Chapter 01: What is Science?

How do we know what we know? Become aware of how you gather, sort, and store information about the physical world you inhabit.

Section 1.1: Objects and Properties

Objects: Concrete vs Abstract

- Is it a thing or an idea? An object is a thing.
- A thing is made of atoms; a thing actually exists (whether or not you personally can make it or touch it or see it is not actually relevant here)
- An idea is an abstraction; it may represent and actual object without being the object, or it may just be a thought without physical reality

Properties: Describe and Define

- "Qualities or attributes that, taken together, are usually peculiar to an object."
- Play 20 Questions: Animal, vegetable, or mineral? Is it bigger than a breadbox?
- Start with the most general, move towards specific. What kind of information do you want?

Section 1.2: Quantifying Properties

What is measurable? What really can't be objectively measured?

- You can't objectively measure or quantify something like "What's the best movie of all time?"
- You can objectively measure or quantify something like, "What movie has won the most Academy Awards?"
- The fact that *Ben-Hur*, *Titanic*, and *LOTR: Return of the King* each won 11 Oscars does not make them the greatest films of all time

Pro Tip: Units Matter!

- In general, measurements need units
- Question: How long was *Titanic*?
- Answer: 195 or maybe 3.25; both 882.75 and 269.06 could be correct

Section 1.3: Measurement Systems

Referent Refers to What?

- Exactly.
- Everyone has to agree on the same referent, or a measurement is meaningless
- It doesn't have to be high-tech (the pyramids were not, in fact, built by aliens)

English (Imperial) System of Units

- Developed over centuries
- Convenient (but inconsistent) human body referents

Metric System (Système Internationale, or SI)

- Decimals! So easy, even 16th century mathematicians can use them!
- Like everything, developed over time
- Thanks for the units, now off with your head!

Section 1.4: Standard Units

Fundamental vs Derived Units

- Fundamental: length, mass, time, charge
- Derived: velocity, force, energy, current, voltage

Length

- 1meter = 39.4inches = 3.28feet
- Area = L^2 = m^2
- Volume = L^3 = m^3

Mass

- 1kilogram = 2.2pounds
- This is a pretty poor equivalence!
- Mass is not the same as weight!

Time

- How long is 1 metric second?
- Trick question: a second is a second is a second
- 1 second = the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom
  What exactly is one second? - James May's Q&A (Ep 2) - Head Squeeze - YouTube

Section 1.5: Metric Prefixes

Scale the Unit to the Measurement

- What's the distance from here to Little Rock?
- Why not express that in feet? Inches?
- Imperial conversions are hard! (Metric is easy!)

Learn a Few Easy Prefixes

- milli = $\frac{1}{1000}$ = 0.001 = 10^{-3}
- centi = $\frac{1}{100}$ = 0.01 = 10^{-2}
- deci = $\frac{1}{10}$ = 0.1
- kilo = thousand = 1000 = 10^3
- mega = million = 1,000,000 = 10^6
- giga = billion = 10^9
- tera = trillion = 10^{12}

Use Water to Remember

- 1 cc = cube with 1 cm each side = 1ml = 1g
- 1000 cc = cube with 10 cm each side = 1liter = 1kg
- water = 1 gram per cm^3 delivers us the definition of density!

Section 1.6: Understanding From Measurements

And Now I Bring You...the Weather

- How do you make sense of all those numbers!?!?!
- Units: temperature in °F, barometric pressure in mb (millibars), etc.
- Context: your experience informs how you interpret the numbers

Data

- A collection of information: might be qualitative or quantitative
- One piece of data is a snapshot; you need multiples to extract meaning
- Cross-sectional: same snapshot at the same time for a large number of subjects
- Longitudinal: same snapshot of the same subjects, repeated over a long time

Ratios and Generalizations

- The first rule of generalizations is don't over-generalize
- A ratio (fraction) is just a comparison: how does A compare to B?
- Looking at many instances, making the same comparison, lets you start to extract the general relationship of trend

Why Babies Need Bundling

- Why are babies always wrapped up in blankets, even when you think it's pretty warm?
- Surface to volume ratio: example in textbook
- Double the length of the side, you get 4 × the area and 8 × the volume!
- Triple the length of the side, and you get 9 × the area and 27 × the volume!

Density: How Much Mass is Crammed Into That Cube?

- Definition: $density = \frac{mass}{volume}$ = simple ratio
- Not everything has the same density
- Keep it simple: assume the matter is equally distributed

Symbols and Equations

- Don't panic!
- An equation is a sentence, and you are perfectly ok with sentences: you read and understand sentences as a matter of course.
- The difference is the symbolic language; math sentences use symbols you are less used to using.
- Like any foreign language: practice! Translate into a normal sentence.
- Or get visual: graphs are all about seeing how things are related to other things

Inverse-Square Relationship

- This shows up all over physics; we will see it at least 3 or 4 times in different contexts
- In words: x and y are related. If you increase x, y gets smaller (that's the inverse part).
- However, y gets smaller faster than x gets bigger (and now you need to see this with some numbers to make it make sense!).

Section 1.7: The Nature of Science

Everyone is a Scientist

- "I don't know, but I'm trying to find out, ok?"
- Science itself isn't hard; it's the discard that's difficult
- Everyone needs to be a better scientist

The Scientific Method

- Observe
- Hypothesize
- Predict
- Test
- Modify
- Repeat

The Words Mean Something

- Hypothesis: best first guess; have a stab at explaining something, but the key word is testable. A scientific hypothesis must be testable.
- Model: tool used to visualize an hypothesis or theory. The better the model, the more it can account for.
- Theory: an explanation which has been tested--repeatedly and over time--and never been found to be false. Explains why it happens.
- Law: describes an important relationship that is observed in nature to occur consistently time after time. Describes what happens.

Pseudoscience, or Please Don't Get Me Started

- Contrary to what you might see presented by the media, there are not "two sides to every story."
- Peer-review exists for a reason; it is not a perfect tool, but it works.
- Science works because we're all in on it; sometimes it doesn't work as fast as you want, but <insert historical context here>