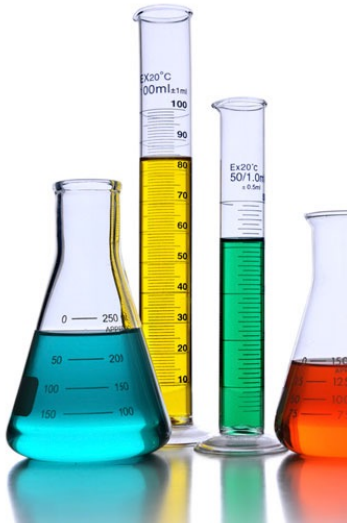
Ch01

Knowledge

What does it mean to know something?

… and how can science help us know things?

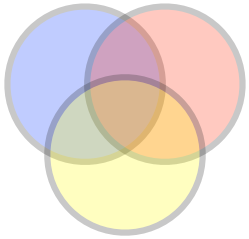


version 1.5

Ch01

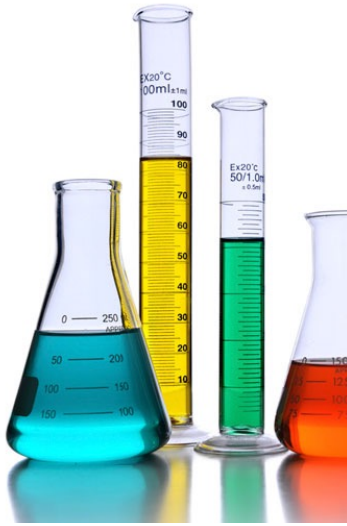
Knowledge

- Knowledge
  - Imagination
  - Truth & Belief
  - Justification



- Science
  - Characterized
    - Reproducible, Testable, Tentative, Predictive, and Explanatory
  - Observation & Hypothesis
  - Models
    - Theories & Laws
  - Experimentation
    - Research & Technology
  - Scientific Method

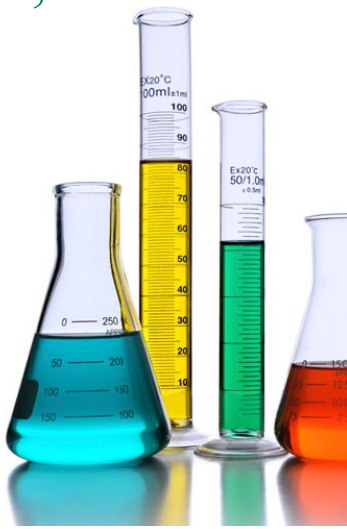
- Chemistry
  - The science of matter
    - Matter
  - From clocks to rocks



"Imagination will often carry us to worlds that never were.
But without it we go nowhere."
Carl Sagan

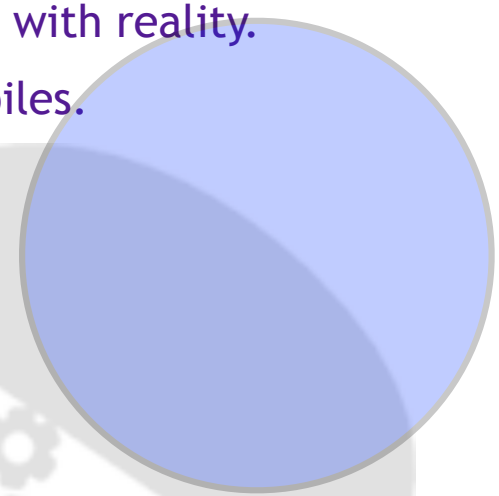
"Imagination is the beginning of creation.
You imagine what you desire, you will what you imagine
and at last you create what you will."
George Bernard Shaw

Imagination is more important than knowledge.
For knowledge is limited to all we now know and understand,
while imagination embraces the entire world,
and all there ever will be to know and understand.
Albert Einstein



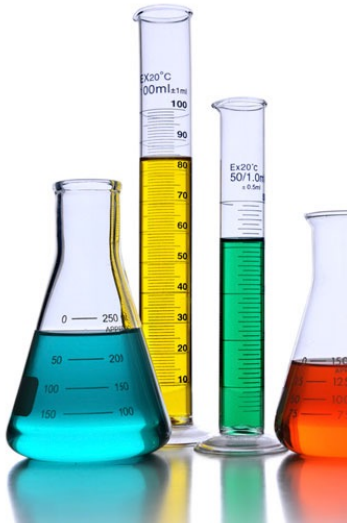
What we can imagine…

- Imagination has no limits. It's not even limited by reality.
- Some things that exist in our minds aren't consistent with reality.
- But everything we can imagine can be put into two piles.
  - The things that are consistent with reality.
  - The things that are not.
- It's useful to sort these things.
  - Reality has consequences.
    - True things can have an impact on us.



- True walls can stop us.
- True pits can trap us.
- True bridges can be relied on.
- False one's just distract us.

- For many things, it matters whether they're true or false.

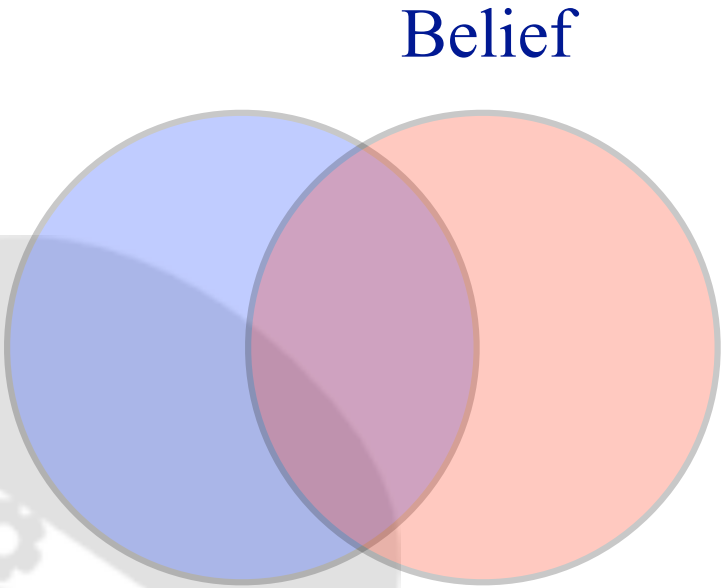


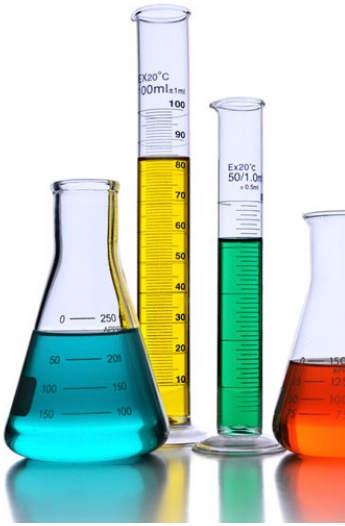
What we can imagine…

- True means consistent with reality.
- False means different than reality.

- It's useful to believe in things that true, and to understand when they're not.
- Believing in something means having confidence it is true.

- Belief is certainty.
  - Not everything we believe in is true.
  - Not everything that is true is believed.
  - Not every belief has consequences.
    - It doesn't always matter if a belief is true or not.
    - But it often does.



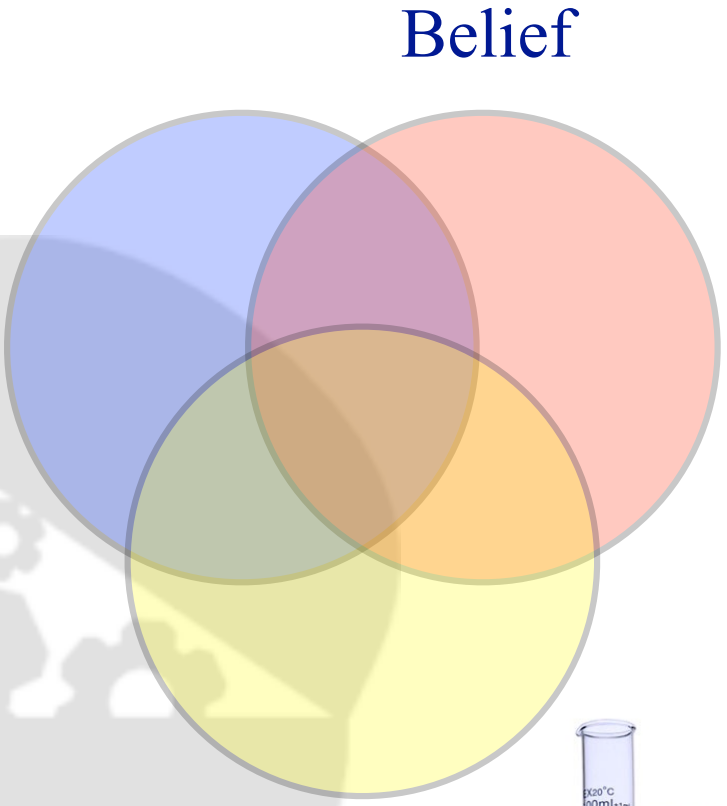


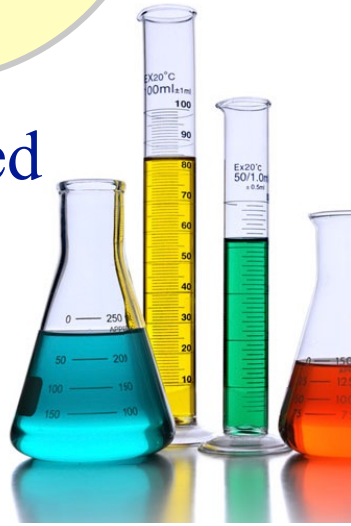
What we can imagine…

- It's hard to know what's true.
- It's easier to know if something is false.
- It only takes one exception from reality to know a statement is false.

- Justifications help us identify truths.
- Justifications are reasons to believe in something.

- Things that are false are harder to justify.
  - Justified beliefs are more likely to be true.
  - Justifications reduce the chance we'll trick ourselves into being certain about something, that is not true.
  - Justifications give us confidence that things are true.

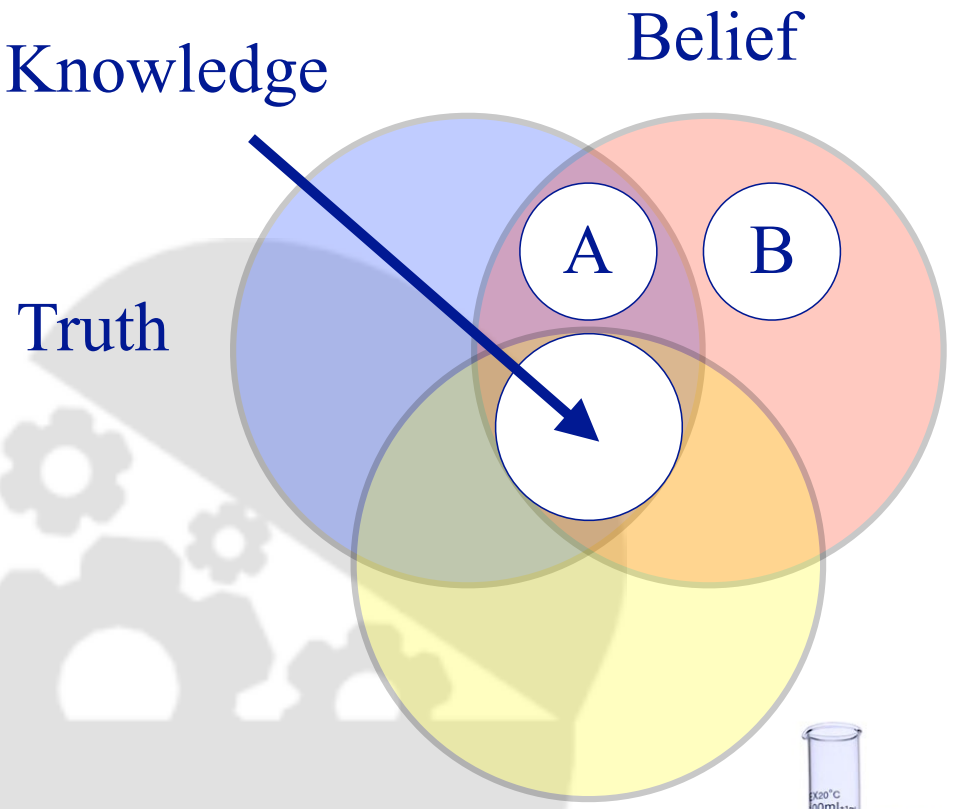




What we can imagine…

- Knowledge is a justified true belief.
- Knowing something means believing it, and having justifications for it's truth.

- Knowledge isn't just an answer.
- You can always guess for an answer.
  - The guess could true (A)
  - The guess could be false (B)
  - A guess still isn't knowledge.
    - Even if it's a lucky guess (A)

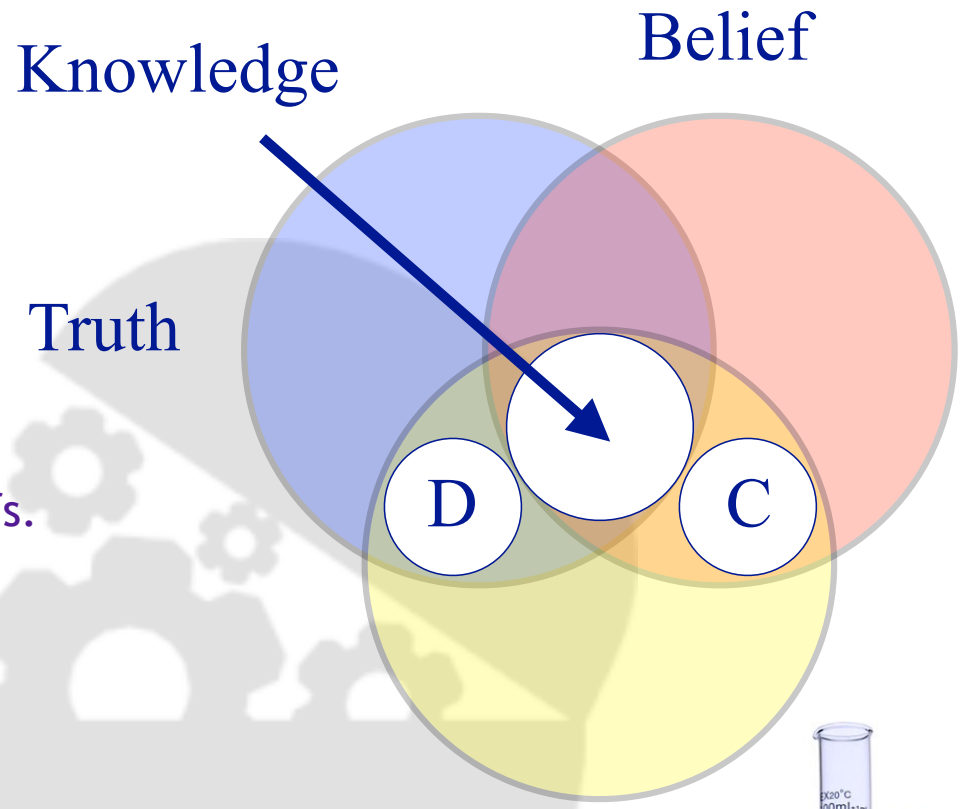


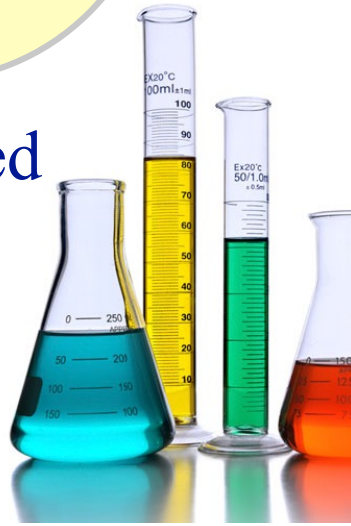
What we can imagine…

- Knowledge is a justified true belief.
- Knowing something means believing it, and having justifications for it's truth.

- Not all justifications are reliable.
  - A false justification (an error), can lead us to a false conclusion (C)
- Careful justifications can direct our beliefs.
  - They can lead us to new truths (D).
  - Things that don't seem true at first, but we come to believe.
    - Like quantum mechanics.
  - They can help us grow our knowledge.

- Science is one process for identifying justified true beliefs.
- Science can produce knowledge.





Knowledge

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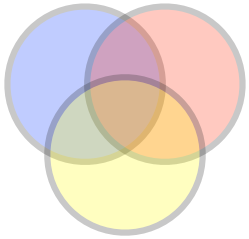

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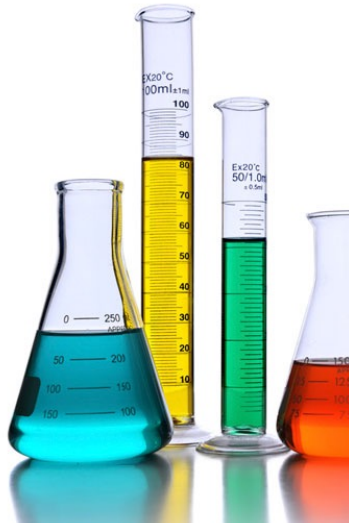


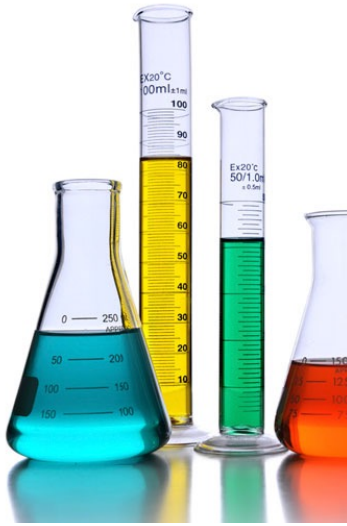
What is science?

Science

noun /sīəns/

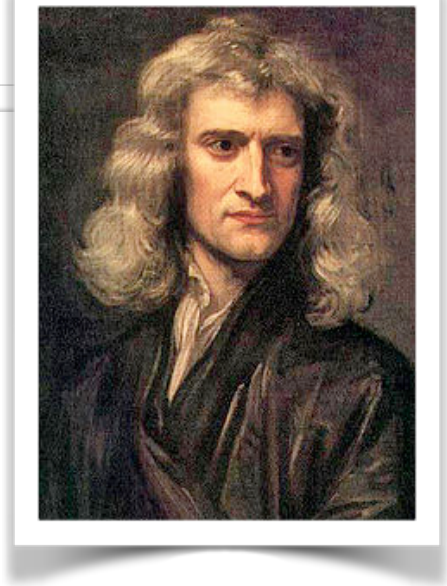
: the systematic study of the structure and behavior of the physical and natural world through observation and experiment.

— Oxford



What is science?

- Knowledge is a justified true belief.
  - There are different ways to justify beliefs.
- Science is one method of justifying beliefs.
- Science is an empirical method.
- Empirical means observable or experienceable. That which can be experienced by others.
- If our justifications are empirical, we can share them.
- Other people can observe what we observed and we can share justified beliefs.
  - That means the knowledge we acquire can grow beyond just us.
    - It means Einstein could start with the knowledge of Newton and build off of it.
    - It means their knowledge can belong to *and be expanded by* new generations, like yourself.

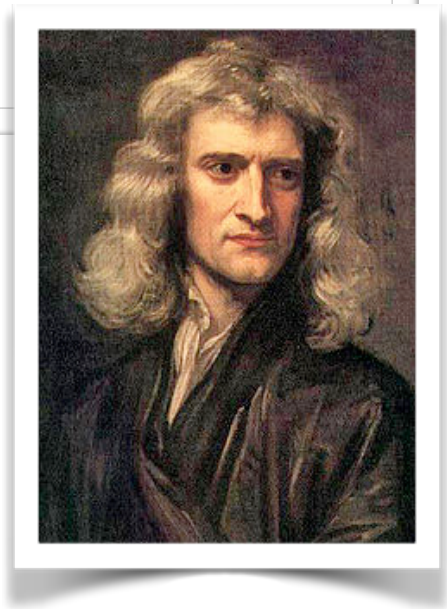


"If I have seen further it is by standing on the shoulders of giants."

— Sir Isaac Newton

What is science?

- Science prioritizes physical and natural phenomena.
- Scientific knowledge can be characterized as …
  - Reproducible
    - If we can't reproduce our observations, that experience is hard to share. That knowledge may end with us.
  - Testable
    - If we can interact with those observations, we can refine them and gain greater clarity of that knowledge.
  - Tentative
    - Gaining knowledge is about stepping into unknown areas. It's necessary to make our assertions tentative, the same way you would step carefully into a dark room.
  - Predictive
    - The best knowledge creates models that we can use to predict future events — reliably.
  - Explanatory
    - Knowing why something will happen gives us greater insight that whether it will happen. If we can explain natural phenomena, we can often direct or cause it.



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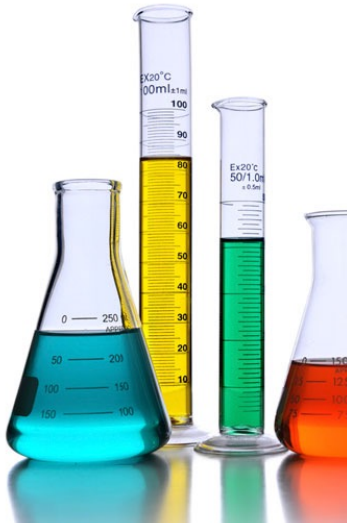

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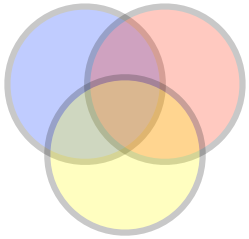

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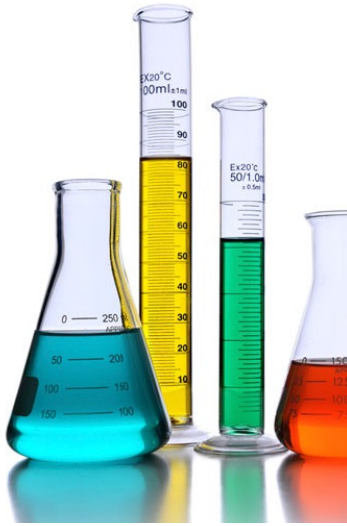
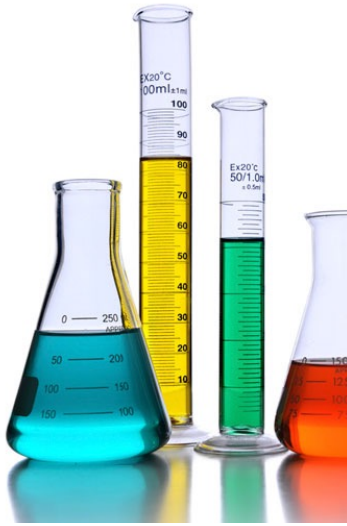


Observation

- Scientists start by collecting observations.
- Reproducible data, that documents how we experience the world.
- Observations are not just what you see, it's any experience we can reproduce and that others can confirm.
  - The taste of honey.
  - The color of the sky.

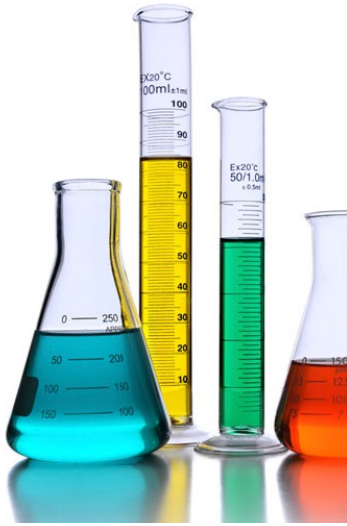
- Observations can be both qualitative an quantitative.
- Measurements are quantitative observations.
  - We'll talk more about measurements in a bit.



Observation

- It's important to keep our observations and our interpretations of those observations separate.

- Observations are truths.
  - If you saw water on your car this morning, it's true you saw water.
- Interpretations are not necessarily true.
  - If you saw water on your car this morning, it's not necessarily true it rained last night.
- But those interpretations, those possible explanations, are valuable.
    - They may be the reason for our observations.
- Hypothesis are tentative explanations of our observations.



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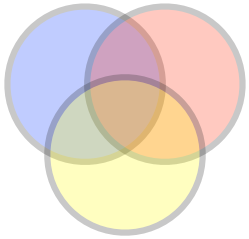

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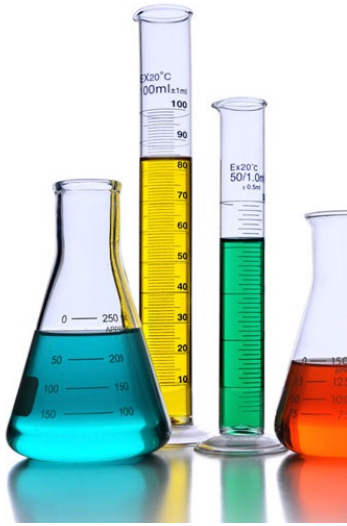


Theories & Laws

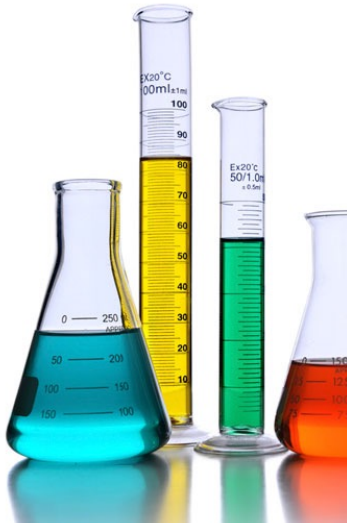
- Scientists express much of the knowledge they collect as models.
  - The same way you might draw a map to share your knowledge of a city.
  - The same way you might use a paper airplane to explain how an airplane flies.

- These models are laws and theories:
  - Law
    - A statement of natural phenomena to which no exceptions are known. A law is not an explanation. (A summary of many consistent observations, without explanation.)

The law of gravity is that two objects pull on each by a force equal to the sum of their masses and divided by the distance between them squared.

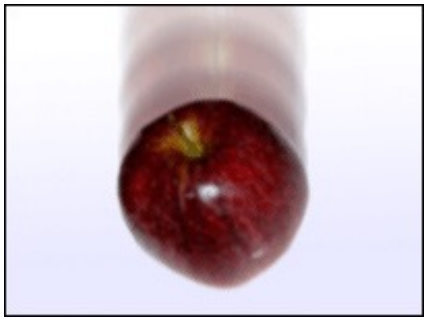
  - Theory
    - An explanation of nature with considerable evidence or facts (observations) to support it.

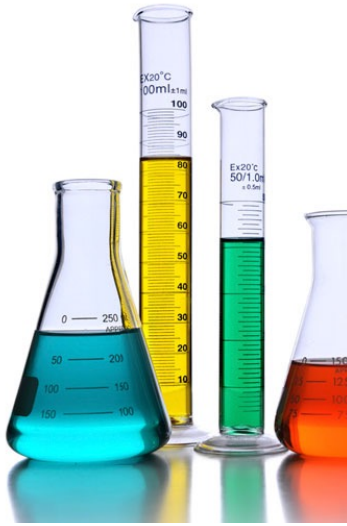
Tectonic theory states that continents can move because the surface of the earth is composed of plates floating on a liquid molten core.



Scientific Laws

- Laws are easy to understand.
  - Laws are truths.
  - Laws are a statement of our collective observations.
    - Something is a law if it truthfully describes every observation mankind has every made of that phenomena.
  - Gravity is a law, because we have never observed an exception to it.
  - Laws don't explain why something happened.
    - We don't have a single, reliable explanation as to how gravity works.
    - We only know what to expect because we always see the same thing happen.
      - But that pattern can be used to predict future behavior.
      - It justifies our belief that if we drop an apple, it will fall towards the earth.
- It's always possible a future observation will disprove a law, at which point it will no longer be a law.





Scientific Theories

- Theories are not truths.
- Theories are an attempt to represent truths.
  - The truths theories offer us are often more valuable than scientific laws — because they explain why.
  - As we make observations we attempt to see the truth of why behind those observations, and then we model it with a theory.
- Like a sculptor has a perfect image in his mind
  - … and then tries to represent that image by taking away everything from a block of marble that is inconsistent with the image.
  - … and like sculptors, scientists are imperfect so a little inconsistency almost always remains.

"I saw the angel in the marble and carved until I set him free."

— Michelangelo

Scientific Theories

- We chip away at theories to improve them, by experiencing that phenomena from different angles and making new observations.
  - We try to improve the explanation by finding where it's inconsistent with reality, and removing that part.
    - To leave the theory as close to truth as possible.
- Experiments are reproducible, designed experiences that provides an opportunity to make further observations and disprove hypothesis.
  (or gain support and confidence in our hypothesis.)

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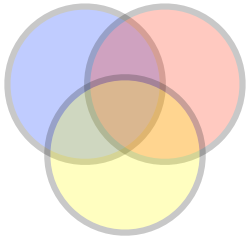

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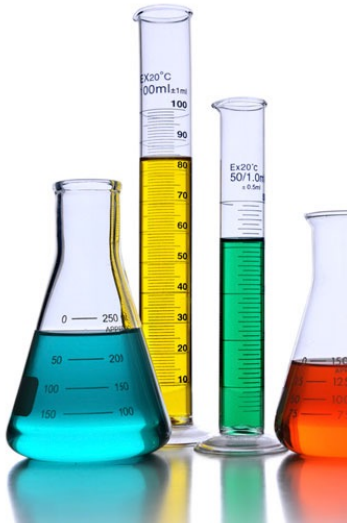

Scientific Method

- Observation: The details of an experience that can be reproduced and confirmed by others.
(Data, Facts)

- Hypothesis: A tentative explanation of observations that provides a basis for further experimentation.
(Hypothesis must be disprovable to have value.)

- Experiment: A reproducible, designed experience that provides an opportunity to make further observations and disprove hypothesis.
(or gain support and confidence in our hypothesis.)

- Theory: "Well-established hypothesis." An explanation of nature with considerable evidence or facts (observations) to support it.

- Law: Statement of natural phenomena to which no exceptions are known. A law is not an explanation.
(A summary of many consistent observations, without explanation.)

Observation

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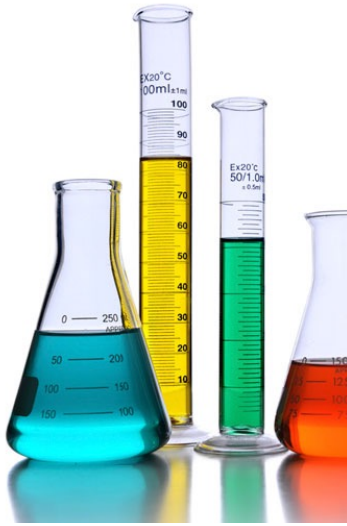
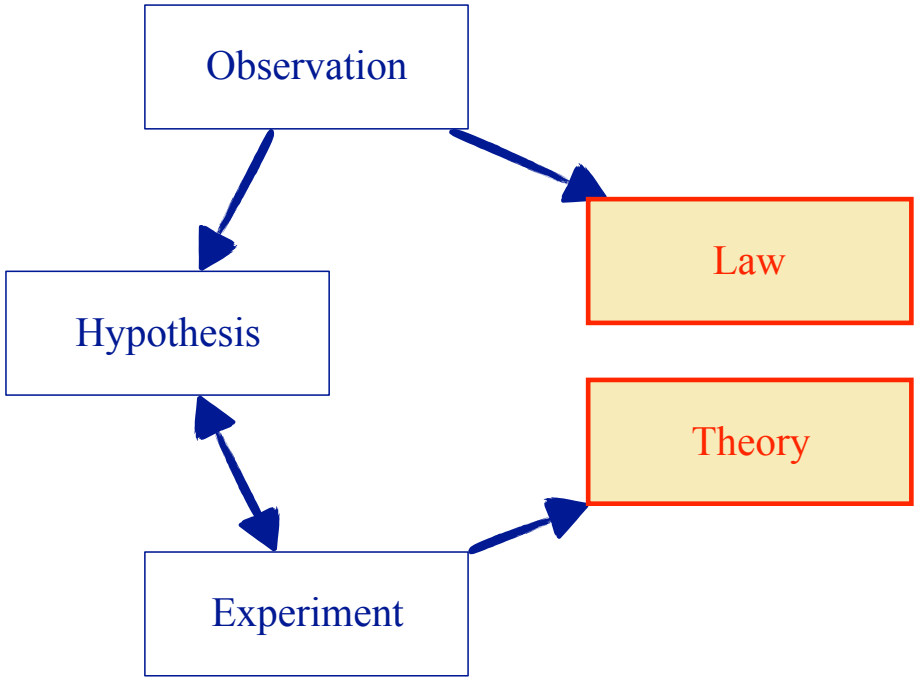
Theory

Experiment



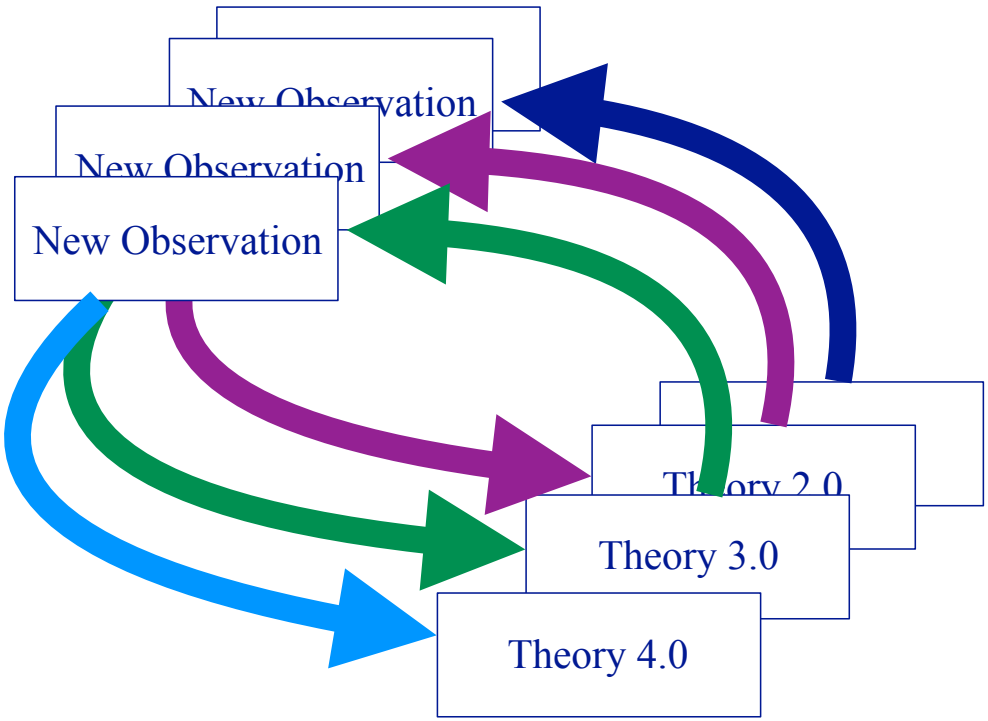
Scientific Method is a process.

- You always start with observations.
  - What do you know is true (real).
  - What you see, touch, hear, smell…
  - No interpretations, just observations.
- Only when you have enough data, enough observations, do you offer a tentative explanation, a hypothesis.
  - It's like a connect the dot game, let yourself see enough connections before you guess what the picture might be.
  - A hypothesis is a model for how things *might* work.
- Then you experiment.
  - You try and test that model, stretch it, break it, find it's limits so you know how much you can trust it.
    - When it holds, you test it more.
    - When it breaks, you fix it. You patch it up and offer a slightly better hypothesis.
- When you start to trust that explanation you call it a theory.
  - Theories are well established explanations.
  - Theories are reliable models.
  - Theories let us predict the future, successfully and with confidence.
- When we can't explain something, but it's showing to be true by many observations, we all it a law.
  - Laws let us predict the future, without knowing why.
  - Laws are patterns that seem to have no exceptions.
- Scientists don't make science, we use scientific theory to produce laws and theories.
  - Science is what we do.
  - Laws and theories are what we produce.



Science is never perfect or complete.

- Science is iterative.
  - It goes in cycles, bringing us closer to the truth each time, but never claiming to be the truth.
- It's never complete.
  - Science never claims to have all the answers.
  - All we try and do is produce useful models, reliable explanations.
    - Tools for predicting results.
  - We never prove theories.
    - We only disprove them
      … so we can improve them.
- We make leaps and reach plateaus in knowledge.
  - Theories that gave us the steam engine, put us on the moon, the electric motor, the internet…
  - Science has produced great theories and important laws on which marvelous technologies are built.
    - But no theory is ever the end of the story.
    - We assume every theory has room to grow.
    - Each theory leads us to new observations, new hypothesis, new theories.
    - The more you learn, the more you realize there is out there to know.
  - Science requires the arrogance to believe you can know anything, and the humility to accept you will never know everything.



Questions…

What's the difference between a hypothesis and a theory?

Trust. A theory is a hypothesis we've decided to trust.

What's the difference between an observation and a law?

Frequency. An observation is something we've seen once, a law summarizes all the observations that have ever occurred.

What's the difference between an observation and and a hypothesis?

What's the difference between a law and a theory?

Explanation. Hypothesis and theories attempt to tell us why, laws and observations just say what we've seen.

True and False:

Observations are facts/truths. ✓

Interpreted observation are hypothesis. ✓

A hypothesis is a fact/truth. ✗

A proven hypothesis is a theory. ✗

An established theory is a fact/truth. ✗

A proven theory is a law. ✗

A law is a fact/truth. ✓

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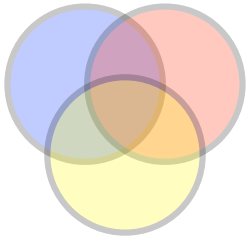
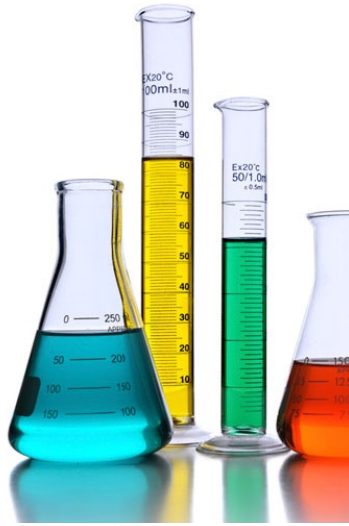


- Chemistry
  - The science of matter
    - Matter
  - From clocks to rocks



Getting Started

"The science of the composition, structure, properties and reactions of matter, especially of atomic and molecular systems."

— Webster

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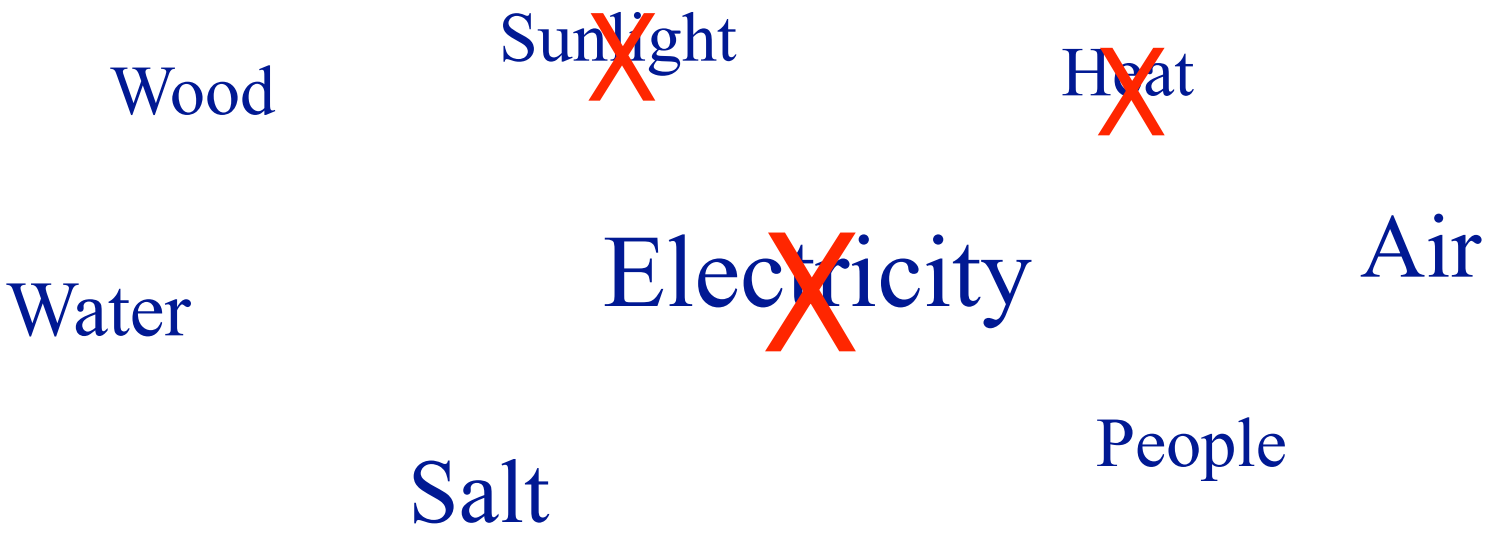
Chemistry Defined

The science of matter.

What is Matter?

Matter is anything that has mass and occupies space.



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Chemistry Defined

What is it made of?

How do the pieces fit together?

"The science of the composition, structure, properties and reactions of matter, especially of atomic and molecular systems."

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What makes it unique?

How do you change it?

How do we answer these questions?

How do clocks work?

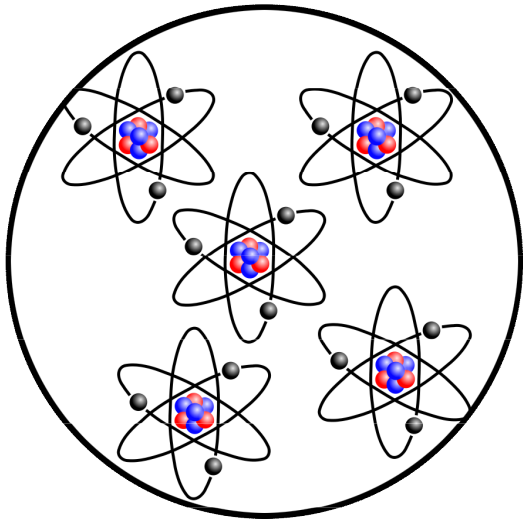
What is it made of?

How do the pieces fit together?

What makes it unique?

How do you change it?

How do rocks work?



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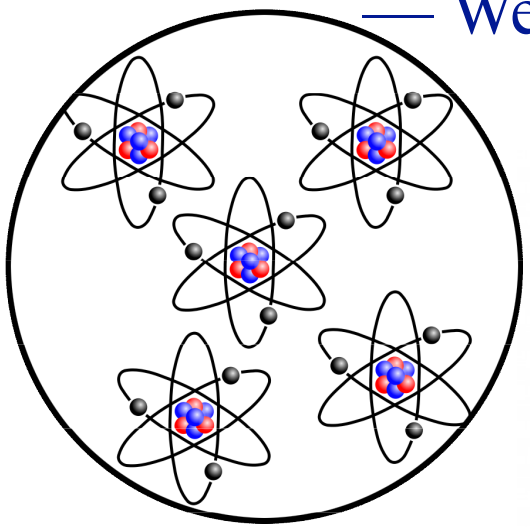
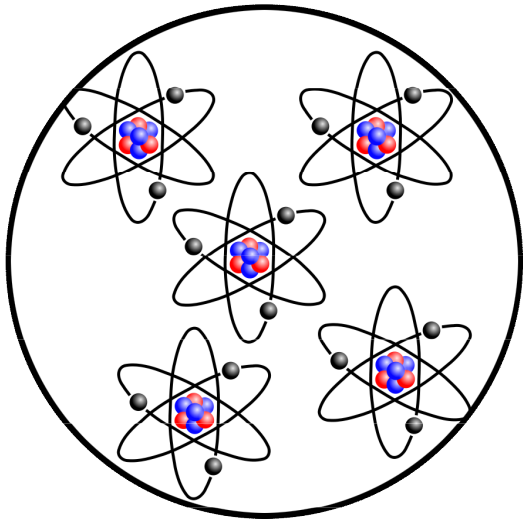


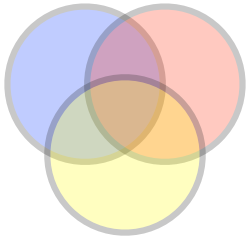
Chemistry predicts & explains matter.

- You can divide all substances into smaller pieces of matter.
- The smallest pieces of a substance, that are still that substance, are atoms and molecules. (We'll just call them particles for now.)
  - **This is atomic theory. The first theory of chemistry.**
  - Chemists explore these small particles and through observation and experiment, offer reliable explanations for the reactivity and properties of the substances they compose.
- This semester, we will help you use scientific method to deduce the composition and understand the structure of the particles that make up all matter in the universe.
- Once you know a substances composition and structure, we will show you how to predict and explain many of the properties and reactivity of those substances.
  - Given similar white powders, you will be able to predict which:
    - Dissolves in water.
    - Floats in water.
    - Turns pink in water.
    - Burns in water.
    - Freezes water.
    - Changes into water.
- This is chemistry, the science of matter.



Knowledge

- Knowledge
  - Imagination
  - Truth & Belief
  - Justification



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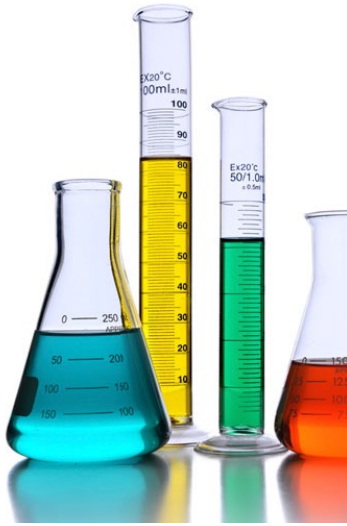

Questions?