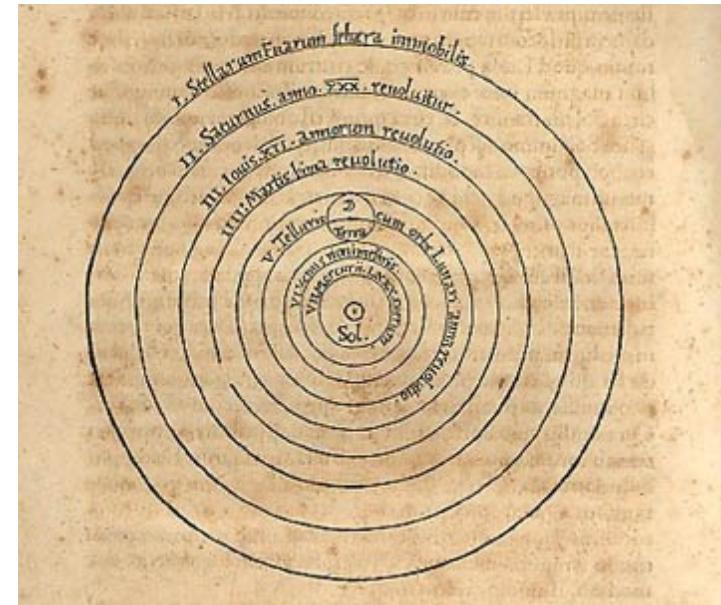
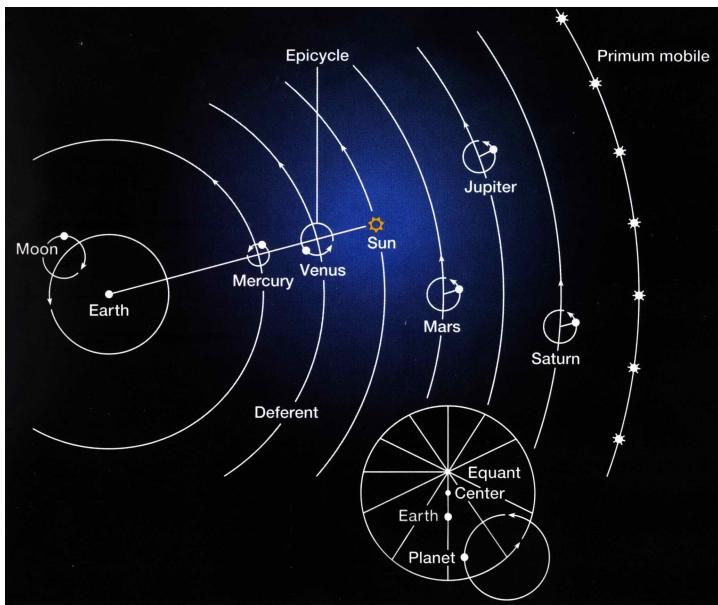


Knowledge and the Universe

Vera Gluscevic

In astronomy...



Heliocentric vs. Geocentric system?

How often do you make decisions or draw conclusions?
How important are they?
How reliable are they?



what about inferences in science?
Are they different?
Why?



The story about the process of science.



Freelance Revolution: Meet Kola...
forbes.com



So, You Want To Be A Scientist?
careerbright.com



Scientists Rises, Pew Poll Shows ...
the-scientist.com



research into medieval p...
theguardian.com



building knowledge

The story about the process of science.



Freelance Revolution: Meet Kola...
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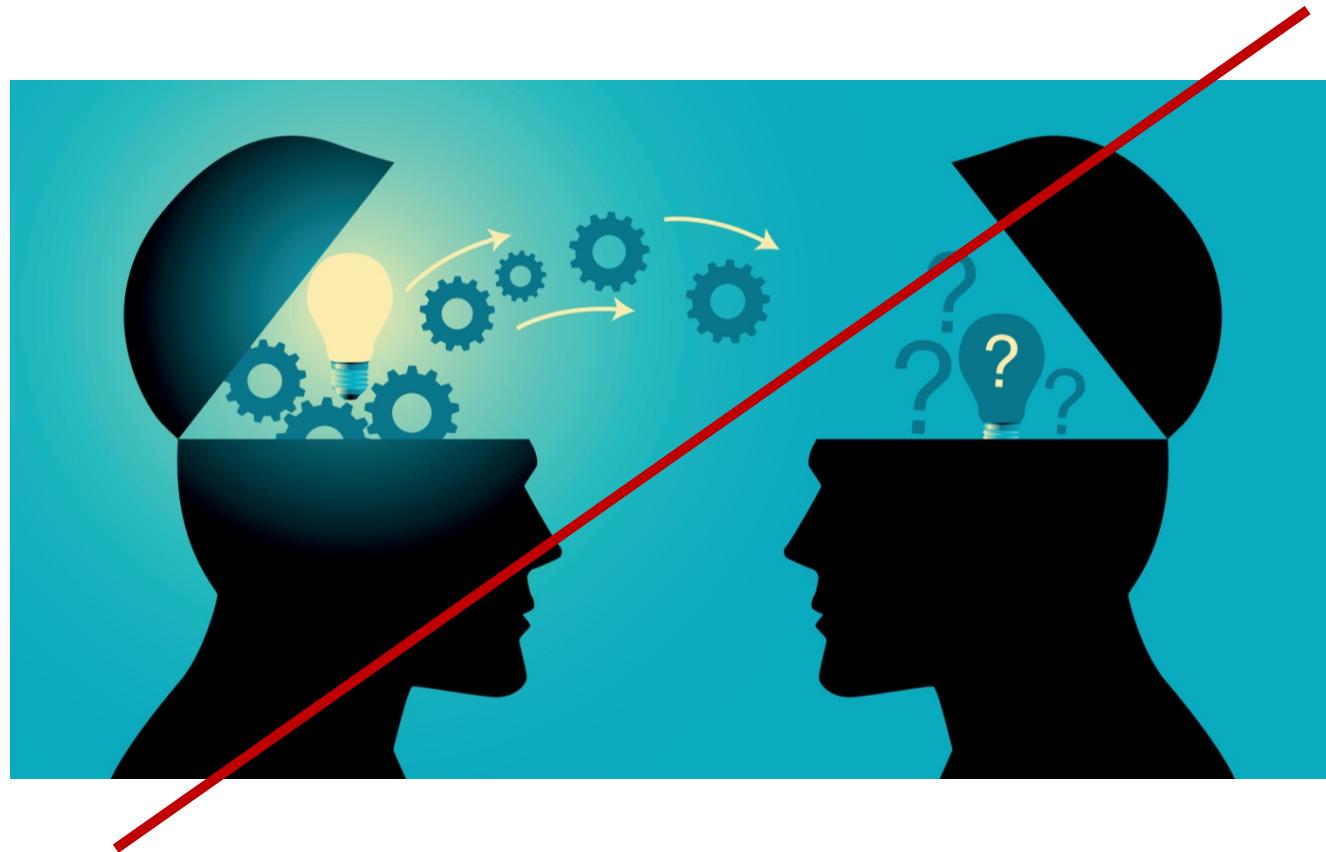
Scientists Rises, Pew Poll Shows ...
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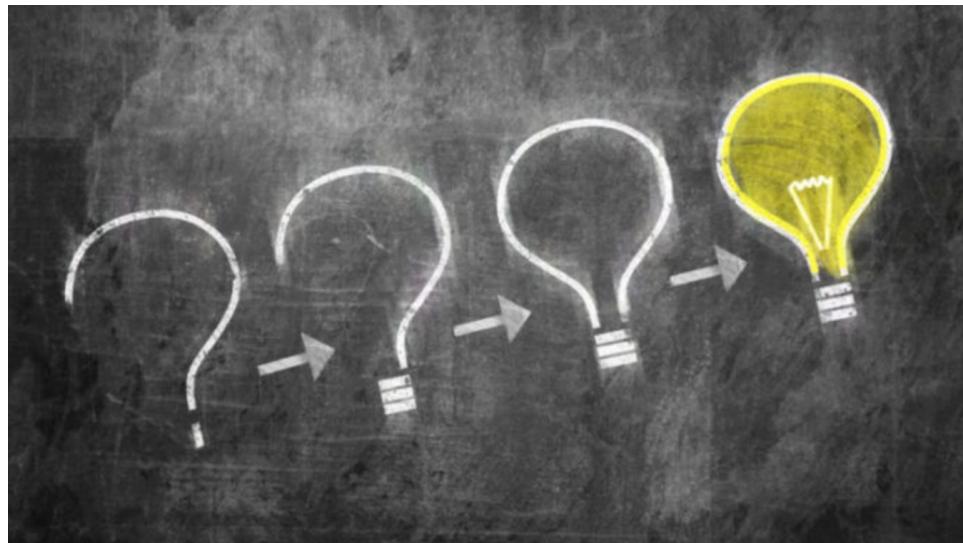


The story about the process of **building knowledge**.



The story about the process of **building knowledge**.

Question



Answer
Knowledge
Belief

human

The story about the process of building knowledge.



Tools for building knowledge

Experience

Experiment

Observation

Common sense

Tools for building knowledge

Questions

Likelihood

Intuition

Evidence

Questions

Common sense

Intuition

Tools for building knowledge

Likelihood

Tools for building knowledge

Evidence

Questions

Likelihood

Common sense
+
Intuition



What is “intuition”?

Tools for building knowledge

Evidence

Questions

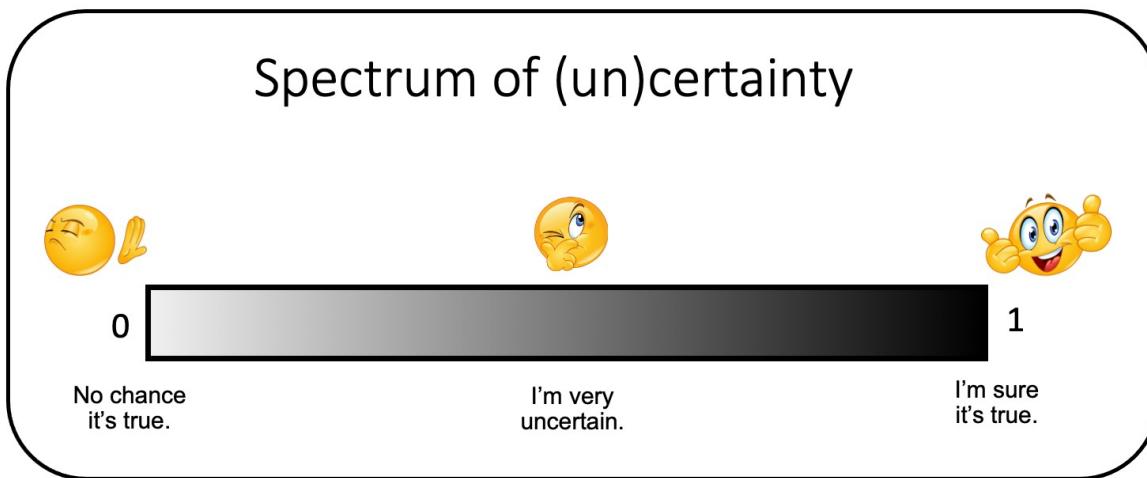
Likelihood

Prior knowledge



What is ``likelihood''?

We're gonna call that *probability*.



Tools for building knowledge

Evidence

Questions

Probability

Prior knowledge



What does it mean to be “uncertain”?
Is that a bad thing?!



What does it mean to be “uncertain”?
Is that a bad thing?!

Uncertainty is a natural part of life & science.

But we'd like to quantify it!

Does that mean there is no Truth??

Does that mean there is no Truth??

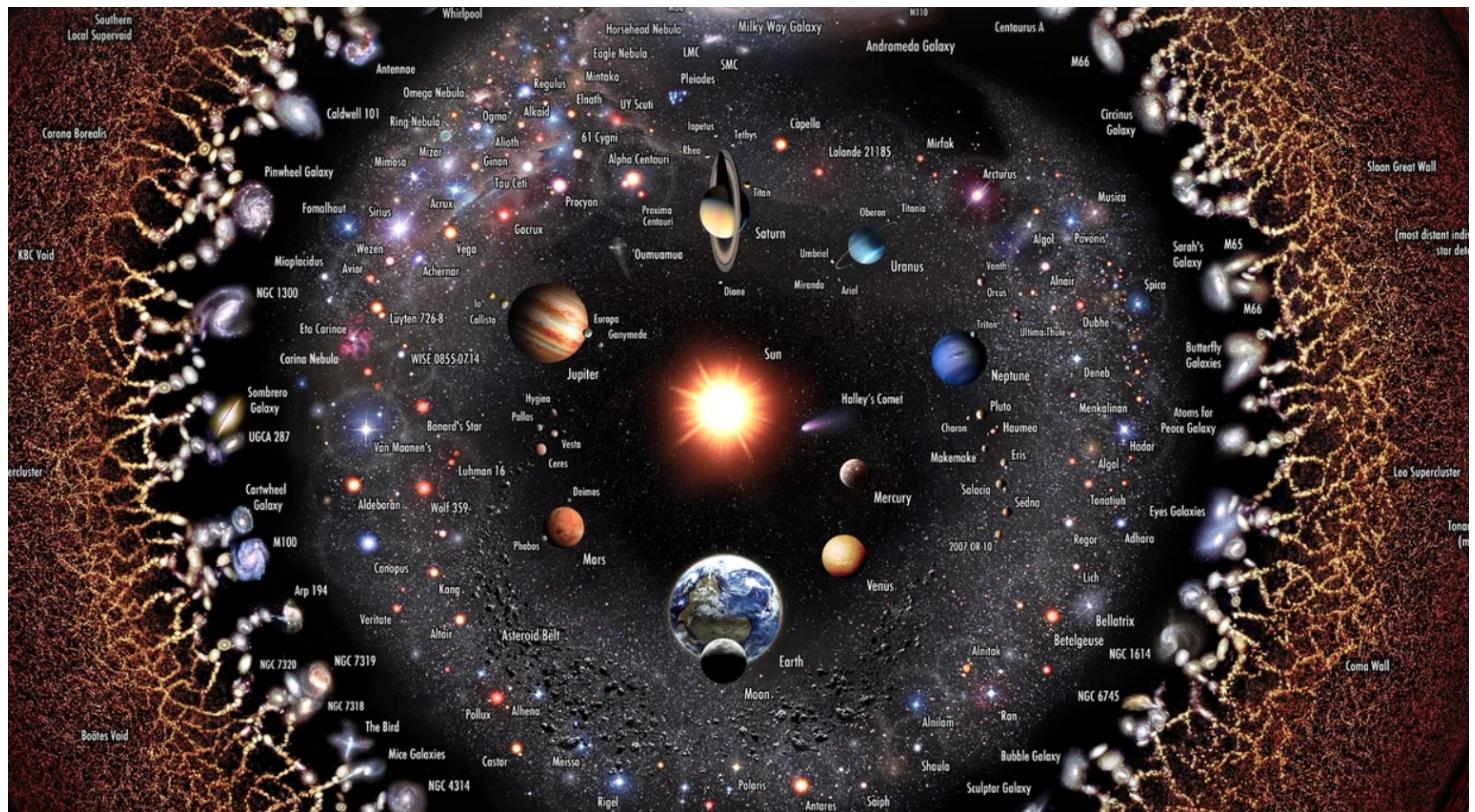


The Moon formed, somehow.



Either he has coronavirus or he doesn't.

Example 1.4 (Compare theories.) Think of two theories mentioned in this course, and discuss how their uncertainty/probability compares. Which one would you be less surprised if it gets refuted? Why?



Example 1.5 (A safe bet.) Imagine you're making a bet on the heads/tails result of a coin flip. How much money would you put on that bet? Imagine instead that you're making a bet that it will not rain tomorrow. How much money would you put this time? Finally, imagine that you are a National Science Foundation officer, deciding whether to fund a new CMB experiment, whose team claims that they would discover gravitational waves from the Big Bang, based on a theoretical prediction; they are asking for 50 million dollars. Would you be willing to make that bet?



Tools for inference

Evidence



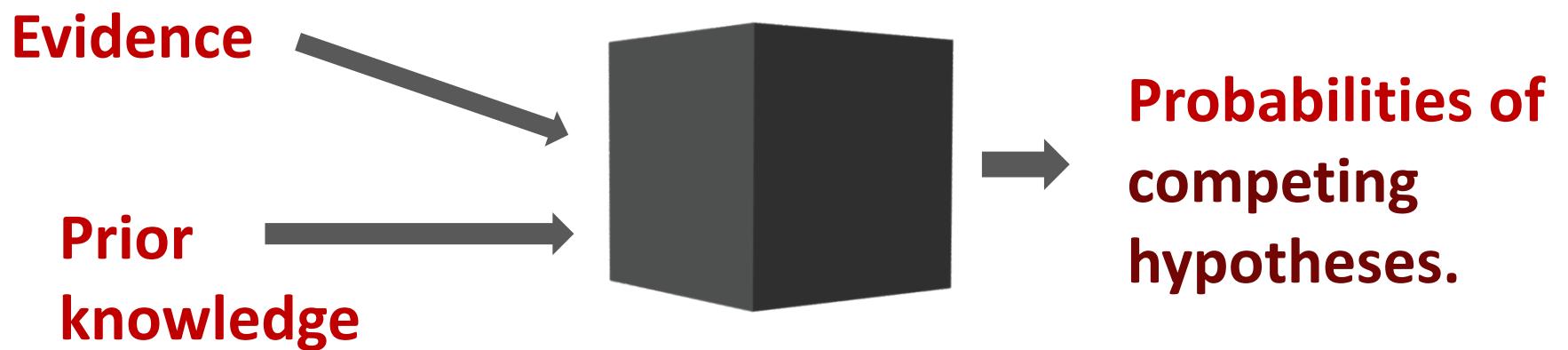
Probability



Prior knowledge

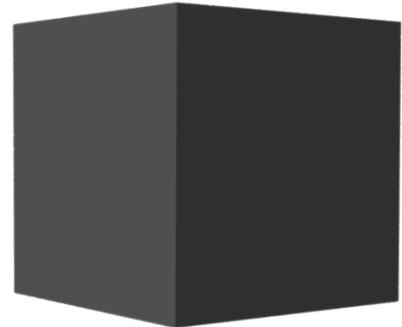


Probabilistic inference

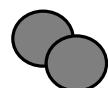
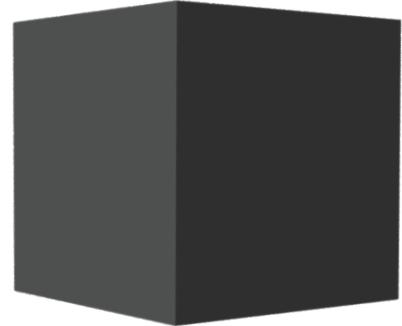


Probabilistic inference

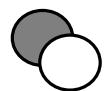
What's in the box?



What's in the box?

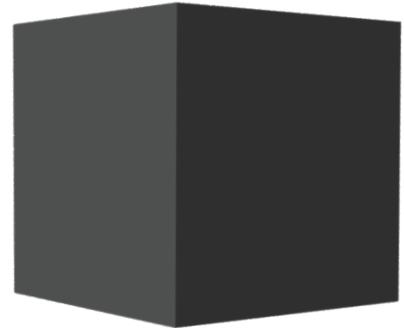


Hypothesis 1 – GG – Both balls are grey.

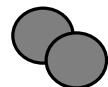


Hypothesis 2 – GW – One ball is grey, one ball is white.

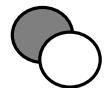
What's in the box?



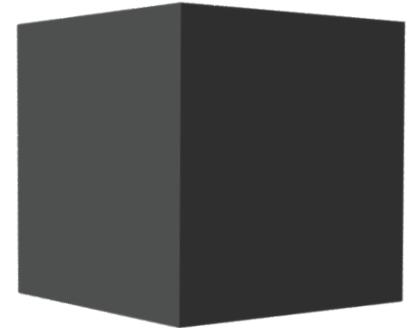
Priors:



$$P(GG) = 0.5$$



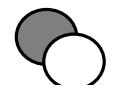
$$P(GW) = 0.5$$

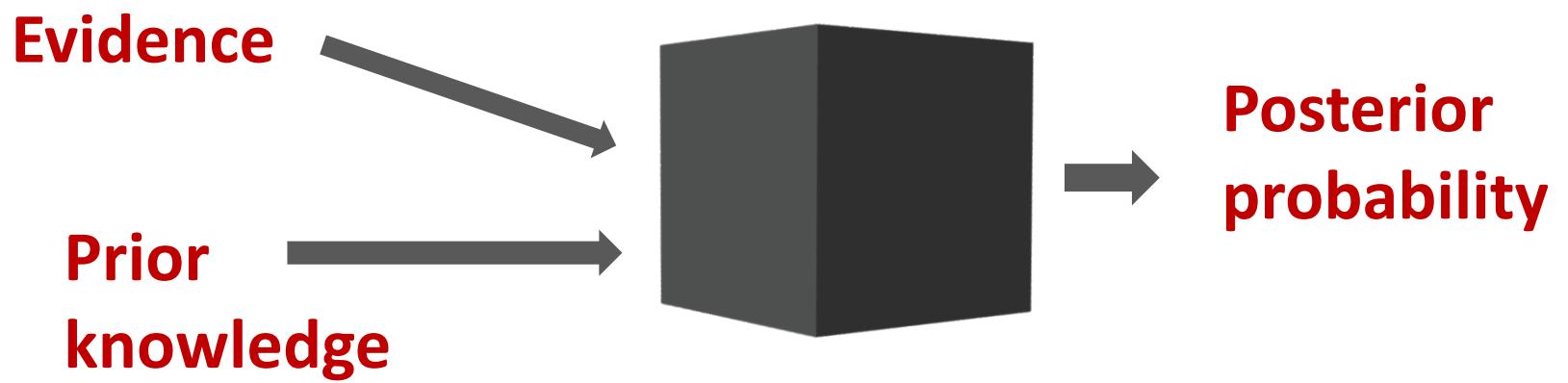


What's in the box?

The result/data: The ball that was removed from the bag is grey. 

 $P(G|GG) = 1$

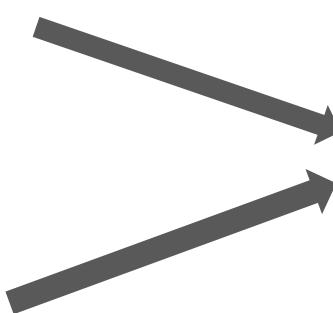
 $P(G|GW) = P(W|GW)$



What's in the box?

Likelihood

(probability of given evidence,
under my hypothesis)

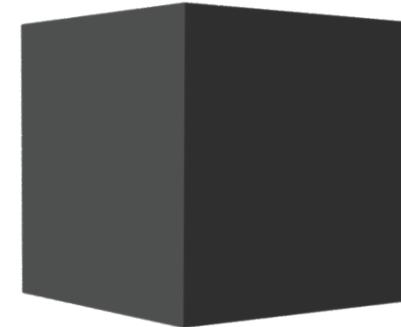


Prior

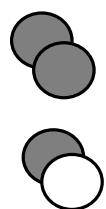
(probability of my hypothesis,
before considering evidence)

Posterior

(probability of my
hypothesis, taking into
account priors &
evidence)



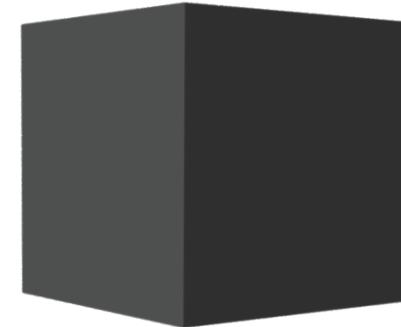
Inference Box



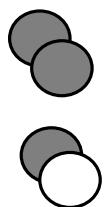
Hypothesis	Prior	Likelihood	$h = \text{Likelihood} \times \text{Prior}$	Posterior
GG	0.5	1	$1 \times 0.5 = 0.5$?
WG	0.5	0.5	$0.5 \times 0.5 = 0.25$?

$$\text{Posterior(GG)} = 0.5 / (0.5 + 0.25)$$

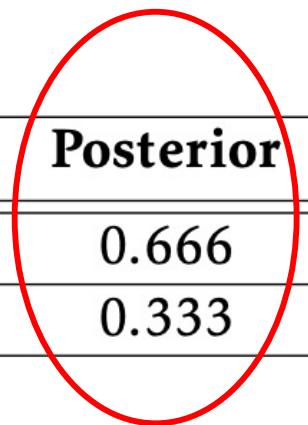
$$\text{Posterior(GW)} = 0.25 / (0.5 + 0.25)$$



Inference Box

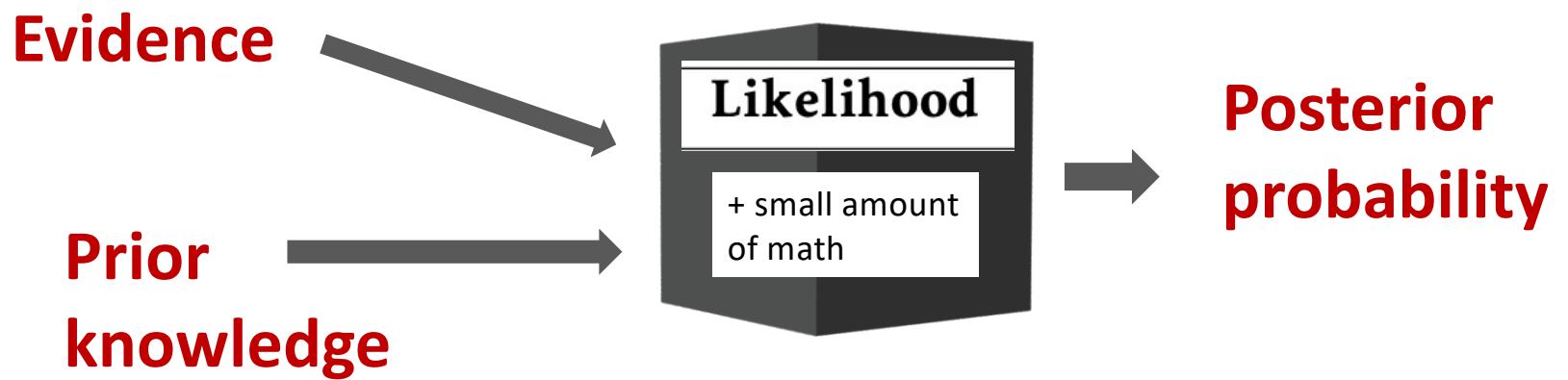


Hypothesis	Prior	Likelihood	$h = \text{Likelihood} \times \text{Prior}$	Posterior
GG	0.5	1	0.5	0.666
WG	0.5	0.5	0.25	0.333

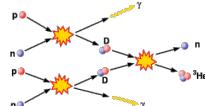
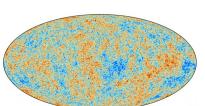
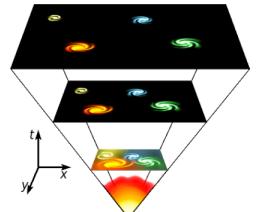


$$\text{Posterior(GG)} = 0.5 / (0.5 + 0.25)$$

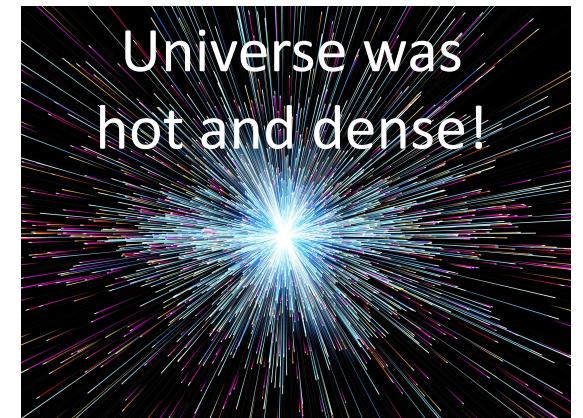
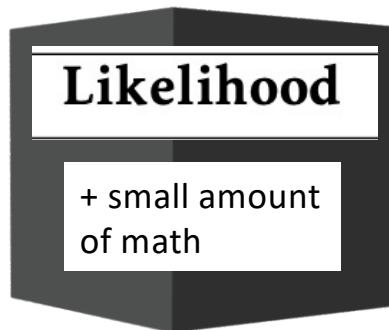
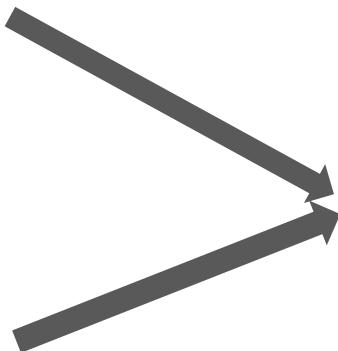
$$\text{Posterior(GW)} = 0.25 / (0.5 + 0.25)$$



Example: The Big Bang Theory



Universe was
probably always
the same...

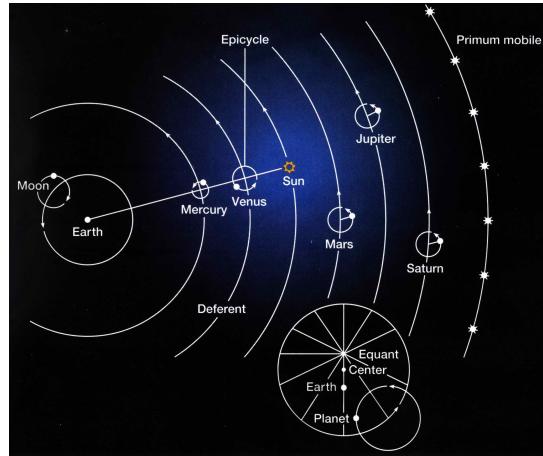


Example 1.7 (Unfair coin?) Imagine that someone gives you to pick one of 10 coins, without looking. And after you take one, she tells you that out of the 10, one was with double heads. You flip your coin, still without looking. It comes up heads. After that one flip, what is the probability that this is that unfair? How many times in a row do you need to get heads before you are fairly sure that you've drawn an unfair coin?



<https://docs.google.com/spreadsheets/d/1YDfMtfwLxTGRFfGtqhcWpylKRqTFsyAxF8unY7JtRPI/edit?usp=sharing>

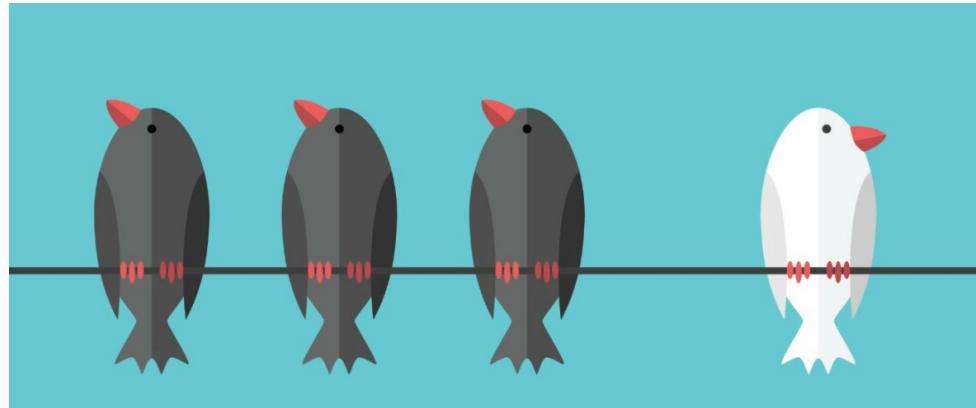
What made the decision??



Let's talk about priors!



Example 1.10 (Good priors.) Can you think of an example situation where a prior assumption is helpful?



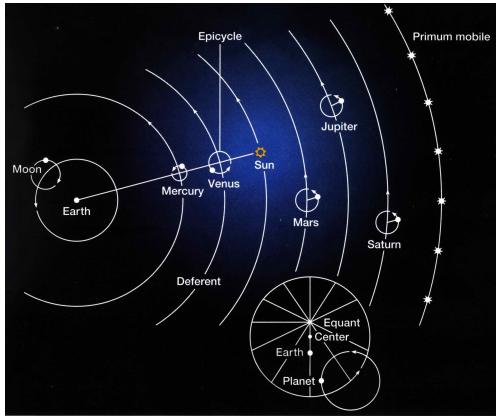
Let's talk about priors!

Example 1.9 (Bad priors.) Can you think of an example situation where a prior assumption causes a problem?

How do you make sure prior is not a problem?

How do you make sure prior is not a problem?

Ensure that you also consider evidence.



Shifting paradigms

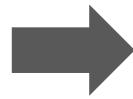
Example 1.12 (Shifting paradigms.) Think of a discovery you learned about in this class that shifted your understanding of the Universe. How uncomfortable are you with this new knowledge? Why do you believe it, or why do you still doubt? What would make you convinced?



Changing minds

Example 1.11 (Changing minds.) Consider something you have always believed to be true. Think about why, and what it would take to change your mind. This example can be something from life or from science.

When do paradigms shift and minds change?

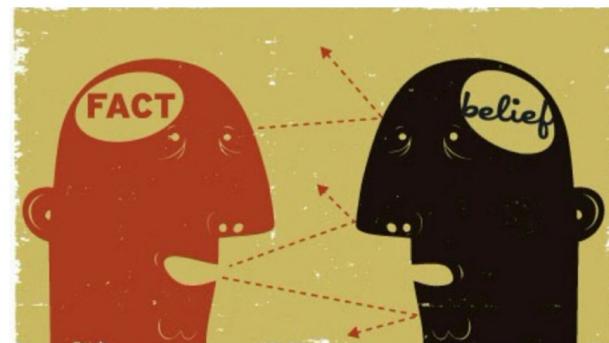


And when do paradigms/minds remain fixed,
in spite of evidence?

And when do paradigms/minds remain fixed,
in spite of evidence?



And when do paradigms/minds remain fixed,
in spite of evidence?



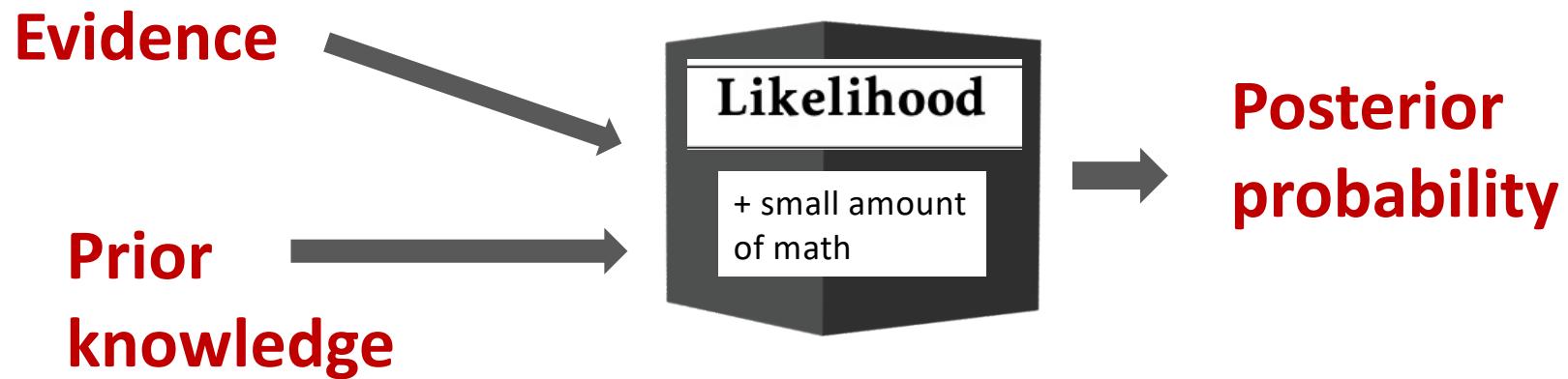
Never the case!!!

How would you approach a person with
different beliefs?

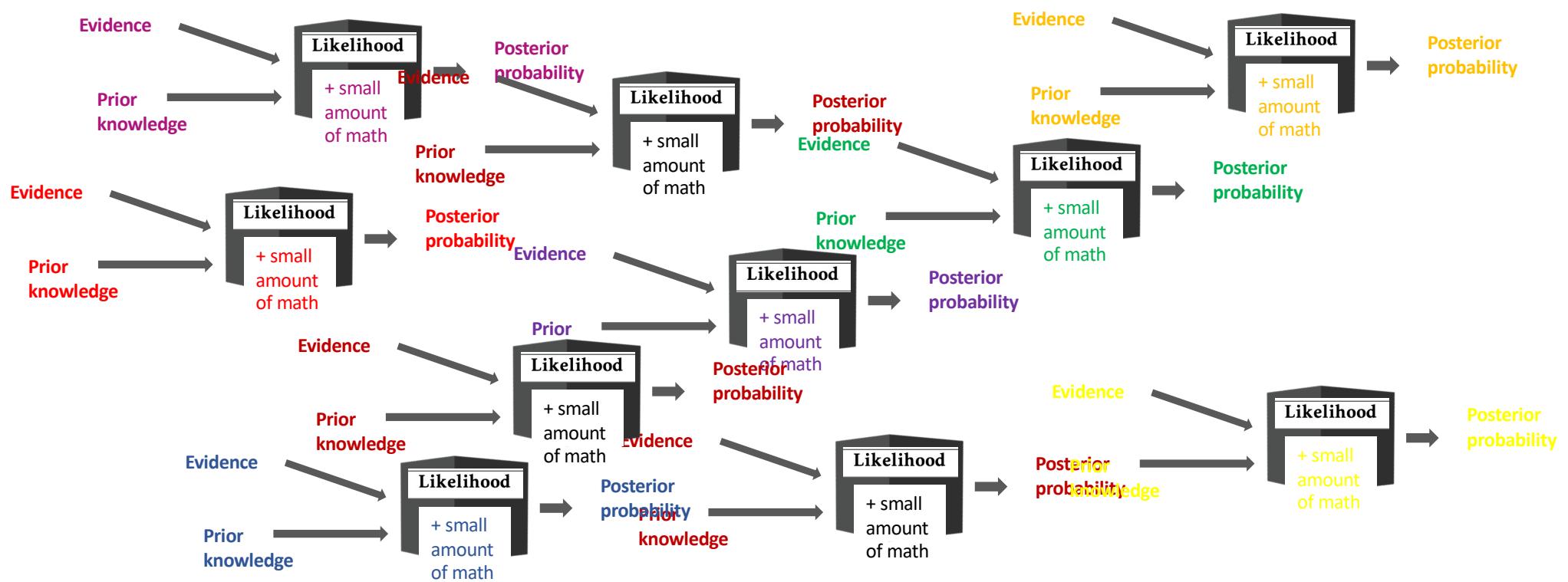


*If this is how it works, what is then **scientific** about scientific inference?*

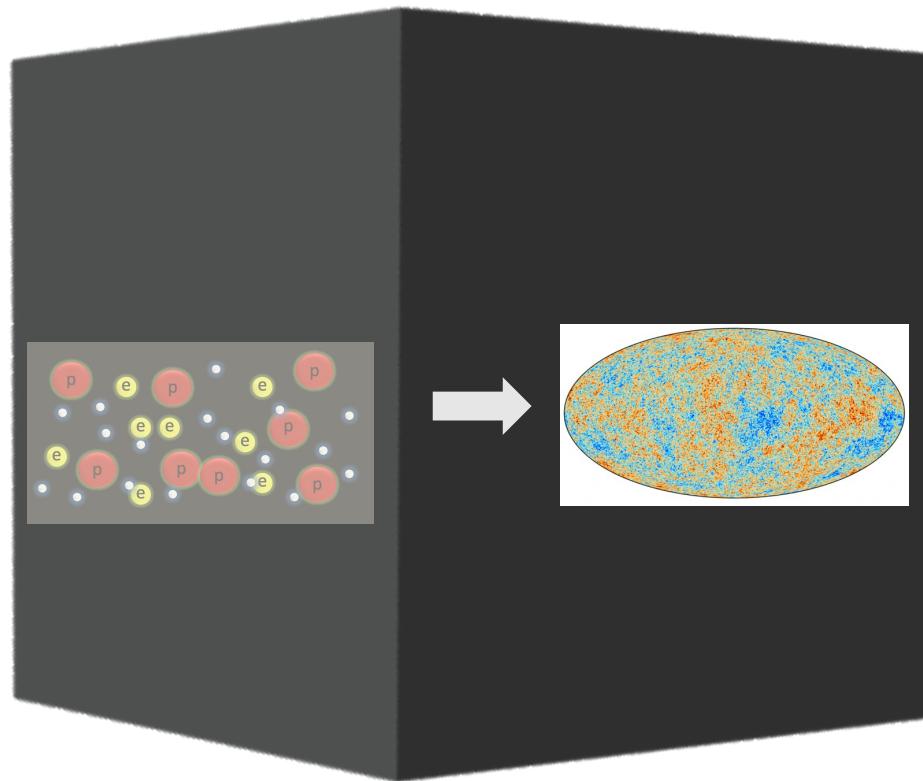
1. We stick to this---no hiding evidence.



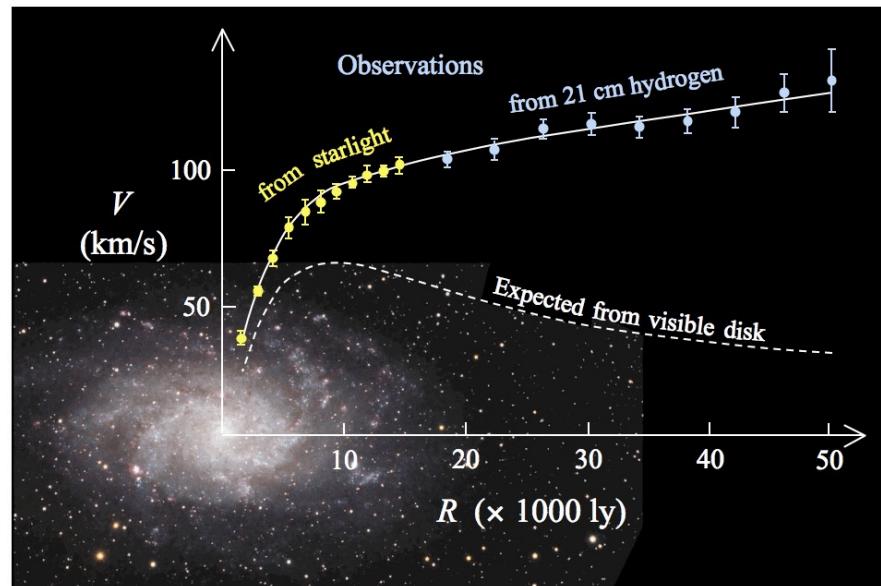
2. We check each other---reproducible science.



3. Likelihood of data, given a theory.

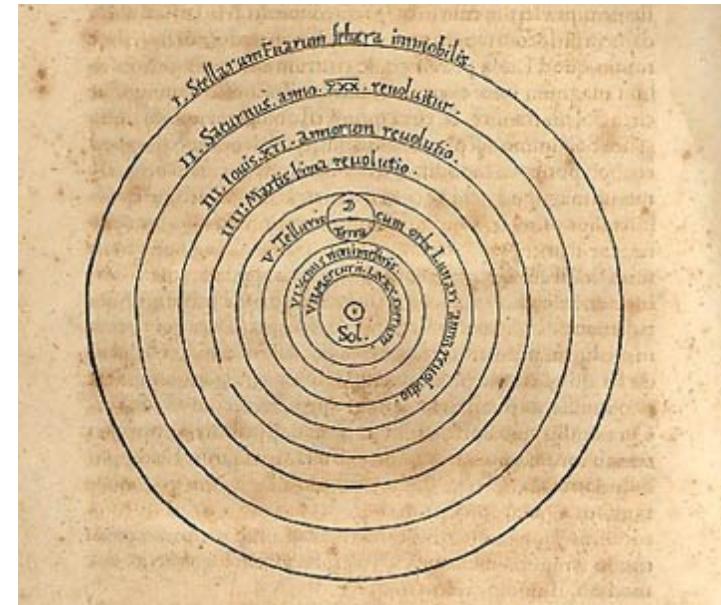
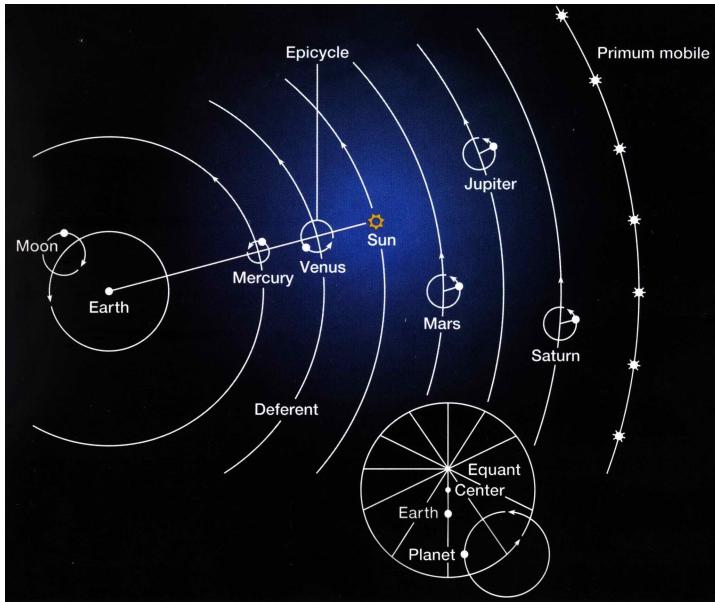


4. A sense of what is possible (= list of all competing hypotheses)



Modified Gravity vs. Dark Matter?

Also, in life and science: Preference for simplicity (Occam's razor)



Heliocentric vs. Geocentric system?

Example question from KU module:

Imagine a situation where two candidates, X and Y, are interviewed for a position in a company. They both perform well, but candidate X gets one point higher interview score. As a result, the hiring committee is considering hiring candidate X. Then, a member of the committee points out that people who came from the same company as the previous employer of candidate Y, have historically performed outstandingly well in this job. The committee considers this argument, and concludes that they should actually hire candidate Y after all.

Using the language of inference, what tipped the decision of the committee?

- A. The likelihood.
- B. The prior.
- C. The posterior.
- D. All of the above.

Example question from KU module:

A doctor is trying to diagnose a patient who presents with a specific symptom. She has narrowed down the possibilities to two ideas of what might be going on: he either has condition X or condition Y. In the doctor's experience, about half the patients with illness X present with the same symptom; on the other hand, patients with illness Y always present with that symptom. Is this enough information for the doctor to make a diagnosis? Why or why not?

- A. Yes, because the likelihood under hypothesis Y is so much higher than under X.
- B. Yes, because if there are only two hypotheses, their priors are always equal.
- C. No, because the doctor also needs to know the priors on X and Y.
- D. No, because the doctor cannot determine the likelihoods with only this information.

Key definitions

- **Probability** = certainty that a statement is true.
- **Probabilistic inference** = a systematic way to *infer* an answer that is most **probable** (given all the prior knowledge and all the evidence) and quantify the remaining level of uncertainty.
- **Prior** is the probability that a certain hypothesis is correct *before* (or prior to) considering any evidence, or data.
- **Likelihood** is the probability that a certain outcome (or data) would result *if* a certain hypothesis is true.
- **Posterior** is the probability that a hypothesis is true *after* considering all the information/evidence/data/experiments, and all the priors, and taking into account all the **competing hypotheses**.

A high-resolution image of a dense field of galaxies in deep space. The scene is filled with numerous galaxies of various sizes and colors, ranging from small, faint blue and white dots to larger, more luminous yellow and orange galaxies. Some galaxies appear as distinct, multi-lensed arcs or ellipses, while others are smaller, more compact clusters of stars. The background is a deep black, representing the void between galaxies.

THE END...