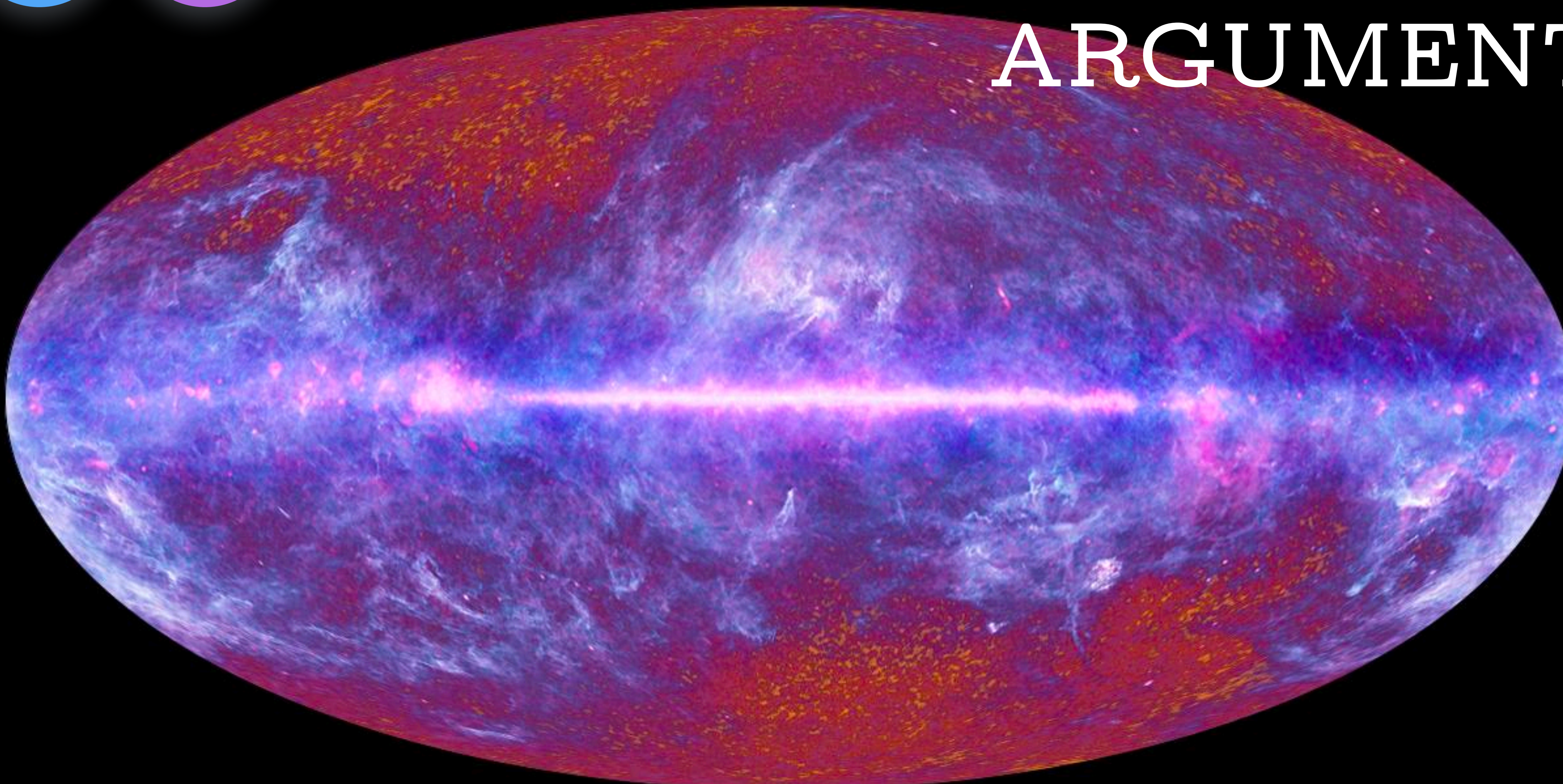
The fine-tuning argument



Suppose that I have an opaque jar with some number of ping pong balls in it. You know that the jar either has 10 ping pong balls in it or 1000 ping pong balls in it. In either case the balls are numbered sequentially. You think that the two possibilities are equally likely.

Suppose that we pick a ball at random. It is #3. Does this favor one hypothesis over the other?

It seems to favor the 10 ping pong ball hypothesis, since that hypothesis makes it more likely that #3 will be picked (rather than some number higher than 10).

But how much? How likely should I think that it is that the jar has 10 ping pong balls in it, vs. 1000?

Suppose someone offered you 50:1 odds that it is the 10-ball jar — so you win $50 if it is the 1000 ball jar, and lose $1 if it is the 10 ball jar. Should you take the bet?

Before we drew the ball, we thought that each theory had a 0.5 probability of being correct. This is called the theory's **prior probability.**

We also know something else. We know how likely each theory predicts it to be that we draw the #3 ball.

We know that the 10-ball theory says that there is a 0.1 probability that the #3 ball will be drawn. The 1000-ball theory says that there is 0.001 probability that this ball will be drawn.

This is a claim about what is called **conditional probability**. This is the probability that something will happen if something else is true. What we seem to know here is the probability of the evidence (e) conditional on the hypothesis (h). We write that like this:

$$\mathrm{P}(e \mid h)$$

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$$\mathrm{P}(e \mid h)$$

So we know the prior probability of the hypotheses, and the probability of the evidence given the hypothesis. What we **want** to know is this:

$$\mathrm{P}(h \mid e)$$

This is the probability of the hypothesis given the evidence. It tells us how likely we should take the hypothesis to be, given the evidence we have observed.

How can we do this?

How can we do this?

One way to answer these questions employs a widely accepted rule of reasoning called "Bayes' theorem," named after Thomas Bayes, an 18th century English mathematician and Presbyterian minister.

To arrive at the theorem, we begin with the following definition of conditional probability:

$$P(a|b) = \frac{P(a\&b)}{P(b)}$$

This says that the probability of *a* given *b* is the chance that *a* and *b* are both true divided by the chance that *b* is true.

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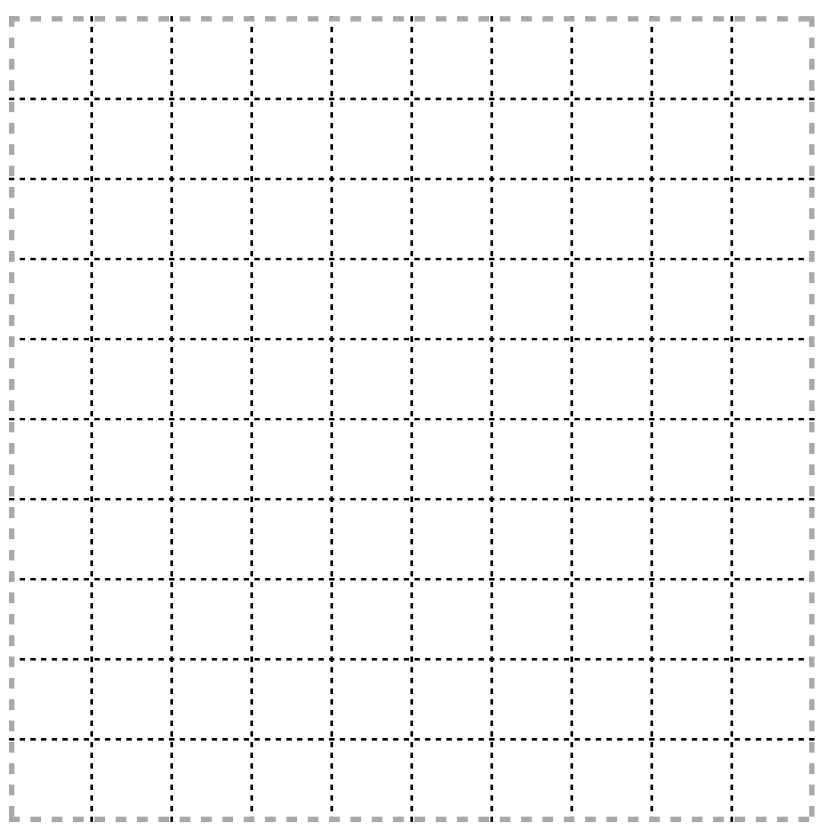
Why might this be true? Intuitively, the idea is this. Take all of the chances that *b* could be true, and look at how many of them *a* is also true in. Divide the situations in which both *a* and *b* are true by the total number of situations in which *b* is true — and that will tell you how likely it is that *a* will be true if *b* is. And that just is P($a\,|\,b$).

$$P(a|b) = \frac{P(a\&b)}{P(b)}$$

Here's an example to illustrate. Suppose that we have three candidates for political office. Mr. A has a 20% chance of winning, Mr. B has a 30% chance of winning, and Ms. C has a 50% chance of winning.

What's the probability that Mr. A wins given that a man wins?



Let's divide the possible outcomes into 100 squares. Then Mr. A wins in 20 of the squares, Mr. B in 30, and Ms. C in 50.

Bayes' theorem

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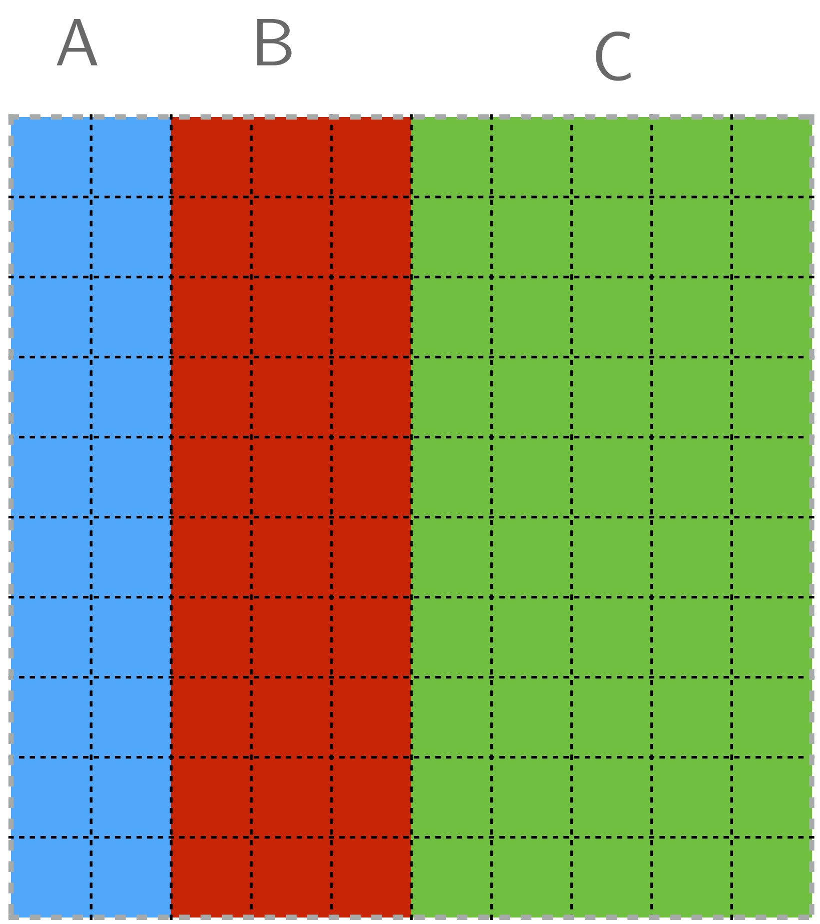

Let's divide the possible outcomes into 100 squares. Then Mr. A wins in 20 of the squares, Mr. B in 30, and Ms. C in 50.

What do we learn when we learn that a man wins? We learn that we can eliminate the green squares.

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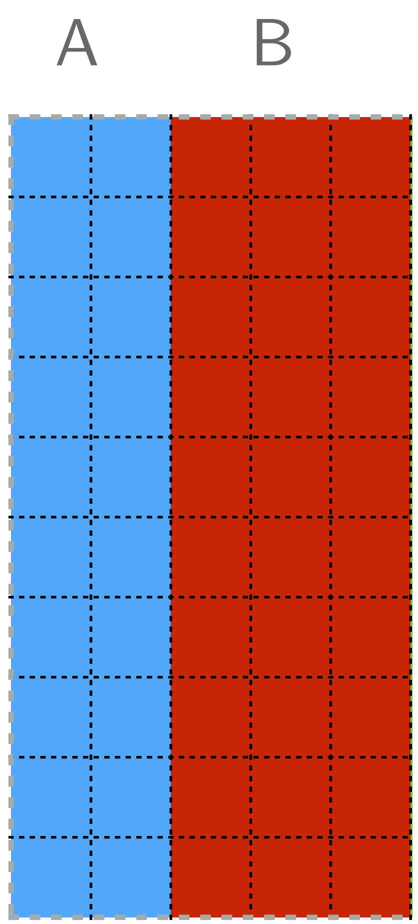

What do we learn when we learn that a man wins? We learn that we can eliminate the green squares.

So what are the odds that Mr. A wins, given that a man wins? We just look at which percentage of the remaining squares are blue squares.

The answer is: 40% of them, just as the formula above says.

$$P(a|b) = \frac{P(a\&b)}{P(b)}$$

Using this definition of conditional probability, we can prove the following:

Bayes' theorem

$$P(h\,|\,e) = \frac{P(h) * P(e\,|\,h)}{P(h) * P(e\,|\,h) + P(\neg h) * P(e\,|\,\neg h)}$$

(You can see the proof here.)

The first thing I want you to see is why this theorem would be useful. It enables us to take some probabilities which are often quite easy to figure out — the prior probability of a theory, and the likelihood of some evidence given that theory — and tells us something which is often quite hard to figure out — the probability we should assign to the hypothesis given the evidence.

This formula looks daunting. But the idea that it expresses is actually fairly intuitive.

Bayes' theorem

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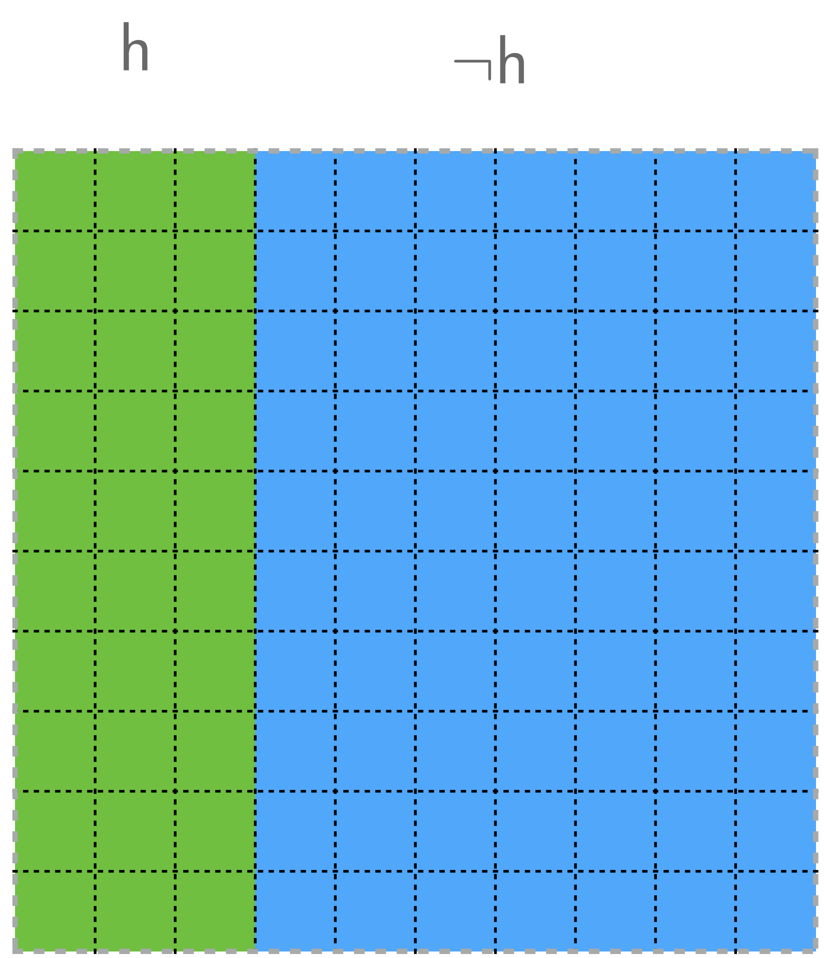
Let's imagine that we have some hypothesis, h, which we think has a 30% likelihood of being true. We can represent this, as before, using a grid of 100 squares.



Suppose now that we get some evidence, e. Suppose further that if h is true, there is a 2/3 chance that e will be true. (That is, $P(e|h) = 2/3$.)

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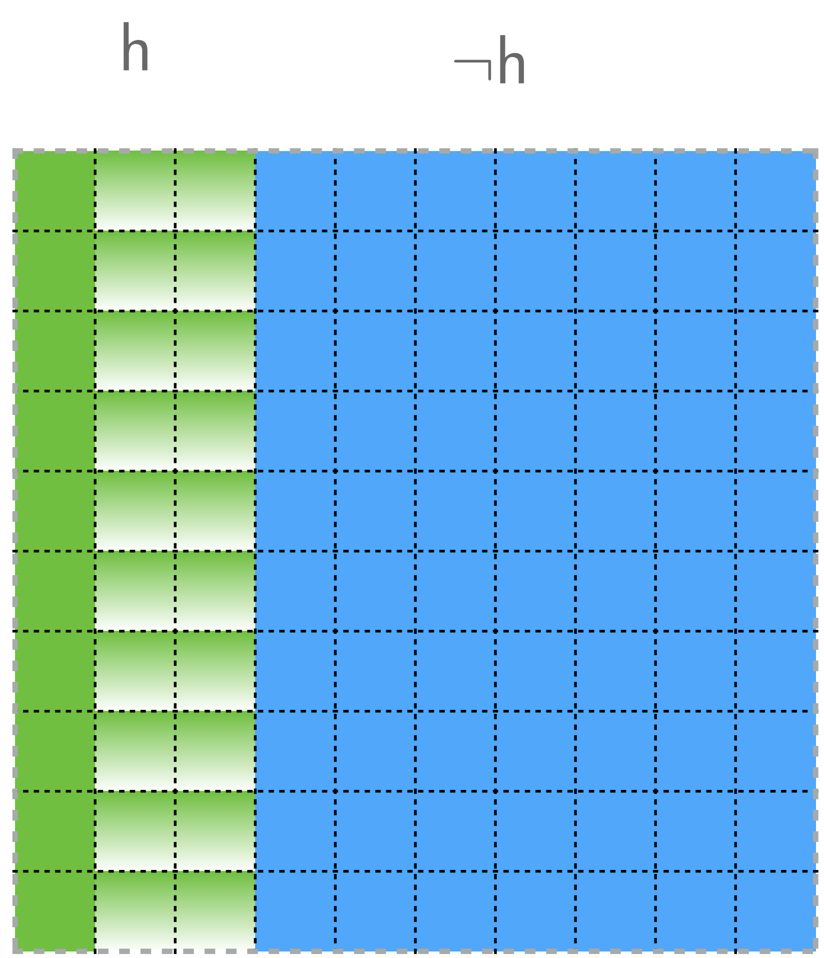

Suppose now that we get some evidence, e. Suppose further that if h is true, there is a 2/3 chance that e will be true. (That is, $P(e|h) = 2/3$.)

Now suppose that if h is false, there is only a 1 in 10 chance that e is true. (That is, $P(e|\neg h) = 0.1$)

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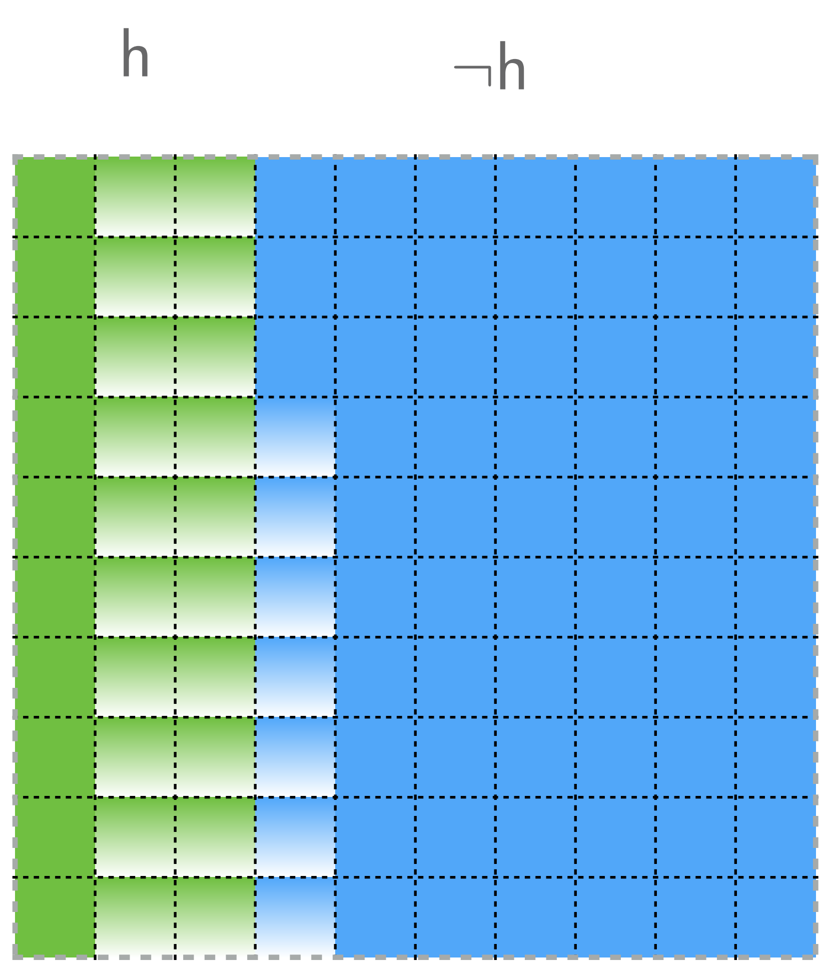

Now suppose that if h is false, there is only a 1 in 10 chance that e is true. (That is, P(e|¬h) = 0.1)

How do we figure out the probability of h given our new evidence? Just as in our previous example, we can start by deleting all of the squares where e is false.

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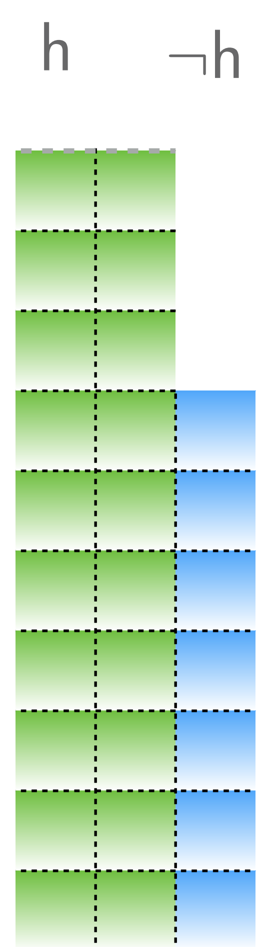

The squares which remain are, intuitively, the possibilities which are not eliminated by our evidence.

To figure out P(h|e), we ask what percentage of the remaining squares are ones in which h is true.

$$P(h|e) = 20 / (20+7) \approx 0.74$$

Note that this is exactly the equation that Bayes' theorem tells you to write down to answer our question.

Bayes' theorem

$$P(h \mid e) = \frac{P(h) * P(e \mid h)}{P(h) * P(e \mid h) + P(\neg h) * P(e \mid \neg h)}$$

Remember now our original case of the urns and the balls. Figuring out the likelihood that the urn contains 10 balls is now a straightforward matter of plugging in some numbers are doing some arithmetic.

After all, we know the following probabilities:
P(h)=0.5
P(¬h)=0.5
P(e|h)=0.1
P(e|¬h)=0.001

This gives us all the information we need to plug into Bayes' theorem:

$$P(h \mid e) = \frac{0.5 * 0.1}{0.5 * 0.1 + 0.5 * 0.001} \approx 0.99$$

Enough about probability (for now). Let's turn now to some results from contemporary physics which will be important to the argument which follows.

A first question: what does the theory provided by physics include?

> "The standard model of physics presents a theory of the electromagnetic, weak, and strong forces, and a classification of all known elementary particles. The standard model specifies numerous physical laws, but that's not all it does. According to the standard model there are roughly two dozen dimensionless constants that characterize fundamental physical quantities." (Hawthorne & Isaacs, "Fine-tuning fine-tuning")

These "dimensionless constants" will be our focus.

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One such constant is the cosmological constant, which measures the energy density of empty space.

The cosmological constant is just a number which (as far as we know) could have different values consistent with the laws of physics.

One thing that the standard model of physics gives us is a measure of how likely it is, given the laws of the nature, that the fundamental constants (like the cosmological constant) would fall in a certain range.

We can make certain plausible assumptions about what it would take for life to have evolved. For example, if there were nothing but hydrogen, it is hard to see how life could have evolved. If there were no planets, it is hard to see how life could have evolved.

Given assumptions such as these, we can look at what the standard model of physics tells us about how likely it is that, for example, the cosmological constant has a value which would permit the evolution of life.

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Contemporary physics tells us that the conditional probability of the cosmological constant having a life-supporting value, given the laws of nature, is very low.

> We should emphasize just how small we take the life-permitting parameter values to be according to the physically-respectable measures. "Small" here doesn't mean "1 in 10,000" or "1 in 1,000,000". It means the kind of fraction that one would resort to exponents to describe, as in "1 in 10 to the 120". The kind of package that we have in mind tells us that only a fantastically small range is life permitting.

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The claim is that, according to current physics, the probability of the cosmological constant falling in a life-supporting range, given the laws of nature, is $\frac{1}{10^{120}}$.

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Let's now ask how to turn these facts about current physics and probability theory into an argument for the existence of God.

Much as we considered two different hypotheses about the number of balls in the urn, so we can consider two different hypotheses about the origins of the universe.

Let the **design hypothesis** be the hypothesis that the universe was created by an intelligent designer.

Let the **non-design** hypothesis be the hypothesis that the universe was **not** created by an intelligent designer.

Let **life** be the claim that the cosmological constant falls in the life-supporting range.

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Let **life** be the claim that the cosmological constant falls in the life-supporting range.

Then what do we know about the relevant probabilities? Consider first the probability of life conditional on non-design.

Our discussion above suggests that this probability should be tiny. The reason is that, according to current physics, the probability of the physical constants being in a life-permitting range is tiny and, if the constants are not in a life-permitting range, there is no life. So that suggests:

$$Pr(\text{life} \,|\, \text{non-design}) = \frac{1}{10^{120}}$$

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It seems at least reasonably plausible that, if the universe were created by an intelligent designer, that designer would make it the case that the fundamental constants are such as to permit life. Just to pick a number, let's suppose that

$$Pr(\text{life} \,|\, \text{design}) = 0.5$$

What we want to know is: what are the probabilities of our two hypotheses, conditional on our evidence?

$$Pr(\text{life} \,|\, \text{non-design}) = \frac{1}{10^{120}}$$

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Bayes' theorem

$$P(h \,|\, e) = \frac{P(h) * P(e \,|\, h)}{P(h) * P(e \,|\, h) + P(\neg h) * P(e \,|\, \neg h)}$$

This is what Bayes' theorem is for. But to apply that theorem, we need the prior probability of the two hypotheses.

Let us suppose that we are perfect agnostics, so that

$$Pr(\text{non-design}) = 0.5$$

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$$Pr(\text{non-design}) = 0.5$$

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With this information in hand, figuring out the probability of the non-design hypothesis given our evidence is a matter of just plugging in the numbers.

$$Pr(\text{non-design} \,|\, \text{life}) \approx \frac{2}{10^{120}}$$

$$Pr(\text{non-design} \mid \text{life}) \approx \frac{2}{10^{120}}$$

This is the probability of the non-design hypothesis being true, given that the cosmological constant is in the life-permitting range.

It is difficult to think about numbers as large as the denominator of this fraction. But to give you some idea: the odds of winning Powerball are about 1 in 300 million. Now consider the odds of winning Powerball one trillion times in a row. Call that a "super Powerball."

Now consider the odds of winning a super Powerball one trillion times in a row. Call that a "super duper Powerball."

Now consider the odds of winning a super duper Powerball one trillion times in a row. The odds of this happening are about 1 / 10^{44} — so much, much higher than the odds of the cosmological constant falling in the life-permitting range by chance.

This means that if you simply take the physics at face value, and begin by assigning a probability of 0.5 to the non-design hypothesis, you should think that the chances of the non-design hypothesis being true are vastly lower than the chances of winning a super duper powerball a trillion times in a row.

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By contrast, the probability of the design hypothesis is very close to 1. It is, in fact, roughly 1 minus the very small number we were just discussing:

$$Pr(\text{design} \mid \text{life}) \approx 1 - \frac{2}{10^{120}}$$

This is about as close to certainty as it is possible to get.

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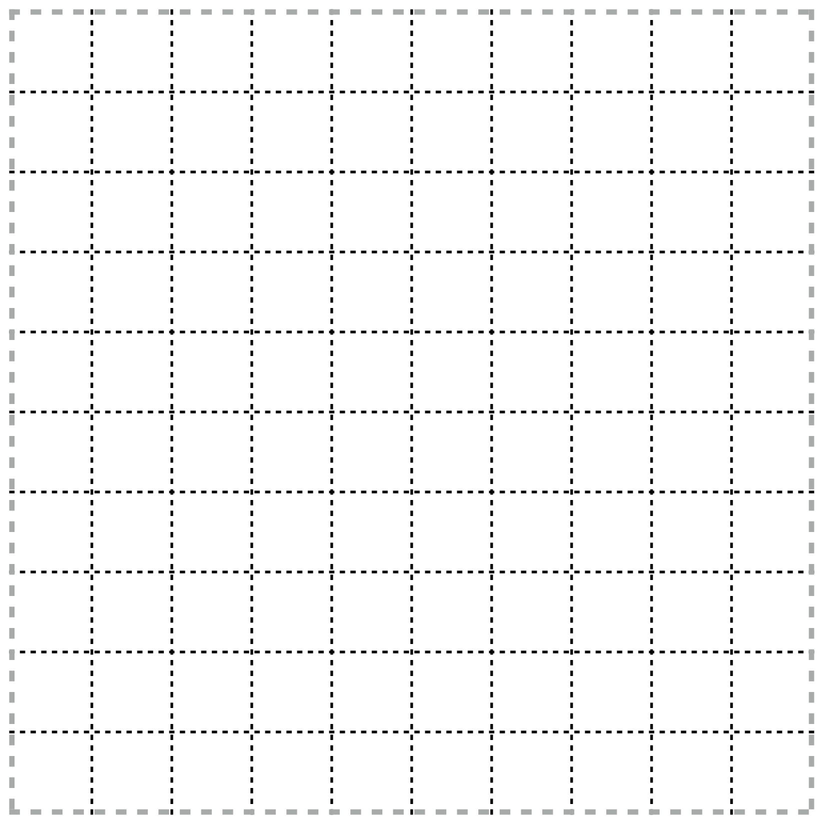

As before, we begin with a grid which represents the possibility of the design and non-design hypotheses being true.

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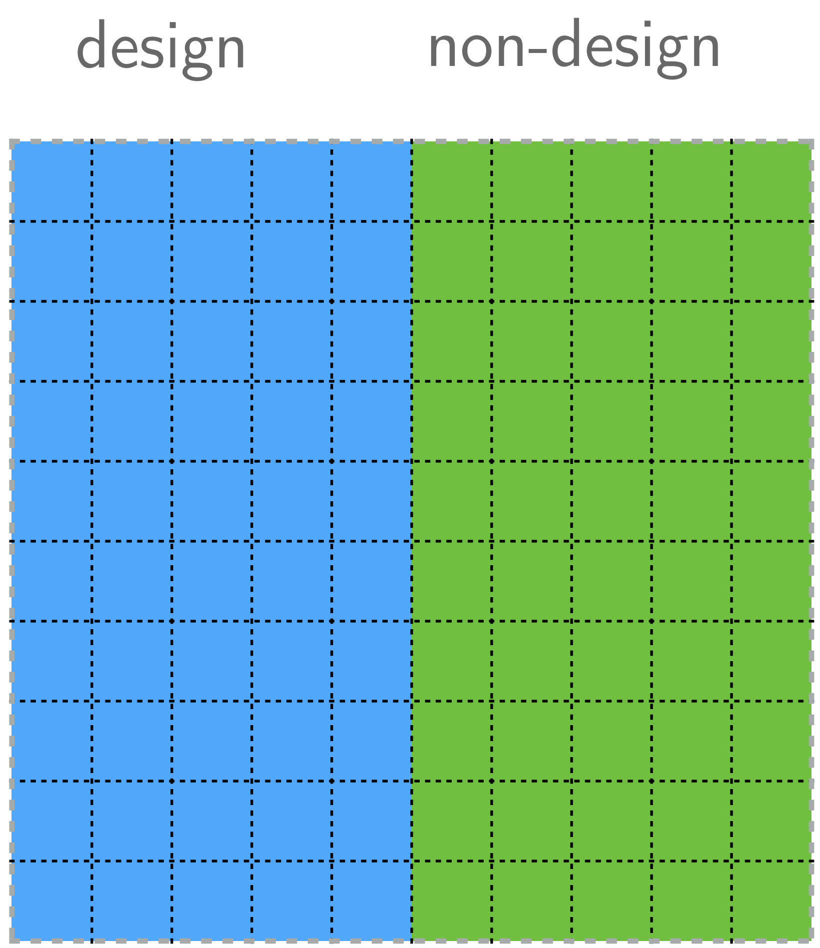

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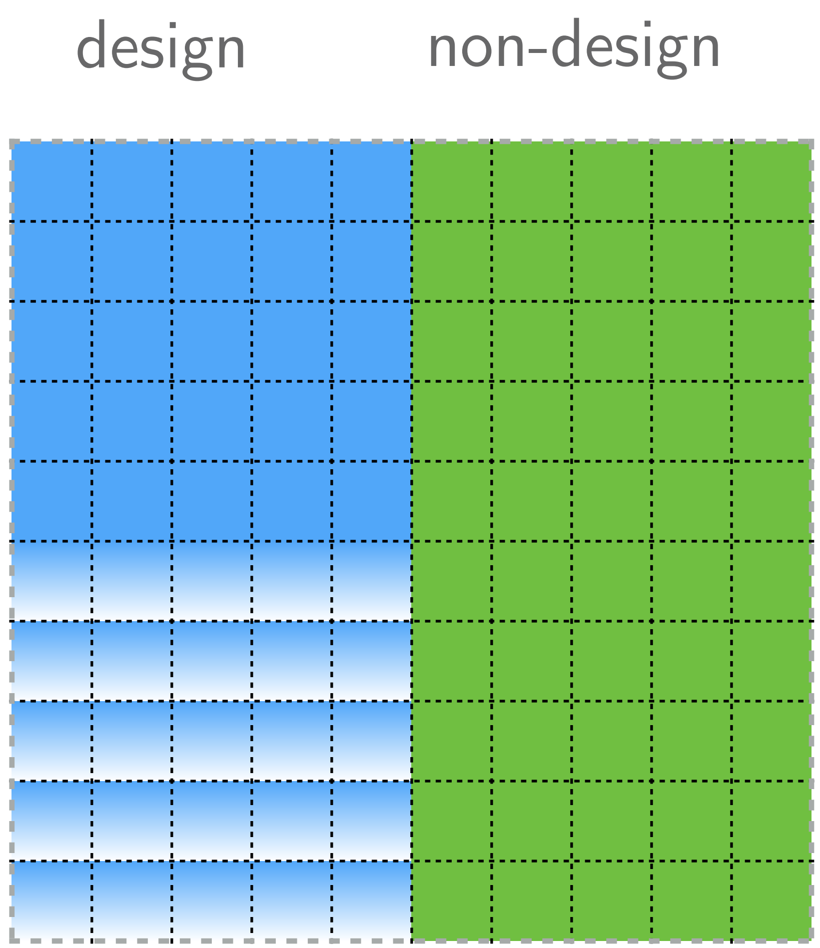

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And let's suppose that the odds of the constant falling in this range given non-design are 1/10^120.

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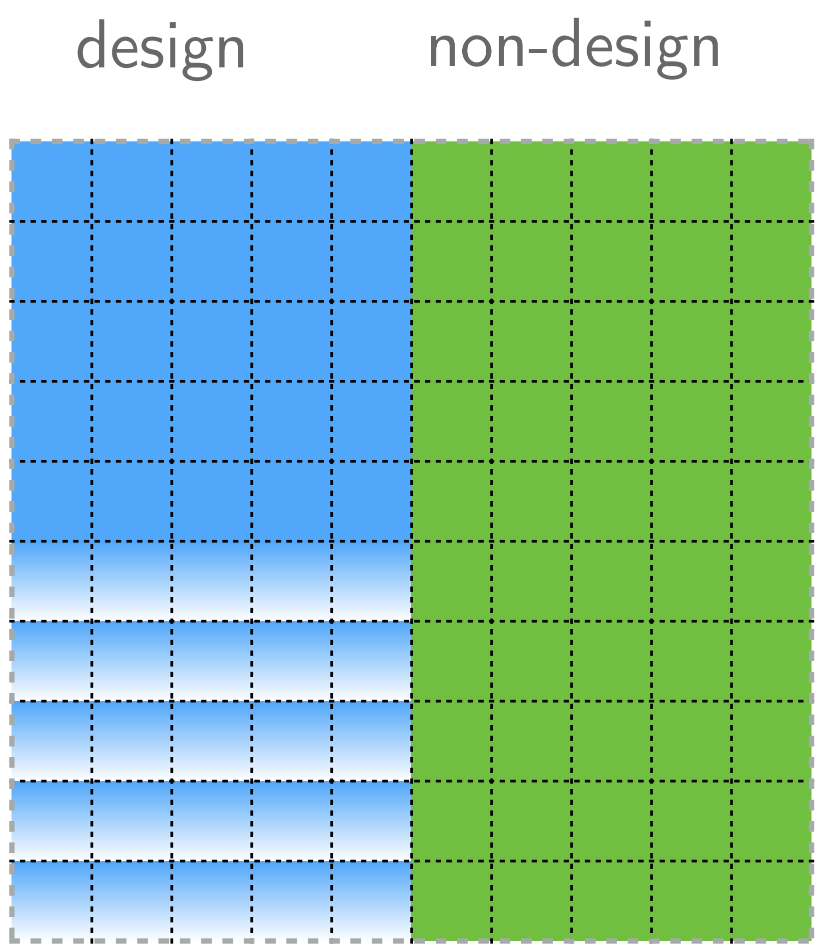

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We now eliminate all of the squares where our evidence — that the cosmological constant is in fact in the life-supporting range — is false.

And let's suppose that the odds of the constant falling in this range given non-design are 1/10^120.

Bayes' theorem
fine-tuning of the universe
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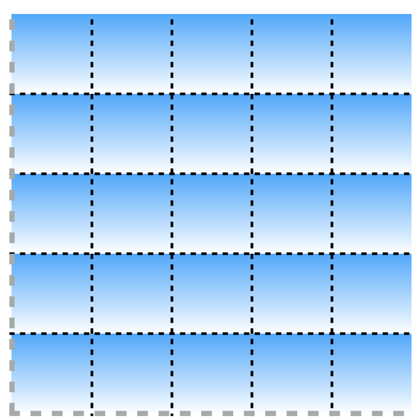
design non-design



We now eliminate all of the squares where our evidence — that the cosmological constant is in fact in the life-supporting range — is false.

The problem is that the non-design hypothesis is so fantastically unlikely that it cannot be represented on a computer screen.

A high end 27" 5K screen has around 15 million pixels. To represent the gap between the probabilities of our two hypotheses given the evidence we would need a 5k screen vastly larger than the size of the universe with one pixel lit.

So far we have not written this out as a premise/conclusion argument. But it would not be hard to do so.

THE FINE-TUNING ARGUMENT

1. $\texttt{P(life|design)} = 0.5$
2. $\texttt{P(life|non-design)} = \dfrac{1}{10^{120}}$
3. P(design)=P(non-design)=0.5.
4. Bayes' theorem.
5. $\texttt{P(design|life)} \approx 1$. (1,2,3,4)
6. Life exists.
7. P(design) ≈ 1. (5,6)
8. If the universe was created by an intelligent designer, then God exists.

C. P(God exists) ≈ 1. (7,8)

This looks like a powerful argument for the existence of God. It is notable that it seems to use no especially controversial philosophical assumptions, like the Principle of Sufficient Reason.

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How might someone object to this argument? I am going to assume that Bayes' theorem is true. I am also going to set aside objections to premise (8) — not because one couldn't object to this premise, but rather because we have already discussed quasi-theist responses to the other arguments for God's existence at some length.

Bayes' theorem

fine-tuning of the universe

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objections

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Instead, I am going to explore the possibility that one might respond to this argument by questioning some of the assumptions about probabilities that the argument makes.

We also know that P(non-design) = 1 - P(design). So there are really only three probabilities that we need to assign.

A = P(design)
B = P(life | design)
C = P(life | non-design)

And we know from Bayes' theorem that

$$P(\text{design} \mid \text{life}) = \frac{A*B}{A*B + (1\text{-}A)*C}$$

Let's have a look at how changing the probability assignments might change the probability that we should assign to the design hypothesis.

$$P(\text{design} \mid \text{life}) = \frac{A*B}{A*B + (1\text{-}A)*C}$$

Let's have a look at how changing the probability assignments might change the probability that we should assign to the design hypothesis.

Here were our initial assignments:

$$A = P(\text{design}) = 0.5$$

$$B = P(\text{life} \mid \text{design}) = 0.5$$

$$C = P(\text{life} \mid \text{non-design}) = \frac{1}{10^{120}}$$

Bayes' theorem

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$$P(\text{design} \mid \text{life}) = \frac{0.5 * 0.5}{0.5 * 0.5 + (1-0.5) * \frac{1}{10^{120}}} = 0.99999999999999....$$

(not infinitely, but for a very long time)

$$A = P(\text{design}) = 0.5$$

$$B = P(\text{life} \mid \text{design}) = 0.5$$

$$C = P(\text{life} \mid \text{non-design}) = \frac{1}{10^{120}}$$

Which of these probability assignments might someone skeptical of the existence of God reasonably challenge?

It is natural to question P(design). Our initial statement of the argument assumed that there is a 0.5 prior probability of the claim that the universe was created by an intelligent designer. But of course not all will agree to that; imagine that an atheist claims that there is only a 1 in 1 million chance that the design hypothesis is true. Will that matter?

Let's run the numbers.

Bayes' theorem

fine-tuning of the universe

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objections

$$P(\text{design} \mid \text{life}) = \frac{0.000001 * 0.5}{0.000001 * 0.5 + (1 - 0.000001) * \frac{1}{10^{120}}} = 0.99999999999999....$$

$$A = P(\text{design}) = 0.000001$$

$$B = P(\text{life} \mid \text{design}) = 0.5$$

$$C = P(\text{life} \mid \text{non-design}) = \frac{1}{10^{120}}$$

It makes hardly any difference. Now the odds of the design hypothesis being false are closer to $\frac{1}{10^{114}}$ than $\frac{1}{10^{120}}$; but that is still a really, really tiny probability.

What if the atheist was completely certain that the design hypothesis is false, and gives that hypothesis a prior probability of 0. Would that matter?

It would. Then the argument would not move the needle. But the problem is that being as sure that the design hypothesis is false as you are that 2+2=4 doesn't seem very reasonable to most people.

$$P(\text{design} \mid \text{life}) = \frac{0.5*0.5}{0.5*0.5 + (1-0.5)*\frac{1}{10^{120}}} = 0.99999999999999....$$

$$A = P(\text{design}) = 0.5$$

$$B = P(\text{life} \mid \text{design}) = 0.5$$

$$C = P(\text{life} \mid \text{non-design}) = \frac{1}{10^{120}}$$

Let's go back to the view that the prior probability of design is 0.5, rather than 1 in a million. Might one challenge the probability assigned to life given non-design?

Sure, that probability was based on the findings of contemporary physics. But we are surely not **certain** that physics is correct about this. What if there is, say, a 10% chance that physics was fundamentally wrong about some major things, and that the odds of the constants having life supporting values in that case is not $\frac{1}{10^{120}}$, but rather something like 0.5?

$$P(\text{design} \mid \text{life}) = \frac{0.5 * 0.5}{0.5 * 0.5 + (1-0.5) * \frac{1}{10^{120}}} = 0.99999999999999....$$

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This changes the probability of life given non-design. It is not $\frac{1}{10^{120}}$, but rather a number very slightly larger than 0.05.

$$P(\text{design} \mid \text{life}) = \frac{0.5*0.5}{0.5*0.5 + (1-0.5)*0.05} \approx 0.91$$

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Unlike decreasing our prior probability in design, this makes a difference! The reason why it makes a difference is that it creates a possibility with a non-tiny probability on which the design hypothesis is false: the possibility that physics is seriously mistaken in the right way.

Now, this doesn't rob the argument of all force. Even if we assign the (pretty high) probability of 0.1 to physics of being messed up, the argument still moves a perfect agnostic to believing that there is a greater than 90% chance that the design hypothesis is true. That is pretty good!

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But note that once we have on the table the possibility that contemporary physics is wrong, one's prior probabilities in the design hypothesis **do** matter. Suppose, for instance, that before encountering the argument you thought that there was only a 10% chance that the design hypothesis is true, and suppose that you also think that there is 10% chance in physics being wrong in the relevant way.

$$P(\text{design} \mid \text{life}) = \frac{0.1 * 0.5}{0.1 * 0.5 + (1 - 0.1) * 0.05} \approx 0.53$$

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Then as a result of the argument you should think that there is about a 53% chance that the design hypothesis is true. This is still a big change — you would go from being a pretty convinced atheist to an agnostic — but the result is not the sort of near certainty in the design hypothesis that we saw on our earlier assumptions.

Summing up: we have seen that changes to our initial probability assignments can affect the force of the argument. But there are two significant limitations to this style of objection.

The first is that it relies on thinking that there is a non-trivial chance that contemporary physics is fundamentally mistaken. And note that this would have to be a pretty big mistake.

The second is that, even if one thinks that there is a pretty big (say, 10%) chance that physics is mistaken, the argument retains considerable force. As we saw above, it can turn a fairly convinced atheist into an agnostic, and can turn an agnostic into someone who thinks that there is a greater than 90% chance that the design hypothesis is true.

Let's now consider a new way of questioning the probability assignments:

The multiverse objection

There are very many — perhaps infinitely many — distinct universes, which can have different fundamental physical constants.

Surely, this objection goes, if there were enough universes, then no matter how improbable it is that one of them would have constants that fall in the life-permitting range, it is not so improbable that some would. This would then be a way of rejecting premise (2) of the argument.

Our situation would then be somewhat analogous to the position of someone who wins the lottery. The odds of **that** person winning the lottery were very small; but if enough people buy tickets, it is not so improbable that someone wins.

It would be unreasonable for the winner to infer that the lottery was rigged in her favor; just so, it would be unreasonable for us to assume that our universe was designed.

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If we take seriously the multiverse hypothesis, that again causes us to revise our view of the probability of life given non-design.

Suppose that we think that there is a 0.5 probability that we life in a multiverse, and think that the probability of life existing in a multiverse is 1 (or very close to it). Then (setting aside for now the possibility that contemporary physics is mistaken) that makes the probability of life given non-design 0.5. And in that case life is equally likely on the design hypothesis and on the non-design hypothesis. And then then fact of life is **no evidence at all** for the design hypothesis.

So the key question is: do we have good reason to think that the multiverse hypothesis is true?

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A first point to note: it would be very surprising if this hypothesis were true. For, if it is, there are very many — perhaps infinitely many — other universes, each as real as ours, in which some near-duplicate of you exists. There is, for example, very likely one in which there exists some being with a qualitatively identical history to you who differs from you only in that she or he scratched his nose one second ago.

This does not show that the multiverse hypothesis is false; the universe might be strange, and science has often shown us that it is. But it does suggest that the multiverse hypothesis is not one that we should believe without argument.

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But one might think that the very facts used in the fine-tuning argument can be used to support the multiverse hypothesis. For consider the following argument:

A Bayesian argument for the multiverse

It is very, very improbable that our universe is the only one and, just by chance, the constants came to be set in such a way as to make life possible. But if there were many many universes, it would not be very improbable that one would be life supporting. So, the fact that our universe is life-supporting is strong evidence in favor of the multiverse hypothesis.

But, while this reasoning sounds plausible, consideration of parallel cases shows that something has gone wrong.

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A Bayesian argument for many dice rollers

I am sitting in my office, and I pick up 12 dice and decide to roll them. I roll all sixes. Amazed, I think to myself: there must be lots of people rolling dice in Malloy Hall right now. After all, what are the odds that someone rolls 12 sixes in Malloy in the case where there is just one person rolling dice?

This would be terrible reasoning; the fact that I rolled all sixes, however improbable, is not evidence for the existence of many rollers. What has gone wrong?

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One diagnosis is that we need to distinguish between two pieces of evidence we might have:

E1. I rolled 12 6's.

E2. Someone in Malloy rolled 12 6's.

The existence of many rollers would make Evidence 2 more likely. Would it make Evidence 1 more likely?

If not, then it looks like Evidence 2, but not Evidence 1, provides evidence for the many rollers hypothesis. Since in our imagined scenario what I possess is Evidence 1, my inference that there must be many rollers was illegitimate.

But now compare this to the case of the multiverse.

E1. This universe has life-permitting constants.

E2. Some universe has life-permitting constants.

Which of these, if either, does the multiverse hypothesis make more likely? Only E2, it seems. But it looks like E1 is the evidence we have; so it looks like the probability of our evidence conditional on the multiverse hypothesis is not higher than the probability of that evidence conditional on the single universe hypothesis.

Could one object that we also have E2 as evidence, and say that E2 **is evidence for the multiverse?**

But if that were legitimate we could do the same thing in the many rollers case -- and we know that that is a mistake.

Summing up: it appears that, if we have good reason to believe the multiverse hypothesis, this would be bad news for the fine-tuning argument. But it also seems that the fact that our universe is life-supporting is not itself evidence for the multiverse hypothesis. So the key remaining question is: do we have any good reason to believe in the multiverse?

This is a question very much in dispute — though the dispute is as much among physicists as philosophers. Some physicists think that there is physical evidence in favor of the multiverse hypothesis. Others think that the very idea of physical evidence about universes distinct from our own makes little sense.

Here — as in other cases — we have an example in which philosophical reasoning and scientific theory are intertwined.

What seems clear is that if (1) there is just one universe and (2) current thinking about the fundamental constants in physics is on the right track, then the fine-tuning version of the design argument is a powerful argument for the existence of a designer of the universe.

Appendix: Proof of Bayes' theorem

Remember our definition of conditional probability:

$$P(a|b) = \frac{P(a\&b)}{P(b)}$$

Using this definition, we can prove Bayes' theorem as follows:

Derivation of Bayes' theorem

1. $P(a|b) = \frac{P(a\&b)}{P(b)}$	def. of conditional probability
2. $P(b|a) = \frac{P(a\&b)}{P(a)}$	def. of conditional probability
3. $P(a|b) * P(b) = P(a\&b)$	(1), multiplication by ='s
4. $P(a\&b) = P(b|a) * P(a)$	(2), multiplication by ='s
5. $P(a|b) * P(b) = P(b|a) * P(a)$	(3),(4)
C. $P(a|b) = \frac{P(b|a) * P(a)}{P(b)}$	(5), division by ='s

To go back to the main lecture, click here.