenario that’s a subset of
  the general one. It’s inevitably more likely that ‘a randomly selected passer-by is female’ than
  that ‘a randomly selected passer-by is female and has long hair’.
- When assessing inductive reasoning, ask: how far is what you know a good guide to what you
don’t know? To what degree is the future, in this situation, likely to resemble your knowledge of
  the past?

\textbf{INTRODUCING INDUCTIVE FORCE}

In general, when talking about how convincing (or not) an inductive argument is, we use the
idea of inductive strength – also known as inductive force.

The greater the strength of an inductive argument, the more likely it is to be true. Where
deductive arguments are either valid or invalid – one of two absolute possibilities – inductive
arguments exist on a sliding scale of strength and weakness. The best we can ever say about
an inductive argument is that it is sufficiently strong for us to accept its conclusion as being
almost certainly true. Imagine I say this:

\begin{quote}
Every single person I have ever met hates me. The next person I meet is going to hate me too.
\end{quote}
REASONING WITH OBSERVATION AND UNCERTAINTY

My argument appears inductively strong on its own terms. If every single person I have ever met really does hate me, it seems quite likely that the next person I meet will hate me too. My opening premise, however, is almost certainly an exaggeration: at the least, you might think that a large number of people I have met are indifferent towards me.

We can thus say that this particular argument is cogent, but not inductively forceful. Its structure is perfectly reasonable, but its premise is not true. A cogent inductive argument resembles a valid deductive argument, in that both have a good structure but do not necessarily lead us to accept their conclusions. Similarly, an inductively forceful argument resembles a sound deductive argument in the sense that both offer convincing conclusions.

Does this mean that deduction and induction have nothing to do with one another, or are somehow rivals in the realm of reason? Not at all. Let’s revisit my opening example, about the gender of the next US president:

There has never been a female president of the United States. So the next president of the United States will almost certainly be a man as well.

This is an inductive argument. Yet we can, if we wish, convert it into a deductive argument by carefully spelling out its underlying assumptions:

**Premise 1:** There has never been a female US president.

**Premise 2:** [Implicit] It is almost certain that the immediate future will repeat the same pattern as the past in this particular case.

**Conclusion:** The next US president will thus almost certainly be a man.

We have now converted our inductive argument into a perfectly valid deductive argument. Does this mean we have magically plucked logical certainty from uncertainty? No. We have simply turned our inductive inference into an explicit premise, spelling out the leap between observation and generalization. If we have done so correctly, we have potentially created a sound argument, but only if we can be entirely certain of the truth of our inductive leap (which of course we cannot).

In other words, we can create a valid deductive argument by clarifying the exact details of an inductive leap, but we can never create an argument we know to be sound. We can make our uncertainty explicit, but we cannot banish it. Here is an example for you to try. Can you turn this inductive argument into a deductive one by spelling out the inductive leap between its premise and conclusion?

**Premise 1:** Even the world’s fastest computers and most advanced software are currently nowhere near replicating the intelligence of a small child, let alone a fully grown adult.

**Premise 2:** [Implicit]

**Conclusion:** Computers will almost certainly never achieve human-level intelligence.
PART I: THE ART AND SCIENCE OF BEING REASONABLE

How did you do – and do you find the resulting argument convincing? Once you’ve thought about it, try spelling out this second example in the same way:

Premise 1: Computer power and capabilities have been doubling around every two years for decades.

Premise 2: [Implicit] …………………………………………………………………………….………
………………………………………………………………………………………………………………

Conclusion: Within two decades, the capabilities of computers will almost certainly have overtaken those of humans.

As you’ll have noticed, the two different opening premises suggest two different patterns that may – or may not – provide an accurate basis of inductive amplification. Certainly, both cannot be true. In the first case, the implicit assumption goes along these lines: ‘the fact that computers have not yet replicated even a small child’s intelligence is almost certainly a good guide to the ultimate limitations of the level of intelligence it’s possible to create in a computer’. In the second case, the implicit assumption is: ‘the increases of the last few decades in computer power and capabilities will almost certainly continue at the same rate over the next two decades’.

Which one should we believe? Both arguments are deductively valid, if written out carefully enough. But we cannot know whether either (or neither) is sound. So what we are left with is a cautious obligation to investigate the strength of each inductive claim – and to keep in mind the illusory nature of any certainty implied simply by being explicit.

INDUCTION AND EVERYDAY LANGUAGE

As the example at the end of the previous sections suggests, the words we use are extremely important when it comes to inductive reasoning. Consider the following example:

Little children are always breaking fragile things. I have lots of breakable things in my house; so if you came round with your little children, they would break my things. I’m afraid you can’t visit unless you leave your children with a babysitter.

This reads like a piece of valid deductive reasoning: its conclusion seems to follow logically from its premises. Yet when we think about the first premise – ‘little children are always breaking fragile things’ – it’s clear that there are a couple of implicit qualifying words that need to be inserted if these deductions are to be based on an accurate inductive inference.

A more accurate statement might begin by saying ‘Some little children are always breaking fragile things’ – or that ‘little children often break fragile things’. This is because it is not literally true that all little children are constantly breaking fragile things. What was meant, and could have been said instead, is something along these lines:
WE OURSELVES CAN MAKE EXPERIENCE VALUABLE WHEN, BY IMAGINATION AND REASON, WE TURN IT INTO FORESIGHT.

Eleanor Roosevelt

#TalkCriticalThinking
PART I: THE ART AND SCIENCE OF BEING REASONABLE

Little children often break fragile things. I have lots of fragile things; if you come round with your little children, I’m worried that they might break them. So, how can we make it less likely that this will happen?

We do this kind of thing all the time in everyday language. Consider these unqualified statements, all of which also appear to make absolute claims:

1. You never help!
2. Young, male ex-cons with no education always end up back in jail.
3. People don’t survive pancreatic cancer.
4. Computers will continue to double in power every two years.

In each case, a careful analysis should begin by getting rid of the pretence that these are universal statements about something that is always the case – and instead supply some qualifying words.

Before looking at my answers below, try it for yourself: re-read each of the three sentences above, supplying a qualification for each that spells out the level of probability involved. Here are my versions:

1. You almost never help!
2. Many young, male ex-cons with no education end up back in jail.
3. Very few people survive pancreatic cancer.
4. Computers may continue to double in power every two years for some time.

As you may have noticed, something interesting happens once we start to spell out these elements of an inductive claim more precisely. By filling in the gaps in everyday speech and thinking, we start to identify uncertainties that we might wish to investigate further.

The absolute statement that ‘young, male ex-cons with no education always end up back in jail’ invites little debate or exploration. But as soon as we qualify it by suggesting that this applies to ‘many’ but not all people in this group, we admit to both the uncertainties and the investigative opportunities surrounding this issue.

Similarly, spelling out the inherent uncertainty and limitations around a prediction like ‘computers will continue to double in power every two years’ opens the door to a debate around evidence, trends and limitations. Is there actually a pattern at all in the sense we originally thought? Perhaps there is something else going on here: a chance to test and to increase our knowledge about a complex, uncertain world.

SMART STUDY 4.2
Choosing and using qualifying words

Using the right qualifying words is one of the most important ways of signalling your knowledge of inductive reasoning, and its uncertainties, in your work. Here are three guidelines:
REASONING WITH OBSERVATION AND UNCERTAINTY

1. Be careful never to express absolute certainty in the conclusion of an inductive argument.
2. Always keep in mind a range of qualifying words, from least to most confident, to allow you to express inductive conclusions precisely in your writing.
3. Always be ready to make explicit the implicit qualifications you encounter in others’ inductive arguments – don’t make the mistake of taking their apparent certainty literally.

THINK ABOUT THIS 4.1

Can you think of something that you believe which contains an implicit qualification that you don’t usually acknowledge or examine? What might you assume is certain, that is only highly probable; or impossible, that is in fact only unlikely?

ADDRESSING UNCERTAINTY THROUGH PROBABILITY

We have said that an inductively forceful argument resembles a sound deductive argument: it is reasonable to accept it as true. But what does it mean to say that it is ‘reasonable’ to accept the conclusion of an inductive argument? Where and how do we draw the line between accepting something as true, or not? To address this, we need to turn to the concept of probability.

Probability is the study of how likely we believe something is to be true, or to occur. It’s extremely useful because it allows us to deal with the uncertainties of the real world without just throwing our hands up in the air and abandoning reasoned analysis.

Probability allows us to compare and contrast the likelihood of different possibilities by assigning them a value on a numerical scale. Something that is absolutely certain has a probability of one, something that is absolutely impossible has a probability of zero, and everything else thus exists on a sliding scale between one and zero, with a half – or 0.5 in decimal terms – marking the exact middle. A simple diagram looks like this, complete with the kind of qualifying words we saw in the previous section:

<table>
<thead>
<tr>
<th>Impossible (zero)</th>
<th>50–50 (0.5)</th>
<th>Certain (one)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible</td>
<td>Probable</td>
<td></td>
</tr>
</tbody>
</table>
PART I: THE ART AND SCIENCE OF BEING REASONABLE

Something is more likely (than not) to be true if it has a probability greater than 0.5, meaning it will happen more than half the time. Something with a probability of less than 0.5 will happen less than half the time, and is more likely to be untrue than true.

We can use these numbers to talk about what it is, and isn’t, reasonable to believe. Imagine that the chance of winning the top prize in a lottery is one in a million, i.e. that for every million tickets sold, there is just one winner. If you buy one lottery ticket, your rational expectation should thus be that 999,999 times out of a million you will not win the top prize, a probability of 0.999999. Another way of putting this is that your only reasonable expectation should be one of near-certain loss.

Importantly, however, how probable we believe something is can be quite different to how probable it actually is. Imagine that a friend tells you they have bought one lottery ticket at a particular shop at a particular time, according to instructions they received in a dream where a talking penguin told them they were going to win the lottery. Their personal expectation is that they have purchased a winning ticket. This makes no difference to the rational expectation that someone in their position ought to have; but it may make a great deal of difference to their behaviour and attitude.

Probability doesn’t care about perceptions; it’s there to describe what it is most reasonable to expect in any given situation. It’s also there to remind us that uncertainty is at least sometimes a quantifiable feature of the world, and that there are many different degrees of uncertainty: being unsure about something is not at all the same thing as knowing nothing.

How does this apply to induction? If there is a worse than 0.5 probability that an argument is false, then it is not inductively forceful: our rational expectation should be that it’s more likely to be false than true. If there is a better than 0.5 probability it is true, then the argument is inductively forceful: it’s more likely to be true than false. Sometimes we can calculate these odds precisely; sometimes it’s a matter of estimation or investigation based on past experience or comparison to similar cases. Try it for yourself. In each of the following scenarios, do you find the argument inductively forceful or not?

Every winter for 30 years my mother has gone somewhere warm on holiday. I guess she’ll do the same thing once again this year.

Yes  No

On the day of my birthday, there has been a record high temperature for that month every year for the last three years. I guess it will happen again this year.

Yes  No

The first of these arguments seems inductively forceful. Unless there is some other information we don’t know, it seems more likely than not that my mother will once again do something she has deliberately done every winter for 30 years. It’s thus rational for you to assume she will do this. The second argument, however, is not inductively forceful. Three instances of a record
temperature on a particular day do not make a fourth instance on that same day more likely than not. It’s in the very nature of exceptional results that they are rare. The ‘pattern’ suggesting this assumption is most likely simply to be coincidence.

We can use an understanding of probability to rank some different forms of inductive arguments in relation to one another, especially when it comes to predictions – something that relies on assessing how specific and/or complex different scenarios are. Consider the following inductive arguments. Can you rank them in order, from least convincing to most convincing?

1. There has never been a female US president – and this suggests there will never be a female US president.
2. There has never been a female US president – and this suggests the next president will not be female either.
3. There has never been a female US president – but all things change and, at some point, there eventually will be.
4. There has never been a female US president – but the time is ripe for change and there will be one within the next decade.

Fairly obviously, the most convincing of these arguments is (3), which argues that at some point there will be a female president. This prediction must be more likely than (4), which offers a more specific version of the same scenario: not only will there be a female president, but she will arrive within the next decade.

This is one firm rule to bear in mind when assessing the relative probability of different possibilities. When one scenario is in effect a more complex version of another, the more complex scenario will always be less likely. ‘Having a female president within a decade’ is a more complex version of ‘having a female president at any point in the future’ – so it is inherently and definitively less plausible.

We can think about the probabilities involved, here, as a spectrum of possible futures. There are plenty of future scenarios in which a female president is elected at some point – just not within the next decade. But there are no scenarios in which a female president is elected within the next decade – yet somehow there isn’t a female president.

A version of the same principle also applies to the other two scenarios. Argument (1) – that there will never be a female president – is far less likely than argument (2) – that the next president won’t be female. Why? Because saying that no future president will ever be female entails making a prediction about an indefinite succession of non-female presidents (i.e. you’re relying on one increasingly unlikely possible future coming to pass) while saying that the next president will be non-female entails predicting just one non-female president.

We can also tease out a subtler fact about these four scenarios. Assuming that every decade sees three presidencies (each lasts four years, and a sitting president still needs to fight a rival for re-election), the claim that the next decade won’t feature a female president means that
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this decade must feature three male presidencies in succession. This requirement is inherently less likely than the requirement that the next president should be male – which in turn allows us to rank the prediction ‘there will be a female president within a decade’ as inherently more probable than ‘the next president won’t be female.’

We are thus left with a rank order for all four scenarios. I’ve spelled this out, below, alongside a synopsis of the possible futures satisfying each prediction – which is, in effect, the technique we have used to establish a comparison of their relative likelihoods:

Least convincing: there will never be a female US president (for this to be true, an indefinite and unbroken sequence of future male presidents is required)

Slightly more convincing: the next president will not be female (for this to be true, the next president has to be male)

Even more convincing: there will be a female president within a decade (for this to be true, either the next presidency has to be non-male, or the next, or the next; i.e. this scenario must come true unless all three of the next presidencies are male).

Most convincing of all: there will at some point be a female US president (for this to be true, just one female is required at any point within an indefinite sequence of future presidents)

SMART STUDY 4.3

Making sure you’re not fooled by probability

It’s important to get to grips with probability, both because it offers a way of thinking carefully about uncertainty and because it doesn’t come naturally to most people. Before you go any further, spend some time thinking through these key points:

• If there is no connection between two different events, then their individual probabilities can have no effect on one another. One fair coin toss has an equal chance of coming up heads or tails. So does the next toss. And the next. The previous result can be completely ignored when it comes to thinking about the next one.

• This doesn’t apply if you are thinking about the probability of several things all turning out a certain way. In this situation, the probability of the end result comes from multiplying each individual event’s probability. One fair coin toss has an equal chance of coming up heads or tails. Two coin tosses have a one-in-four chance of coming up heads and heads. Three tosses have a one-in-eight chance of coming up heads, heads and heads. And so on.

• The more precise a result you’re looking for, the less likely it is to happen. For example, it is less likely that every subject sitting a test will get full marks than it is that half the subjects will get full marks, which is less likely than one person doing so.

• Similarly, a more specific scenario is always less likely to happen than a general scenario that encompasses that specific scenario. It is, for example, inevitably less likely that someone chosen from a crowd at random owns a blue car than that they own any car.
REASONING WITH OBSERVATION AND UNCERTAINTY

- Just because something seems striking to a human observer doesn't make it remarkable. Six sixes are exactly as likely to come up as any other dice throw: the fact that they attract more attention has no particular significance.
- Most coincidences only seem astonishing because we inexorably ignore millions upon millions of daily events that don't strike us as astonishing. Rare and unlikely things happen all the time.

MAKING USE OF SAMPLES

Induction is a process of generalization. It moves from the particular to the general, and this makes the concept of sampling important. A sample consists of some particular cases you are examining in order to make generalizations about a larger shared feature, trend or regularity.

If I’m investigating feline behaviour, I might use my pet cat, Basil, to stand for cats in general – and I might make an inductive argument along the following lines. Is this a weak or a strong inductive argument?

<table>
<thead>
<tr>
<th>Weak</th>
<th>Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td>My pet cat, Basil, is very shy and will only let himself be stroked by people he knows. Therefore, cats are shy animals and will only let people they know stroke them.</td>
<td></td>
</tr>
</tbody>
</table>

This is not a very strong inductive argument, because there is only a single cat in my sample. In research, the letter n is often used to denote sample size, in the form n = 1 for a sample of one, n = 100 for a sample of 100, and so on. Because one is the smallest possible sample size, the phrase n = 1 has become a kind of shorthand for the fact that an anecdote involving a single instance will almost inevitably produce a weak inductive argument.

If someone tells you ‘my uncle smoked every day of his life, and he lived to the age of 90: how can it be bad for you?’ then the correct (if impolite) answer is that basing this conclusion on a sample size of one is an extraordinarily bad way to think about health issues.

So far as cats are concerned, my argument would be much stronger if it were based on a larger sample. In general, it is true to say that:

- The larger the sample, the more reliable it tends to be as a representation of the whole. Inductive arguments based on small samples are likely to be far weaker than those based on large samples.

It is not enough, however, simply to use a large sample and assume this makes your assessments correct. Imagine that I run a website that's all about coffee. I want to know how many people prefer coffee to tea, so I put a survey on the site under the title 'Tom's Big Coffee Survey', inviting people to click and answer a few questions about their beverage preferences. Here is a summary of my results:

Sample: the particular cases you are using to stand for the entire category about which you wish to make an inductive generalization

\[ n = 1: \text{a sample size of one indicates an anecdote rather than a serious investigation; any inductive argument based on a single instance is likely to be very weak} \]
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In a recent survey of over 2000 people, an astonishing 80 per cent named coffee as their favourite hot drink – over four times as many as prefer tea – and over half named it as their favourite among all drinks, beating even alcoholic beverages. Coffee is officially the biggest drink in the country!

Can you see what might be wrong with my claims? The problem is that I run a website that’s all about coffee. Although over 2,000 people responded, every single one of these responses comes from someone who both visited a specialist coffee website and then decided to participate in a survey about coffee.

Is this particular group of people likely to represent the views of the population as a whole? No. My claim that coffee is ‘officially’ the biggest drink in the country is ridiculous. All I can legitimately claim is that ‘coffee appears to be the biggest drink among readers of my coffee website who decided to take part in a survey about coffee’. This is because I have used an unrepresentative sample – one that, while quite large, is a poor representation of the overall population I’m making claims about.

A good sample should be as representative as possible, meaning that it closely resembles the larger group about which general claims are being made. This brings us to the most important question of all: how can we ensure we are using a representative sample?

There’s no easy answer to this, partly because no sample is ever perfectly representative. In general, the best samples are both as large as possible and successfully randomized from across the entire field of study, meaning that the sample is randomly selected from all possible cases of interest, using a method that does not bias the results.

Because no sample is ever perfectly representative, it’s important to remain aware of both potential sources of sampling bias and the degrees of error involved in your investigation. Errors are inevitable in all samples and measurements, and are not the same thing as mistakes.

The observational error relates to the accuracy of your measuring system, and is usually expressed in the form ‘plus or minus X’ where X is the potential difference between measured and actual values. For example, if you are using a set of scales you know to be accurate to within ten grams, your results should be reported as ‘±10g’ – and should never be reported to apparent fractions of a gram, which might give a false idea of accuracy.

The margin of error is more complex and expresses the greatest expected difference between the results you’ve obtained from your sample and the results you might have got had you been able to test the entire population. Typically, this takes the form of ‘±X with a confidence level of Y%’, meaning ‘if we kept on repeating this test, then Y% of the time the results from our sample would be within X of the entire population’s results’. For example, if you reported that a survey in your research had a margin of error of ‘±5% with a confidence level of 80%’, this means that you believe your results would fall within 5 per cent of the total population’s results 80 per cent of the time.

Potential sources of sampling bias to be avoided – or to be aware of in others’ investigations – include:

Representative sample: one that closely resembles the larger group about which claims are being made, while unrepresentative samples fail to do so.

Randomized sample: one selected at random from across a field of study, with no particular element misleadingly over-represented.

Observational error: an error due to the accuracy of your measuring system, usually reported as ±X, where X is the potential difference between measured and actual values.

Sampling bias: a bias introduced by imperfect methods of selecting a sample.

Margin of error: an expression of the degree to which results based on a sample are likely to differ from those of the overall population.
REASONING WITH OBSERVATION AND UNCERTAINTY

- **Self-selection**: setting up your sample in such a way that a certain type of participant effectively selects themselves. For instance, the kind of person most likely to fill in a detailed survey may differ substantially from the population at large.
- **Specific area selection**: selecting your sample so that one particular area is over-represented. For example, conducting research into global population trends based only on statistics gathered in London and New York.
- **Exclusion**: selecting your sample in a way that disproportionately excludes certain elements. For instance, conducting a wildlife survey only during daylight hours might exclude nocturnal animals.
- **Pre-screening**: conducting your sample selection via an initial method that is likely to select only a certain kind of participant – for example, exclusively advertising for volunteers to participate in a health trial in hospital waiting rooms.
- **Survivorship**: a sample that considers only successes can be highly biased if failures are also relevant. For instance, an investigation of business debts that looked only at companies with more than ten years of accounts would ignore all companies that had failed within a shorter period.

Each of the following examples has at least one major problem in its sampling methodology. Try to identify the problem in each case:

1. To test pollution in a lake, I took 20 water samples at different times of day from one spot on the beach next to my lab.
2. To test pollution in a lake, I took three water samples from three different locations spaced throughout the site.
3. In order to find out whether literacy was in decline, I included my questionnaire about reading habits with every copy of a monthly political magazine.
4. My first major experiment about motivation levels in the general population involved a cohort of 50 student volunteers from Harvard Business School.

In the first example, taking every sample from a single spot makes them less likely to be representative of the entire lake – even though it’s a good idea to take 20, and to take them at different times of day.

In the second example, it’s a good idea to take samples from three different locations – but three is a very small number of samples to use in order to represent an entire lake.
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In the third example, including a questionnaire about literacy in a monthly magazine is likely to get responses from people who are unrepresentative of the population as a whole: the kind of people who not only read a monthly political magazine but also take the time to respond to literacy surveys.

The final example is also unlikely to represent the general population accurately, because the kind of people who are both studying at Harvard Business School and volunteer to take part in experiments seem likely to be more motivated than the population as a whole – not to mention likely to represent a narrower spectrum of traits such as age, wealth and education.

Here’s an improved sampling methodology for each of the three studies (the first and second examples being taken from the same one):

1+2 To test pollution in a lake, we took samples each day over the course of a year from 50 randomly selected sites across the lake at a variety of depths.

3 In order to investigate whether literacy was in decline, I gathered comparable data from the last 50 years across a representative sample of 100 schools.

4 My first major experiment about motivation levels in the general population involved a telephone poll conducted across a representative sample of 500 adults.

None of the above techniques are perfect, but they all represent an improvement and make it more likely that inductive inferences will meaningfully apply to the whole.

SMART STUDY 4.4

Picking a representative sample in four steps

Picking a representative sample means considering as fully as possible the variations that exist within whatever population you’re studying, or the range of circumstances you’re examining. Understanding the basic principles of successful, methodical sampling is vital for social scientists, and extremely useful for everyone else. In general, good sample design will:

- Establish as thoroughly and accurately as possible the specifics of the target population: without this, there is no way of knowing what variations you need to represent.
- Determine an appropriate sample size: in general, a larger sample size is better, but the exact size you need depends on how confident you need to be in your result, the level of variability within the population you’re studying, the margin of error in your measurements and the proportion of the population displaying whatever attribute you’re interested in (there are plenty of good online tools for calculating sample sizes).
- Determine an appropriate sampling method: this depends on what you’re studying and on what resources you have at your disposal; all methods have their limitations, and range from relatively simple ‘convenience’ samples based on volunteers or case studies to more complex ‘multi-stage’ samples based on dividing a population into clusters, and then selecting clusters at random for close examination.
REASONING WITH OBSERVATION AND UNCERTAINTY

- Consider whether results need weighting: this entails giving more weight to certain results within your sample in order to better reflect the overall situation - for example, giving adults twice the weight of children in a piece of research exploring transit costs, on the basis that adults' tickets cost twice as much as children's ones.\

THE PROBLEM OF INDUCTION

The best an inductive argument can ever do is suggest that something is very, very likely. This can be confusing, because most of the time we work on the basis that very, very likely things are effectively certain. Consider this famous example of an inductive argument:

Every day for millions of years, the sun has risen. Thus, the sun will rise tomorrow morning.

As the 18th-century philosopher David Hume pointed out, all of us believe that the sun will rise tomorrow: we act as though this has a probability of one. Yet this apparent fact is something we cannot prove with absolute certainty, any more than I can say something like this with absolute certainty:

I have been alive every day for the last 10,000 days; thus, I will always be alive.

Some day, I will die. Or – to put it in truly rigorous inductive terms – it is much, much more likely that I will die at some point than that I will live forever. Similarly, a day will almost certainly come when the sun itself no longer exists. Hopefully, this will happen many millions of years from now. Yet, it could in theory be tomorrow.

We can put this another way by noting that, although it will always be a perfectly valid deductive argument to say – ‘For millions of years, the sun has risen; every single day in the future will conform to this pattern; so the sun will always rise’ – at a certain point, this will cease to be a sound deductive argument. Eventually, the premise that the sun’s future will eternally resemble its past will cease to be true.

The fact that something happened in the past cannot guarantee that it will happen in the future, no matter how many times it has happened; this is sometimes known as the problem of induction. It is theoretically possible that I might never die, or that the sun might exist for ever and ever. It’s just very, very, very, very unlikely, based on our current understanding of the universe.

To this, you might reasonably say: this is just a made-up problem for philosophers to talk about. No one – not even a philosopher – actually talks about the world like this! We do not say, ‘the sun is very likely to rise tomorrow, but there is a tiny chance the world might end’. I do not say, ‘I will almost certainly meet you at Starbucks tomorrow at 2pm, apart from the small chance that I die or am incapacitated’.
FOUR

KNOW YOUR LIMITS. DON’T PRETEND TO KNOW WHAT YOU DON’T KNOW.
PRACTICE SAYING: I DON’T KNOW, I HAVEN’T READ THAT, I NEED TO FIND OUT MORE.
SEEK OUT OTHERS’ EXPERTISE. BUT REMEMBER: EXPERTISE IS ALWAYS SPECIFIC.
Even in science and research, the same is true. We say, ‘the flame heats the water’ – not ‘the flame is very likely to heat the water based on past experience’. We accept countless things as facts based on experience and consensus without feeling the need to constantly invoke probability. Why, then, does it matter that inductive reasoning is always concerned with probability rather than certainty? There are at least two important ways in which remembering this can make us better thinkers, researchers and writers:

- It helps us realize that many things we take for granted are not necessarily the whole truth, and that everyday thinking often ignores or under-estimates the uncertainties of the world.
- It allows us to avoid a misleading method of research that simply involves seeking confirmation of an idea, and instead to think rigorously about how likely something is to be true – and how we might most thoroughly test this through falsification.

**INDUCTION AND FALSIFICATION**

Here is a famous example of the way in which inductive reasoning can lead us into error – the error of overconfidence when using past experience as a basis for general conclusions:

Every swan ever observed has been white. Therefore, all swans are white.

This was believed to be true for many centuries in Europe – until the exploration of Australia, at which point a black species of swan was first glimpsed by Europeans (in 1697, during a Dutch voyage along its west coast). The sample of swans available to Europeans did not, it turned out, accurately represent the entire global population of swans. The global swan population actually existed across a wider range of possibilities than had previously been imagined.

It only takes one strong counter-example like this to falsify an inductive line of reasoning. Here, the discovery of a black species of swan demanded changes to all existing European beliefs around what a swan was. After 1697, it became necessary to replace the earlier generalization with something along these lines:

Every European swan ever observed has been white. Therefore, all European swans can be assumed to be white. But we now know that there are black swans, in Australia. Therefore, being white seems not to be a defining characteristic of all swans, only of European swans.

In this example, both the strengths and weaknesses of inductive reasoning are evident. The weakness is summed up by the phrase a black swan, which is now used to describe anything that lies so far outside previous experience and assumptions that it shows that a generalization previously thought to be true cannot be the case. The 2008 financial crisis was labelled a black
PART I: THE ART AND SCIENCE OF BEING REASONABLE

Black swan event: an event that defies both previous experience and expectations based on that experience, making it almost impossible to predict.

Black swan

swan by some in the finance industry, because it was something that lay entirely outside the expectations created by their previous experience.

The strength of a rigorous approach to inductive reasoning lies in the fact that even a black swan event can be learned from – and that, as when Europeans rethought their definition of a swan after 1697, we can use new evidence to produce a better description of the way things are.

Indeed, we can go further than this and argue that – given that inductive methods can never leave us in a position of absolute certainty – the most valuable kind of inductive reasoning actively sets out to invite falsification rather than seek confirmation.

Why is seeking falsification better than confirmation? Because evidence can be found to support any theory at all, whether it is correct or not. If I am determined to prove that all swans are white, I can point to a million white swans while ignoring anything that contradicts my belief. If a Dutch explorer returns from Australia with tales of black swan-like birds, I can simply laugh and dismiss his reports, saying that everyone knows swans are white. After all, I have personally seen one million white swans.

If, however, I am genuinely interested in coming up with the best possible account of what a swan is, the possible discovery of a black swan represents a wonderful opportunity for improving my concept of swans – because it falsifies an existing account of the way things are, creating the opportunity for me to come up with a new account that corresponds more closely with the real world.

THINK ABOUT THIS 4.2

What other examples of black swan events can you think of from history or from your own experience?

When has new information completely falsified something that people had simply assumed to be true?

Bearing in mind that the most important evidence you can gather is that which potentially falsifies a theory, here’s a famous puzzle for you to try. Imagine that there are four playing cards in a row in front of you. Each of them has a single patch of colour on one side and a number on the other – but you can only see the upturned sides. You are allowed to turn over as many or as few of the cards as you like in order to find out whether this particular rule applies to all of these cards:

If a card has an even number on one side, then it must have the colour yellow on the opposite side.
The upturned sides of the four cards show an eight, a three, a yellow patch and a grey patch – as in the diagram below. What card or cards must you turn over in order to test this rule, using the fewest steps possible?

Before I tell you the answer, it’s worth mentioning that when it was first devised as an experiment in 1966 around 90 per cent of people got this puzzle wrong. It’s called the Wason Selection Task, after the cognitive psychologist Peter Cathcart Wason, who designed it to explore the ways in which people struggle with logical reasoning.13

If this is the first time you’ve attempted this puzzle, and you haven’t yet looked at the answer, here is a hint: you need to turn over exactly two cards in order to test the rule, one showing a colour, one showing a number. Does this match your answer? If not, go back and think again before reading the next paragraph.

Ready? The answer is that you need to turn over the card showing the eight, and the grey card. Why? Because these are the only two cards capable of falsifying the rule.

We have said that a card with an even number on it will be yellow on the other side. Three is not an even number, so the card with the three on cannot test the rule: the rule doesn’t say anything about odd numbers also having yellow on the other side.

Similarly, no matter what number is on the other side of the yellow card, it cannot falsify the rule. If the number is even, then the rule holds; but if the number is odd, we simply have an example of an odd number that also has yellow on the other side.

The other two cards can falsify the rule, however, and so we need to test them both. If the eight has anything other than yellow on its back, the rule is falsified. And if the grey card has an even number on its back, the rule is also falsified – because even numbers are only allowed to have yellow on their back.

The Wason Selection Task is both a tricky logic problem and an exercise in gathering evidence to test a theory. In this, it’s a useful starting point both for thinking about induction and what it means to move beyond straightforward induction towards scientific notions of theories and proof: the subject of our next chapter.

**SUMMARY**

When applying **inductive reasoning**, you are dealing with degrees of certainty rather than absolutes; you are looking for reasons that suggest a conclusion is likely to be true. Inductive
reasoning is sometimes known as **ampliative reasoning**, to spell out the fact that its conclusions are an ‘amplification’ of its premises:

- In general, good inductive reasoning is based on well-established patterns with consistent supporting evidence, while weaker inductive reasoning results from poor evidence, no clear patterns, or a high degree of unpredictability and complexity.

When talking about how convincing an inductive argument is, we use the idea of **inductive strength**, also known as **inductive force**:

- A **cogent** inductive argument is one that has a good structure, but whose conclusion we should not necessarily accept as true, because we are unsure about the truth of its premises (similar to a valid deductive argument).
- An **inductively forceful** argument is one that has both a good structure and premises we accept as true, meaning we also have good reason to accept its conclusion as true (similar to a sound deductive argument, although without its certainty).

Inductive reasoning requires us to spell out the **implicit qualifications** in a premise: when a general statement is not literally true, we need to indicate whether it applies to a few, most or some cases; or often, sometimes, or infrequently.

**Probability** is the study of how likely something is to happen or to be true:

- Probability is usually expressed on a scale between zero and one, where a zero probability is entirely impossible and a probability of one is a certainty. A probability of 0.5 is equally likely to happen or not, while values above 0.5 are more likely than not and values below 0.5 are less likely.
- Assessing **rational expectation** is a key question around inductive arguments. Rational expectation asks: assuming the premises are true, is it more reasonable for you to expect an inductive argument’s conclusion to be true or false?
- By considering the relative plausabilities of different possible futures, we can **rank** a variety of inductive scenarios in terms of likelihood. More complex versions of a scenario – entailing more precise or specific predictions – are inherently less likely than simpler or less precise versions of the same scenario.

Making use of **samples** is a vital part of inductive reasoning. A sample consists of the particular cases you are examining in order to make larger generalizations:

- In general, the larger the sample, the better. A sample tends to be expressed in research through the letter **n**, where **n = 1** indicates a sample of one – an anecdote based on a single instance.
A representative sample is one that closely resembles the larger group it is taken from, while an unrepresentative sample is one that does not. Inductions based on an unrepresentative sample are likely to be distorted compared to reality.

A successfully randomized sample is one of the best ways of escaping bias in sampling, and means selecting elements of the sample at random from across the entire field of study, with no particular element misleadingly over-represented.

Because no sample is ever perfectly representative, it’s important to be aware of the margin of error (the chance that the result from a survey is the same as in the overall population) and of observational error (the accuracy of your measuring system).

The problem of induction describes the fact that, no matter how likely we believe something to be, no inductive argument can ever actually be confirmed – it can only seek refutation and counter-examples:

Falsification is an important investigative process for inductive reasoning, because a single counter-example can prove that an inductive line of reasoning is false – while no amount of positive instances can ever actually confirm one.

A black swan is something that defies all previous experience, and the expectations based on that experience, making it almost impossible to predict.

Now watch the video ‘The importance of proving people wrong’. It’s on YouTube. Tell me what you think via #TalkCriticalThinking