

Building Scientific Knowledge

Unit 2, Lesson 3: How Do
We Know What is Real?

Barash, “Paradigms
Lost”

Science is....





What is Science?

- ▶ A method that we can use to carefully gain knowledge of the physical and social world
- ▶ Reasoned inquiry on the basis of observation and experimentation
- ▶ A *process*



Why Are We Seeing So Many Public Health Challenges? And What Can We Do About It?

September 20, 2022 | [Matt Shipman](#)



Does cracking the knuckles cause arthritis?



Despite popular beliefs, several studies have concluded that cracking knuckles is unlikely to be linked to arthritis.

Dr. Donald Unger researched his own knuckle-cracking, in response to complaints from his family. He cracked the knuckles of his left hand at least twice a day for 50 years, but not those of his right hand.

Unger did not develop arthritis in either hand, and there were no differences between the two hands.

He concluded that knuckle cracking was not linked to arthritis.

The Uniformed Services University of the Health Sciences looked at 215 people, 20 percent of whom popped their knuckles regularly.

Of the knuckle crackers, 18.1 percent had arthritis in their hands, compared with 21.5 percent of participants who did not crack their knuckles.

The study showed that the chances of having arthritis are around the same whether or not you crack your joints.

Does Shaving Cause Hair to Grow Back Thicker?

Medical Myths: Shaving your hair makes it grow back thicker

Dr Max Pemberton



Does Sugar Give You a “Sugar Rush”?

HEALTH & SCIENCE / BEHAVIOR

There’s No Such Thing as a Sugar Rush, According to Science

*There’s no link between sugar and
demonstrated the*

By Joshua A.

It’s true, and it’s hardly news. The case of the putative sugar rush was essentially closed in 1995, when researchers analyzed 16 high-quality studies of children post-sugar binge, and concluded that “sugar does not affect the behavior or cognitive performance of children.” The evidence from this work was so compelling that the statistician who reviewed the paper told its authors that he had never seen such consistently negative results in a statistical analysis. And even earlier, in 1982, the National Institutes of Health concluded that sugar rushes don’t exist.

Science and Critical Thinking

- ▶ No scientific theory is ever beyond all doubt
- ▶ But some theories are best supported by the evidence we have!
- ▶ The scientific method provides each of us with guidelines about how to think: how to develop, test, and verify what we consider real

Four Key Ingredients of Science

1. Observation





Four Key Ingredients of Science

2. Proposing an explanation

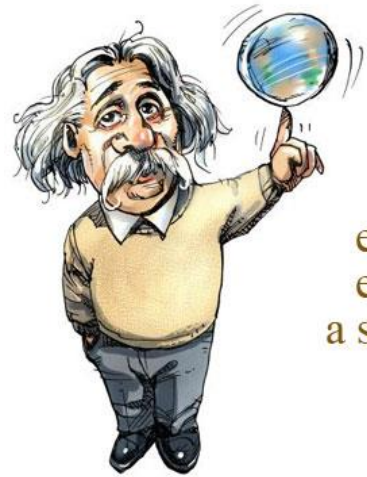
▶ Hypothesis:

- ▶ An educated guess about how the world works
- ▶ A provisional answer to one's question and explanation for one's observations

Four Key Ingredients of Science

3. The Explanation is testable + tested, with something being measurable/quantifiable
 - ▶ Testable: there are some observations that would confirm that the hypothesis is true





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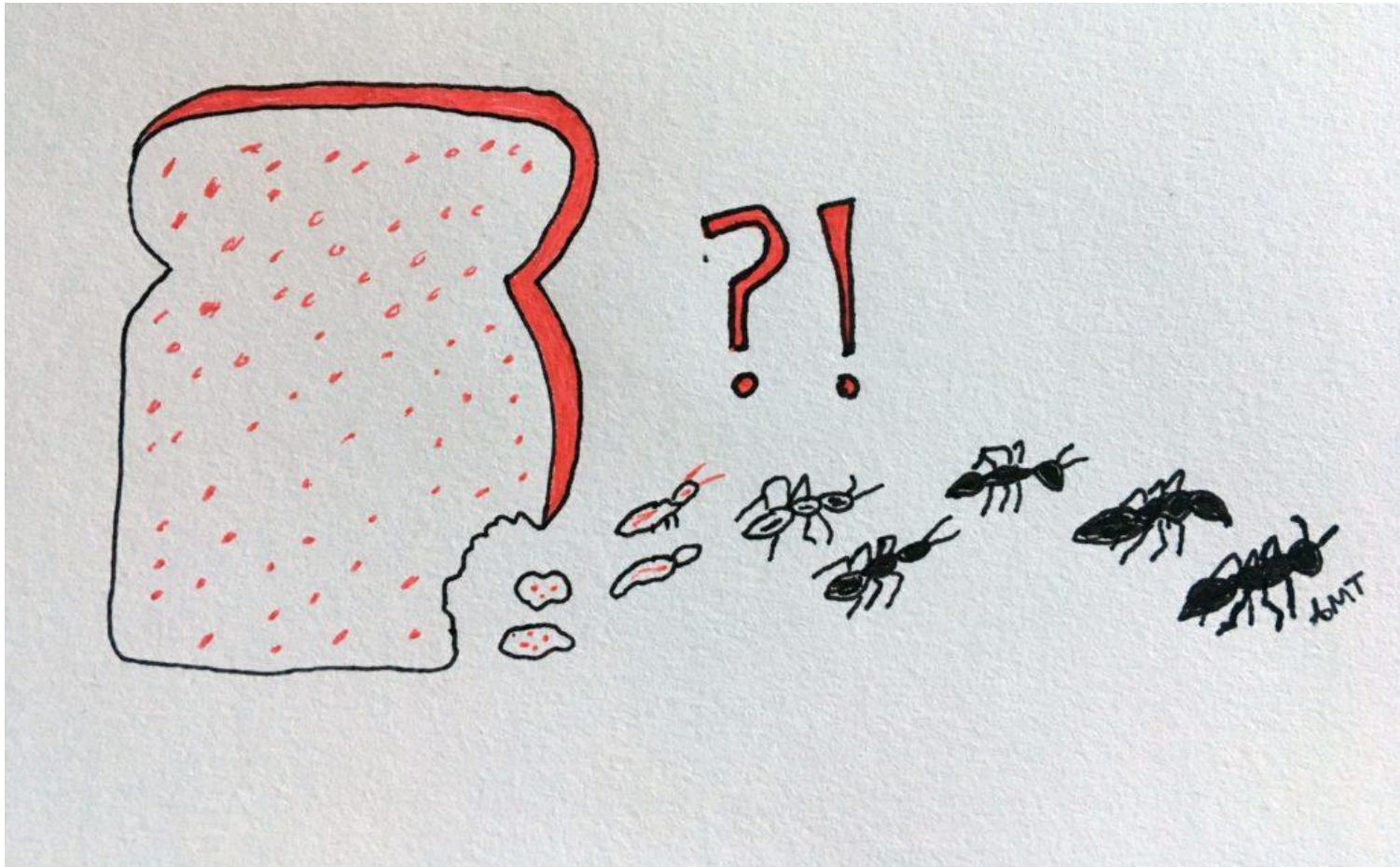
No amount of
experimentation can
ever prove me right;
a single experiment can
prove me wrong.

~ Albert Einstein

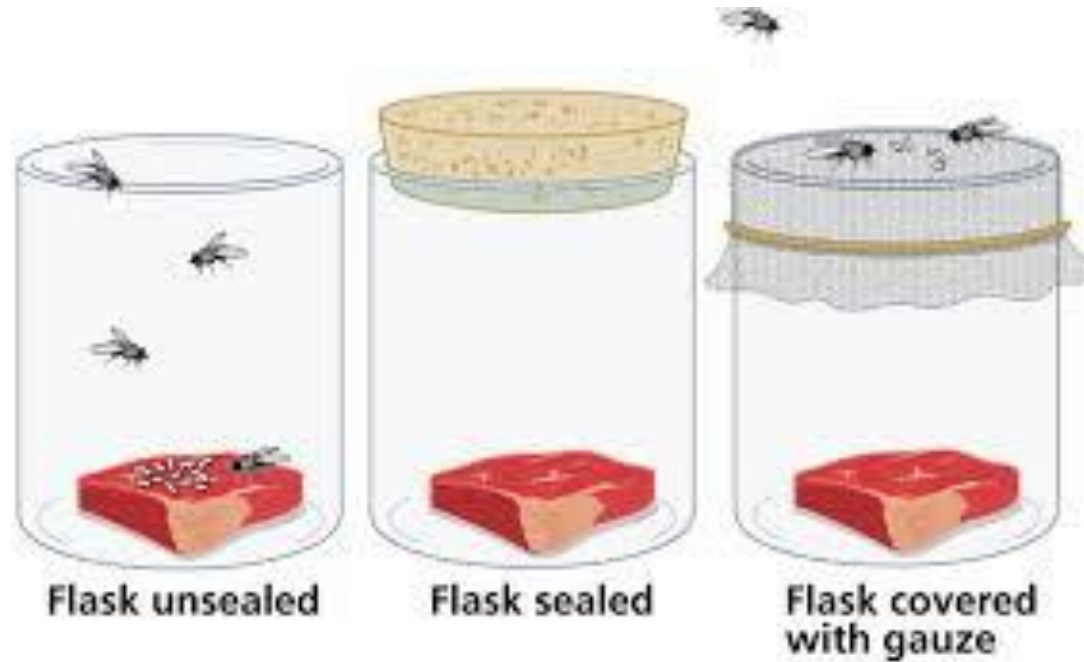
Falsification

- ▶ For an explanation to be scientific, there has to be something that could prove that it is false

Spontaneous Generation

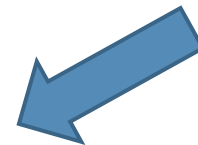


Francesco Redi (1612-1697)



1. If spontaneous generation occurs, then there will be maggots in all the jars.
2. There aren't maggots in all the jars.
3. Spontaneous generation does not occur.

Explanation falsified



Four Key Ingredients of Science

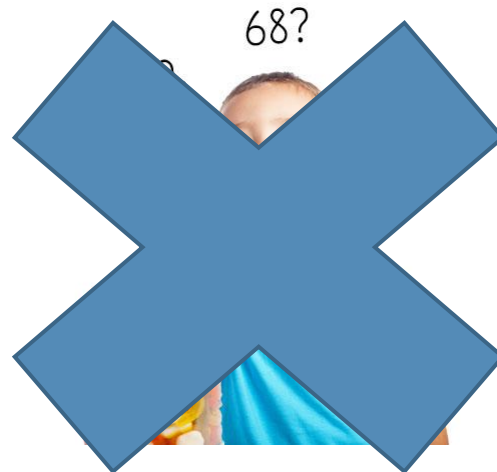
4. Test results must be replicable + replicated



- ▶ **Textbook science:** The (established) science found in textbooks, which has been rigorously (thoroughly) tested and is usually highly reliable
- ▶ **Frontier science:** The (new) science found in scientific journals, which may not have been reproduced and is therefore much less reliable

Scientific Theory

- ▶ A body of **well-substantiated** explanations about how some part of the natural world works, composed of claims that have been **repeatedly confirmed** through observation and experiment
- ▶ Theories explain facts



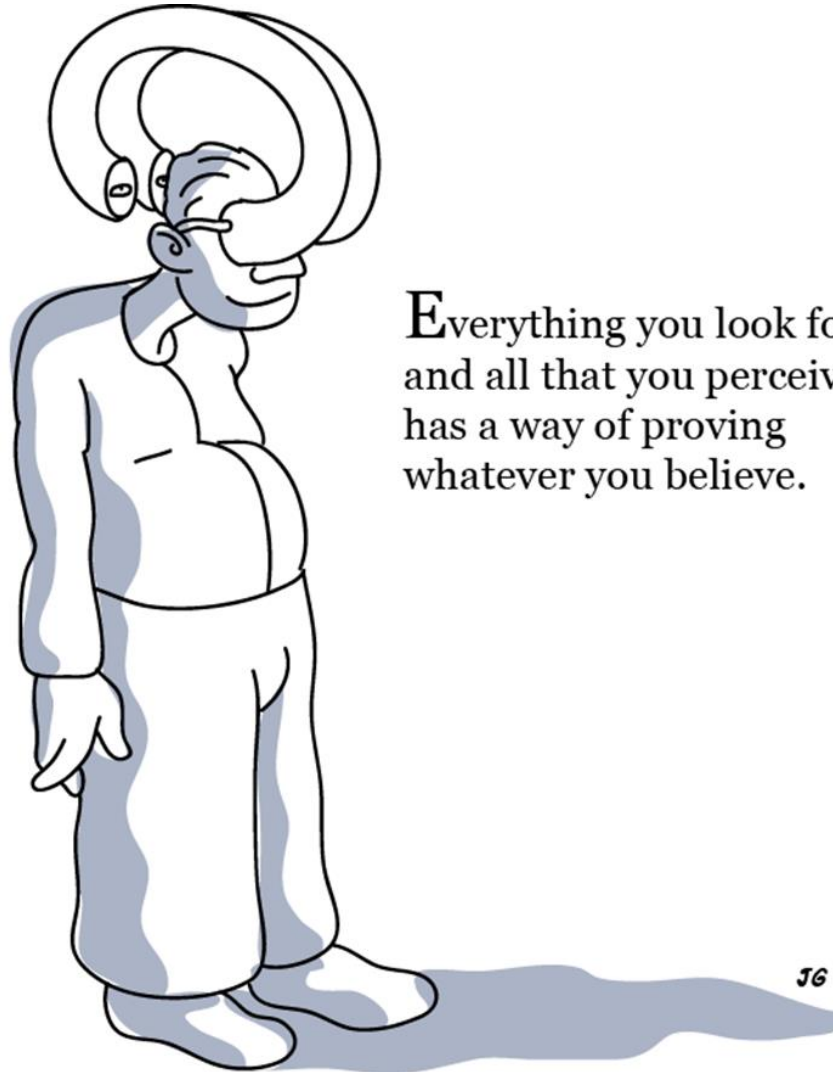
NOT just guessing
or speculation

Pseudoscience (Fake Science)

- ▶ Lacking when it comes to one or more of the ingredients of science:
 - ▶ Ignoring past evidence collected by scientists and well-supported scientific theories
 - ▶ Making claims that are not testable, measurable, or falsifiable
 - ▶ Not clearly defining the terms that one uses, so that it's not clear if a claim has been confirmed through observation/experimentation or not
 - ▶ Overreliance on personal experience or anecdotes to form beliefs/explanations
 - ▶ Not controlling for bias in the testing of one's claims
 - ▶ Not accepting evidence that goes against one's hypothesis or beliefs
 - ▶ Lack of openness: being secretive with information related to test results or methodology, so that others cannot verify or reproduce your findings
 - ▶ No self-correction and progression of ideas over time

Confirmation Bias

- ▶ The tendency to look for evidence that matches one's pre-existing beliefs, and interpret new information as confirmation of these beliefs

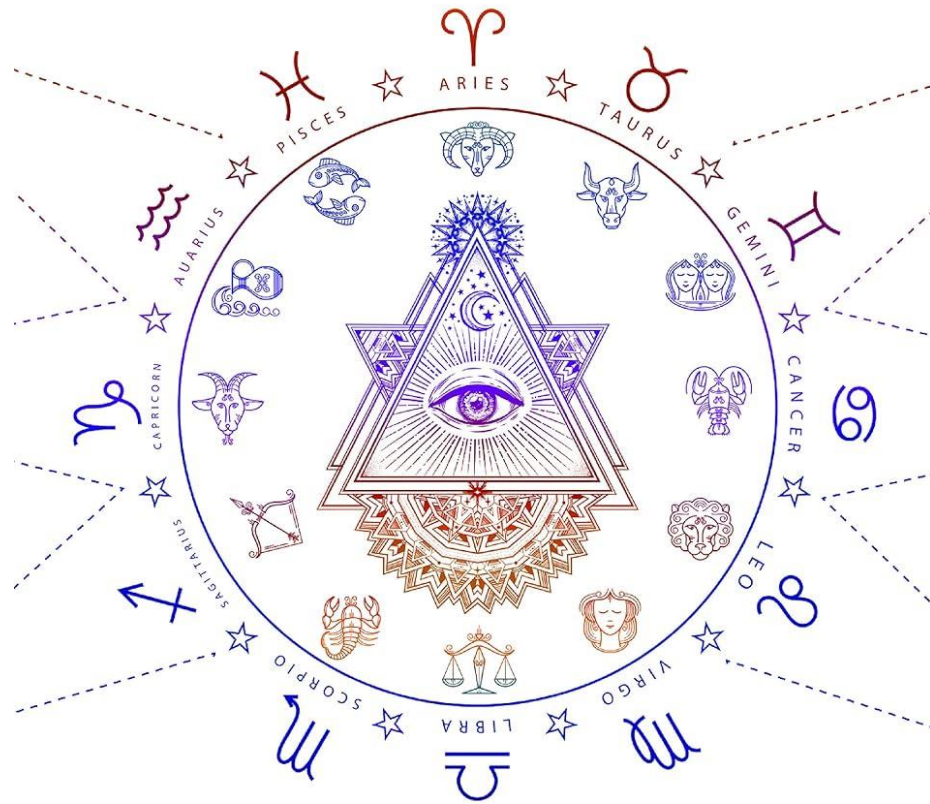


Everything you look for and all that you perceive has a way of proving whatever you believe.

For Example:

ASTROLOGY

Embrace Your Sign and Play to Your Astrological Strengths



Why are people
skeptical of
science?

"Scientists change their
minds!"

One reason for skepticism...

Canadians are confused about science vs. opinion, poll suggests



Almost half of survey respondents think the science of global warming is still unclear



Emily Chung · CBC News · Posted: Sep 20, 2017 3:13 PM EDT | Last Updated: September 20, 2017



He is concerned about some of the findings that suggest a lack of trust in science and media coverage of scientific issues such as:

- 31 per cent of respondents agree that "because scientific ideas are fluid and subject to change, they can't be trusted."
- 68 per cent agree that media coverage of scientific issues is "reported selectively to support news media objectives."
- 59 per cent agree that media coverage of scientific issues is "presented to support a political position."



Science is a Process

- ▶ Scientists don't claim to have an eternal, unchanging truth
- ▶ Part of science is **self-correction** and this is a **strength** of science as a means of gaining knowledge
- ▶ **Paradigm shift**: a change in the dominant explanation of a phenomenon in response to new evidence

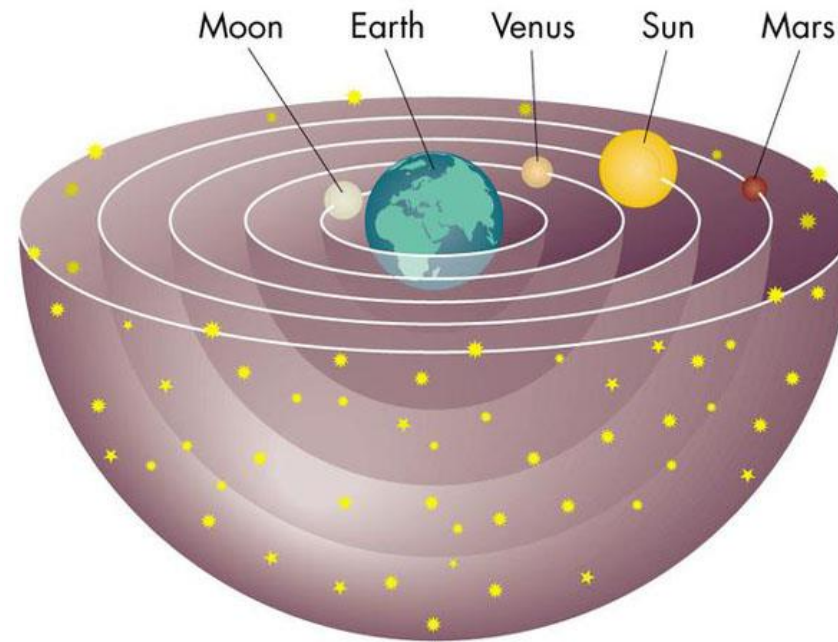
Aristotle's (384-322 BCE) Cosmology

- ▶ Observing the world around him, Aristotle noticed that:
 - ▶ Every object on Earth falls to the ground when it is dropped
 - ▶ No object moves unless there is a force acting on it
 - ▶ But the “heavenly bodies” all move in perfect, never-ending circles across the sky
 - ▶ They appear to orbit the Earth



Aristotle's Cosmology: Geocentrism

- ▶ The heavenly bodies are perfect (made of 'aether') and they all orbit in perfect circles around the Earth within celestial spheres of aether



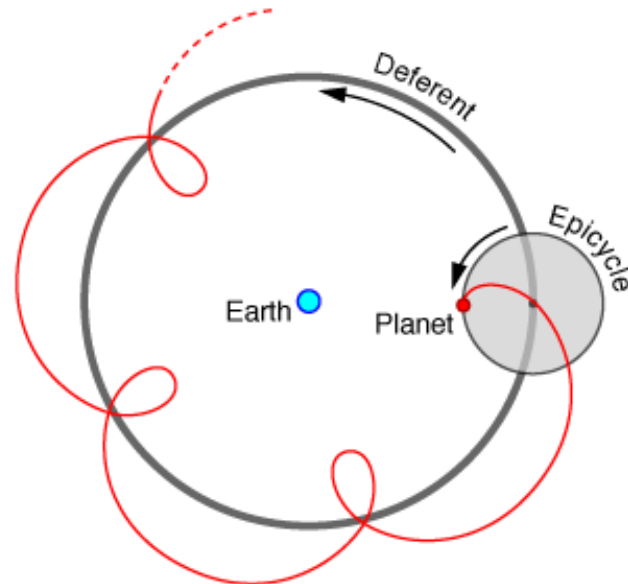
The Problem of Backwards Motion

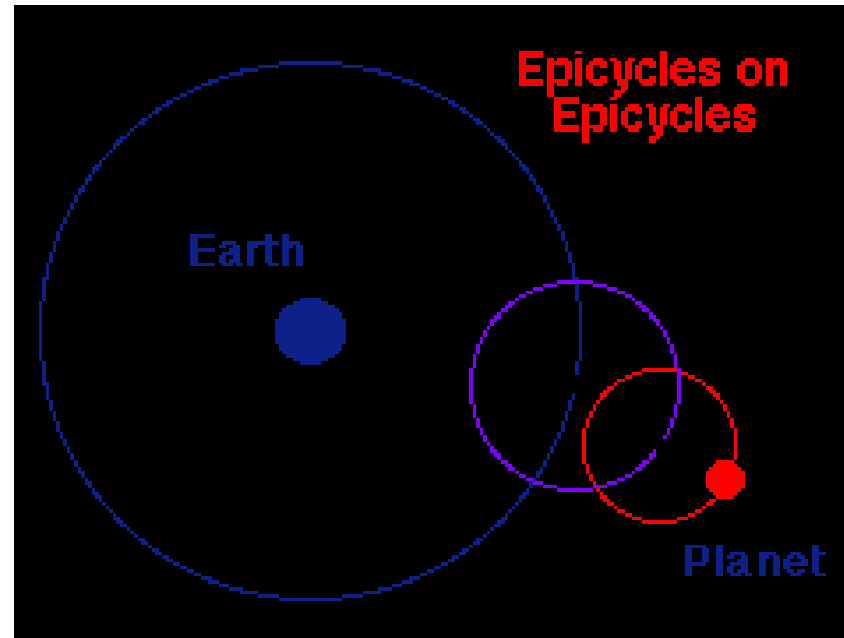
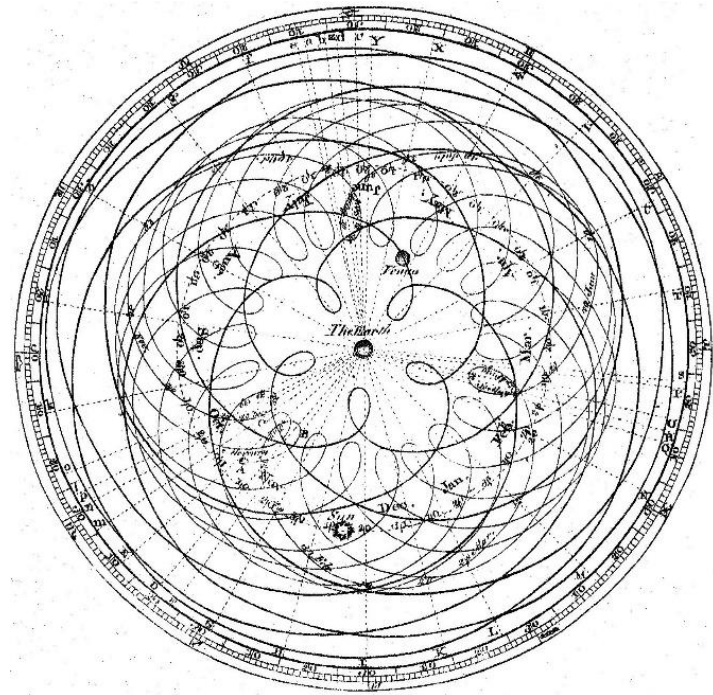


- ▶ Problem: sometimes the planets aren't observed to move in perfect circles around the Earth
- ▶ This backward motion is called "retrograde motion"
- ▶ An **anomaly**

Ptolemy (90-168 CE): “Fixing” Aristotle’s Theory

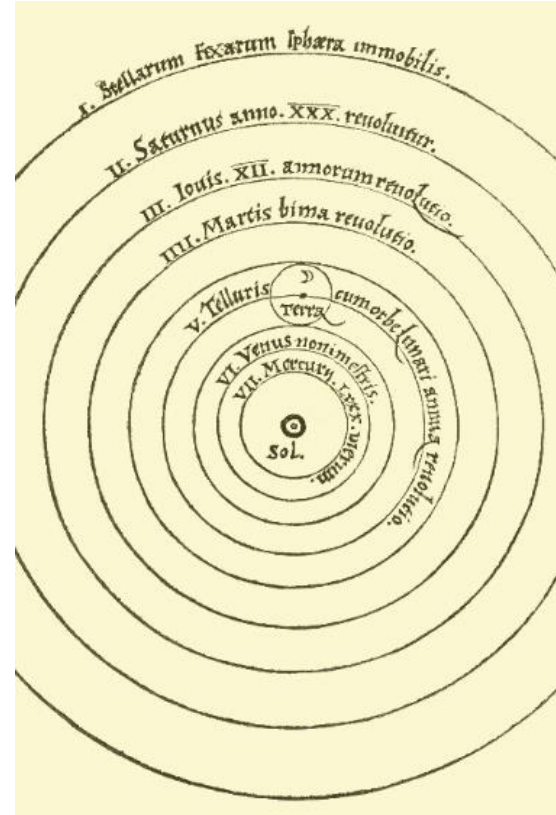
- ▶ Saved Aristotle’s theory by adding *more* spheres!
- ▶ These smaller circles are called “epicycles”





More and More Epicycles...

Copernicus (1473-1543): Heliocentrism

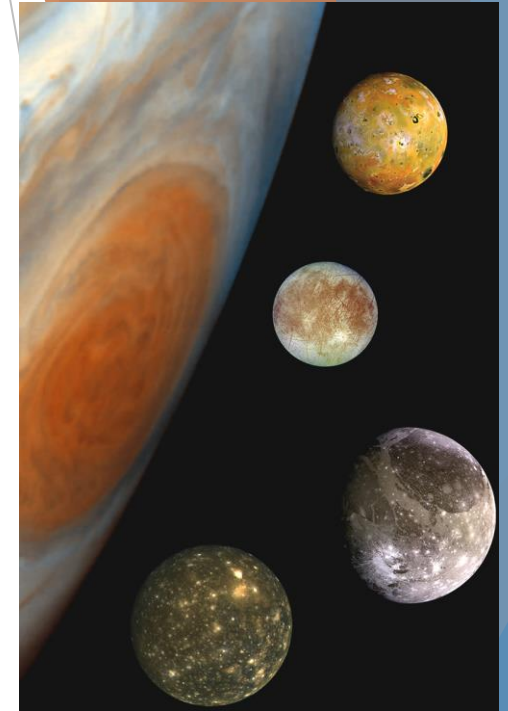
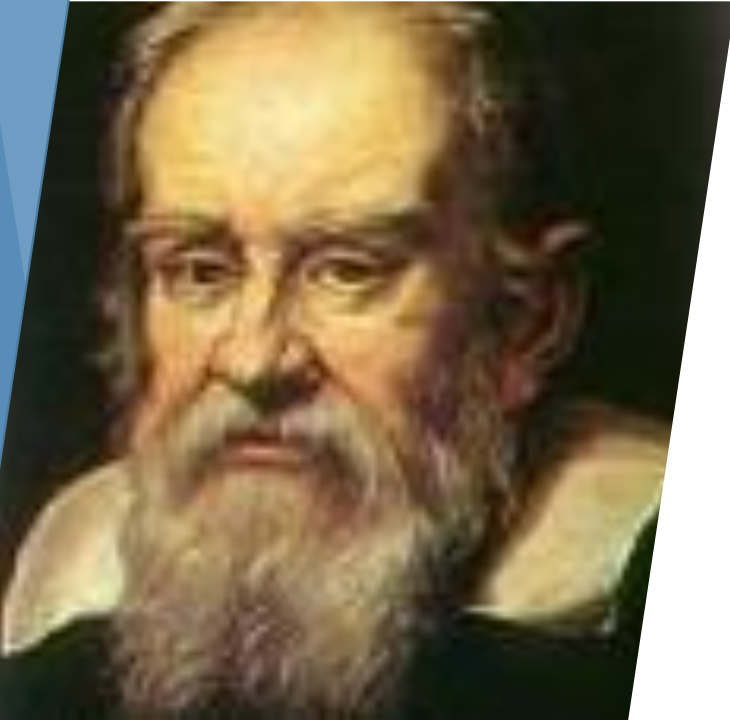


- ▶ Complexity of Ptolemy's model bothered him
- ▶ **Ockham's Razor:** all else being equal, the simplest explanation is better
 - ▶ Simpler explanations make fewer assumptions
- ▶ Path to simpler theory: put the sun at the centre: ***heliocentrism***



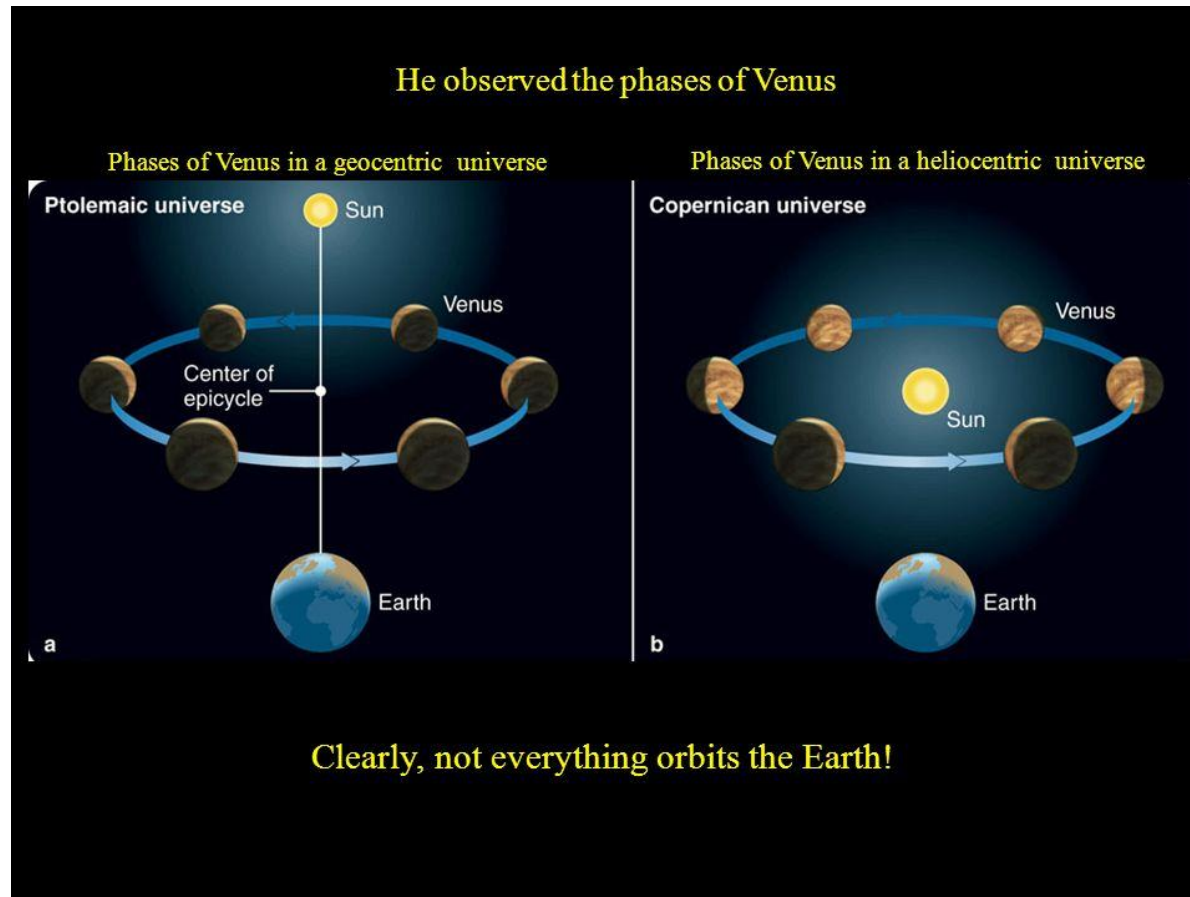
Galileo (1564-1642): New Tools = New Evidence

- ▶ Half a century later, Galileo used a new tool to *prove* that the Aristotle/Ptolemy model was wrong
- ▶ Craters on the moon
- ▶ Jupiter's moons



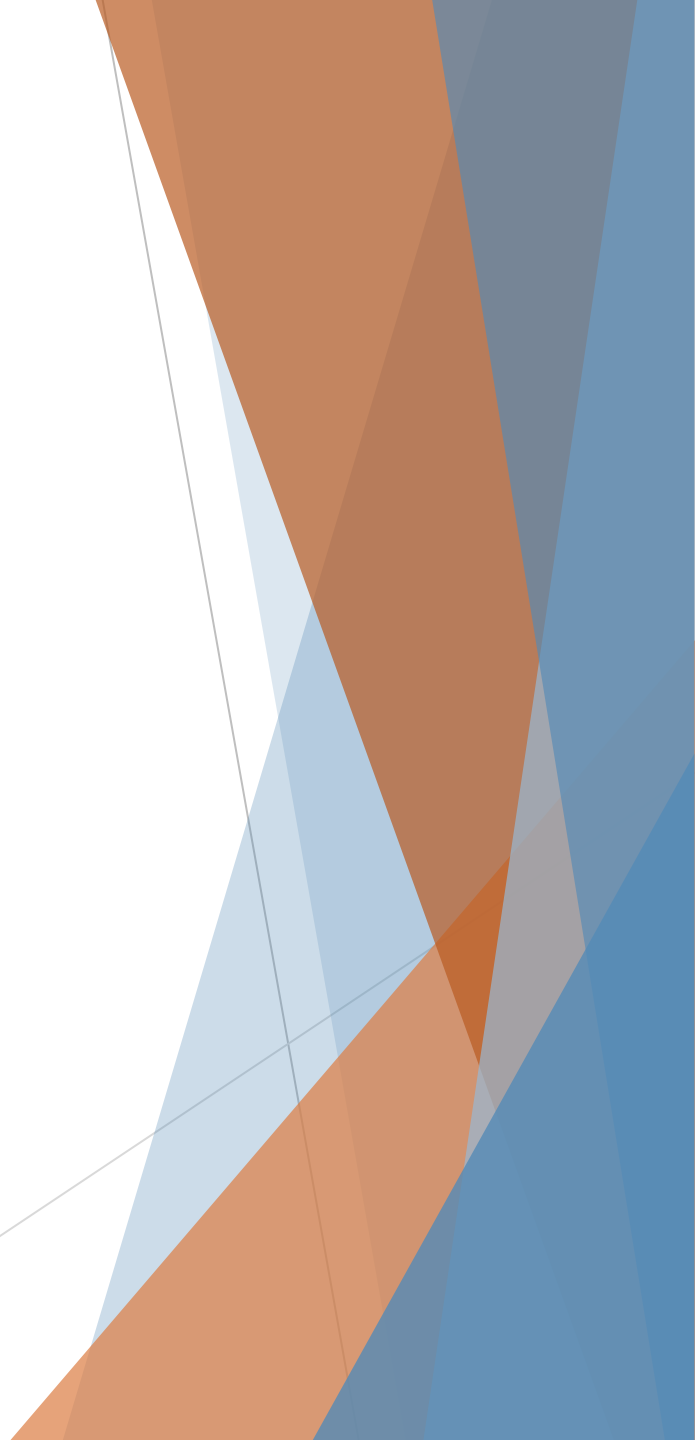
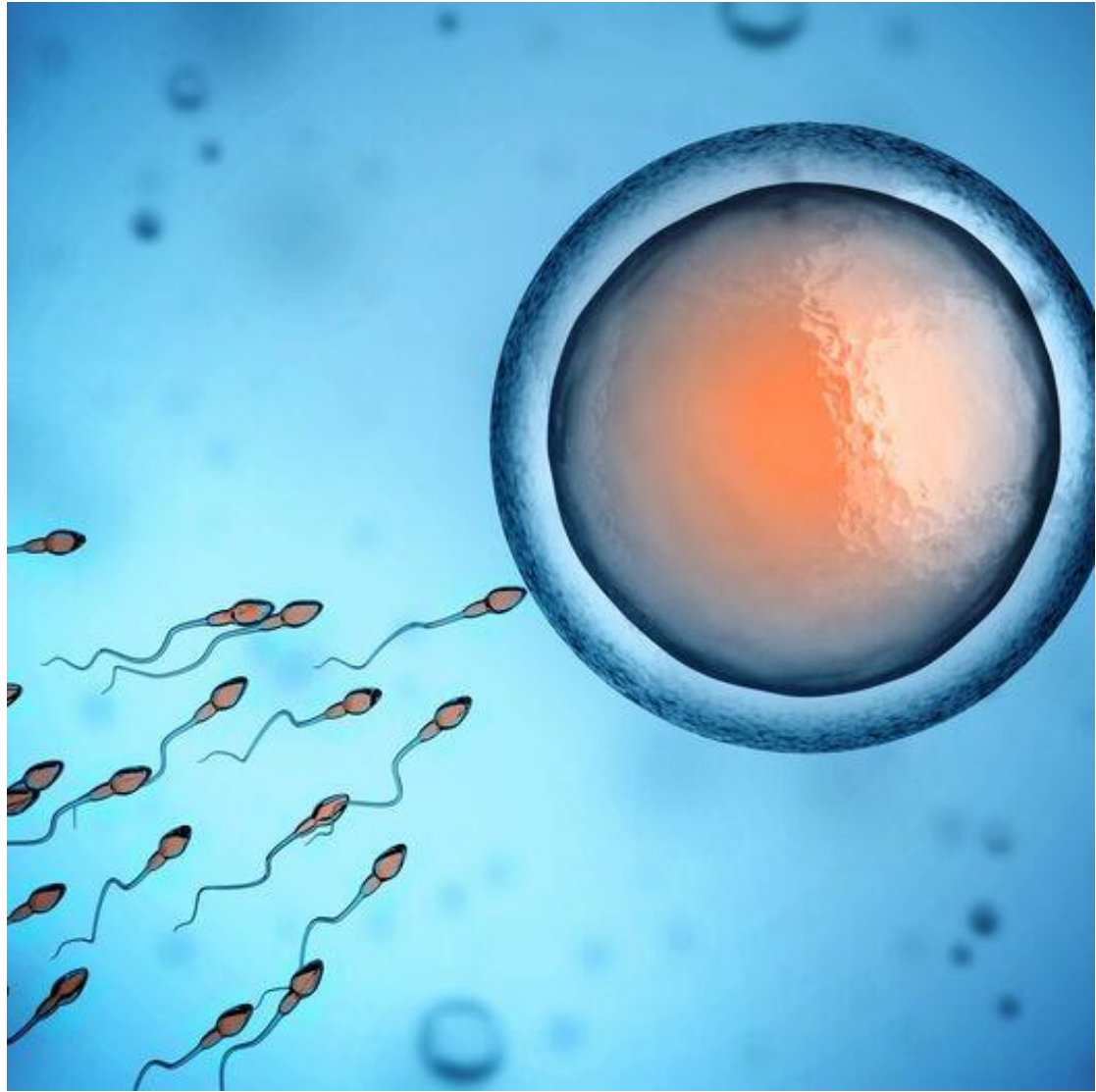
Phases of Venus

- ▶ If geocentrism were true, Venus could never be viewed as fully lit from the perspective of Earth, but it can be viewed this way.
- ▶ We now know that the planets orbit the sun, not the earth - a **paradigm shift!**



“ Denied the comforting blanket of illusory permanence and absolute truth, we have the opportunity and obligation to do something extraordinary: to see the world as it is, and to understand and appreciate that our images will keep changing, not because they are fundamentally flawed, but because we keep providing ourselves with better lenses ”

- David Barash



- ▶ Textbooks have tended to describe the behaviour of sperm as active and eggs as passive

NewScientist

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Enter search keywords

Human eggs release chemicals that attract some sperm more than others

By Layal Liverpool

10 June 2020



It's Not A Race: Female Eggs Choose Which Sperm Gets To Fertilise It, Study Shows

They looked at how sperm responded to follicular fluid -- fluid that surrounds eggs and contains sperm chemoattractants. They were looking to find if follicular fluids from different females attracted sperm from some males more than others.

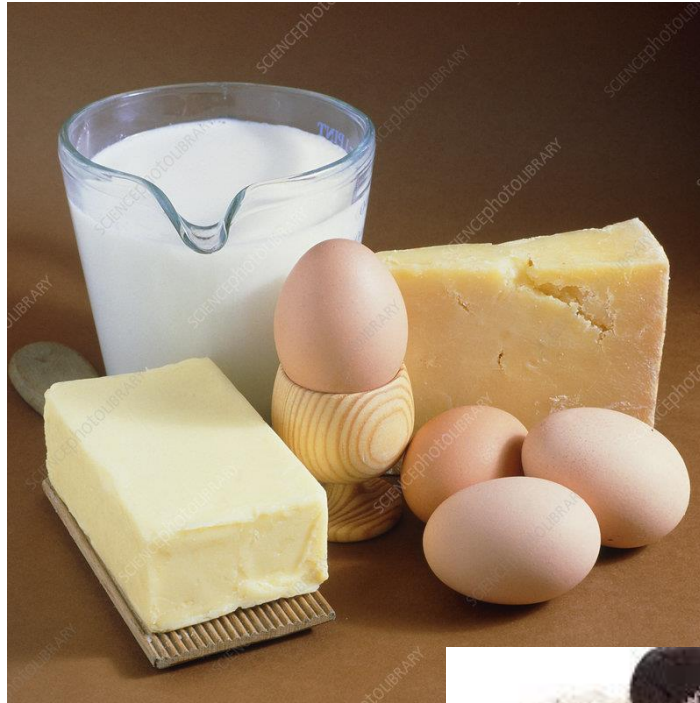
Monit Khanna — Updated: Mar 17, 2022, 18:47 IST — 2 min read — 



Why Are Some People Skeptical of Science? Other Reasons...

- ▶ Many scientific findings run counter to common sense
- ▶ Science can conflict with religious belief
- ▶ Scientific findings can be a challenge to some ways of doing business
- ▶ Some instances of scientists being influenced by financial motives or being unscrupulous

Dietary Research at Harvard in the 1960s



50 Years Ago, Sugar Industry Quietly Paid Scientists To Point Blame At Fat

SEPTEMBER 13, 2016 · 9:59 AM ET

 Camila Domonoske



A newly discovered cache of internal documents reveals that the sugar industry downplayed the risks of sugar in the 1960s.

Luis Ascui/Getty Images

“

If you listen to the experts,
you're just a sheep!

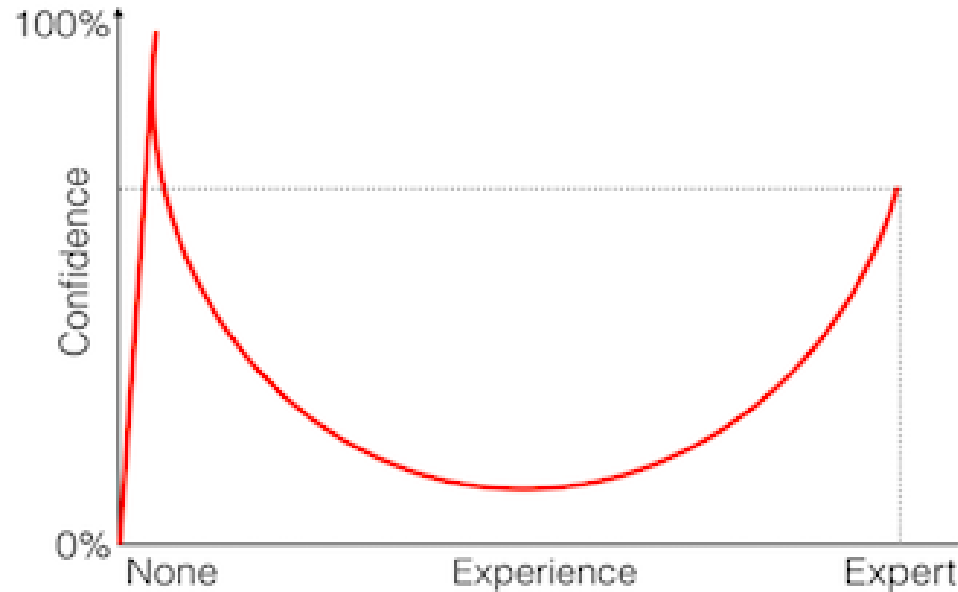
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Does critical thinking require that you figure
it out all on your own?

The Dunning-Kruger Effect

- ▶ "You need expertise to be able to recognize lack of expertise accurately...So those who lack expertise lack the knowledge to know that they're lacking [expertise]." - David Dunning

Dunning-Kruger Effect



How the Dunning-Kruger effect explains anti-vaccine attitudes

There is a reason why anti-vax attitudes are hard to shake, explains a new study.

PAUL RATNER 10 July, 2018



By conducting the survey of **1,310 adults**, the team led by Matt Mota discovered that **36%** thought they knew more than the doctors and **34%** claimed to know more than the scientists about the possible causes of autism. The highest degree of overconfidence was shown by those with the **lowest knowledge** and high levels of endorsing misinformation. They were also more likely to support non-experts (like celebrities) being involved in policymaking.

We also found strong evidence of Dunning-Kruger effects in our sample. **Sixty-two percent** of those who performed worst on our autism knowledge test believe that they know as much or more than both doctors and scientists about the causes of autism, compared to only 15 percent of those scoring best on the knowledge test. Likewise, 71 percent of those who strongly endorse misinformation about the link between vaccines and autism feel that they know as much or more than medical doctors about the causes of autism, compared to only 28 percent of those who most strongly reject that misinformation.

- ▶ Ideally, the scientific method is not dogmatic: a powerful tool for learning about reality
- ▶ *You* can take a scientific approach to knowledge seeking
- ▶ There is value in understanding what scientists do, and carefully considering scientific findings