Defining Science
The Scientific Method

science is a process of uncovering knowledge of our universe

but there are many ways to investigate things
there are many different kinds of knowledge:
scientific knowledge
musical knowledge
art
poetry
philosophy
theology
etc

all these can teach us new facts about ourselves and our world
→ focus on different aspects of the same thing

eg flower, a sunset,

all are just different languages or ways to describe the world

science is a **language**, a **tool,** a method for searching for knowledge
(but only one of many)

a language is more than just the written word
→ it is possible to be able to read the words of
science but not to understand the language

(even though it's the same "language")

→ the jargon of science

some things appear scientific on the surface
ie. are in the language of science
but are not really science
→ they ignore its requirements or
assumptions

eg. alternative medicine (Mannatech)

many people think of science as a giant dictionary; a
body of knowledge

but it is more:
a process; a way of looking at the world; a way to uncover knowledge

Aim of Science

to develop an accurate objective picture of what the world is and how it works

to be able to predict what will happen in the future
(based on a certain set of conditions)

Major Assumptions of Science

like any other method of study, science is based on a particular set of assumptions that must be met:

1. its guided by natural laws
   eg. "creation science" is an oxymoron

2. must be empirically testable

   eg. car wont start because it was hit with alien ray gun

3. must be falsifiable

   scientific hypotheses are not necessarily more likely to be true
   but they are only scientific if they could be proven false

   science doesn't prove, only disproves

   if its unable to be disproven, its not a **scientific** fact

   scientists think like everyone else does but with more awareness of the possibility that they may be wrong!

   versus a politician who must act like he can never be wrong

   eg. "God created universe" not falsifiable

   eg. astrology can predict important events in your life
   there is always a "yes/but", no way to disprove

4. Must have predictive value

   eg. virtually ALL strides in medical treatments have come

from scientific knowledge

our medicine has not advanced at all through witchcraft, magical charms or shamans though they have been around 100's of times longer

almost all rigorous testing of alternative medical practices have shown them to be ineffective

(but what modern medicine has ignored are the nonscientific aspects of treatment: psychological outlook, spiritual ideals, positive imaging, etc

it is often too cold and onesided

this has led many to reject modern medicine)

5. In themselves, scientific facts carry no value judgements, no moral weight

eg. the knowledge used to split the atom was neither good nor bad

how it is used must be determined by society, not the scientists

→ it would be futile and stupid to strive for a strictly "scientific" way of life or government

→ could never tell whether it was right or wrong to commit murder or "love ones neighbor"

but that doesn't exonerate scientists from operating with human values

In science, we assume that everything is **reducible** to simple understandable natural explanations:

body functions
smile of a baby
philosophical and religious beliefs

there is no room in science for magic or supernatural

such cold calculating analytical techniques may be part of the reason why some distrust science

Can science explain everything?

right and wrong?
Why we are here?

life after death?
existence of god?

Throughout history magic and mysticism have given way to science

virtually ALL major progress in civilization and society have come by way of increasing our scientific knowledge

magic and the supernatural are only left to explain what science cannot yet explain

Scientific Facts

What exactly are scientific facts:

1. is it a scientific fact that the earth is round?
2. is it a scientific fact that I am touching this desk
3. is it a scientific fact that science is a boring subject
4. is it a scientific fact that some can predict the future
5. is it a scientific fact that changing your answers on a multiple choice exam lowers your grade

1,2,5 are myths, not scientific facts

5: 1800 questions
100 changes;
21 wrong to right
21 wrong to wrong
58 wrong to right
→ 3 to 1 chance the changing answer would improve your grade

3 is a value judgement not a fact

4 is only valid scientific fact
that's exactly what science does is predict the future
and it's a much better predictor than astrology, palmistry, etc

The Scientific Method

How are natural laws discovered?

Scientific method
→ a specific way of seeking scientific knowledge

it is a process that incorporates several interacting processes to learn more about our natural world

its not a step by step recipe
it's a group of interrelated activities

1. Observation
all science begins with observations

sets limits: what cannot be observed cannot be investigated
but can be direct or indirect
→ instruments can extend our senses

we all make observations
→ not necessarily scientific observations

few observe correctly:
people see what they want to see or
what they think they ought to see

eg. brain teaser questions

observations must be based on logical or tested assumptions

must be unbiased
→ can't set out to "prove" something

eg. if you already believe in bigfoot or flying saucers
you are biased and cannot make very effective *scientific* observations

eg. Loch ness assumes something is there then builds elaborate theory to "explain" data or lack of data

eg. Bermuda Triangle
source of most stories is Gaddis article that

appeared in Argosy in 1964
some losses occurred 1000's of miles away and were moved to the triangle
percentage of vessels lost in triangle are no higher than anywhere else
but percentage of false losses are much higher for this area of the worlds oceans

it is very difficult, even for scientists to eliminate bias; to keep an open mind

what we observe is very much determined by what theory suggests should be observed

the scientific method is colored by scientists own values, attitudes and general philosophies of life

one way to reduce bias is that an observation must be repeatable by others

eg. one persons claim of UFO or abduction is not a scientific observation

eg. ask each of 100 people to define a car
would get oa much more accurate description if all worked together on a single definition
→ eg. committee work

2. Create Hypotheses

everyone makes observations
not everyone shows further curiosity

scientists try to define a problem
look for why something occurs

create an hypothesis based on repeatable observations

ask questions, look for an explanation
use inductive reasoning

→ generalizations about observations

a very creative process; requires artistry,

experience, hunches, accidents, luck

eg. in biochemistry, a vast amount of discoveries is based on the structure of benzene
Kelule (german biochemist) was trying to figure out its structure
went to bed afte a "fairly alcoholic" party
he dreamed of 6 monkeys in a ring, tail in mouth
gave him the idea for possible structure of benzene ring
→ tested his hypothesis of 6 carbon ring

the "art" of science is to ask questions very carefully

eg. it is very difficult to collect *scientific* data through surveys unless very carefully worded
How often do you take a bath?
…Broken the law
…performed an incestuous act
How long did you study for this test?
→ will you get dependable answers?

it also matters who's asking the question:
peer, parent, cops, etc

must be testable, must be falsifiable

eg. Did God create the earth?
need something to compare
→ need a world he didn't create

eg. In pseudoscience there's *always* a "yes/but"
→ so even negative evidence doesn't disprove it

Best to pose question or hypothesis as an "either/or" statement

→a given question may have 1000's of logical answers but only one is correct, therefore the chances are high that a random guess will be wrong

eg. observation: my car wont start

hypotheses: battery is dead
wiring is fried

out of gas
someone stole the distributor cap
aliens zapped car with energy sucking ray

all are possibilities best to take it one at a time with most likely first

Occam's Razor:

The simplest logical solution/ explanation is the one preferred

Extraordinary hypotheses require extraordinary evidence

eg bigfoot, ufos, astrology, etc

3. Experimentation

purely scientific → separates science from other forms of inquiry

most of us are content to develop our own hypotheses (opinions) but don't feel a strong need to test them

a scientist wants to test the strength of his hypothesis through experimentation

try to disprove hypothesis you just made

→ needs to be rephrased as an either/or question

in the past it was easier and more convenient to eliminate the scientist than to risk having to change "common sense" public opinion

eg. Galileo, Spontaneous Generation

experiments must be rigorously **controlled**

→ must be aware of your assumptions

eg. JIR: "National Geographic, the Doomsday Machine" – G. H. Kaub

1. >6.8 million issues of NG each weighing 2 lbs are sent to subscribers monthly
2. not one copy has been throuwn away since it began publication 141 yrs ago
3. instead they accumulate in attics, basements,

garages, libraries, goodwill, salvation army, etc

4. soon the geologic substructure of the country will no longer support the load:
   - rock formations will compress
   - great faults will appear
   - continents will sink
5. conclusion: demand congressional action to halt its publication

eg. huge amounts of data collected concluded that pickles cause
- cancer
- communism
- auto accidents

why?
- 99.9% of cancer victims had eaten pickles sometimes in their lives
- 100% of all soldiers
- 96.8% of communist sympathizers
- 99.7% of those involved in car accidents

moreover,
- those born in 1839 who ate pickles have sufferend 100% mortality rate
- rats force fed 20 lbs of pickles a day for a month ended up with bulging abdomens, poor health and loss of appetite

eg. 2 researchers observed a close relationship between rapes and assaults increasing in summer, and robberies increasing in winter

hypothesized that this was due to seasonal fluctuations in testosterone levels

the experiments they designed seemed to support their hypotheses

SJG: but, "quite simply rapes and assaults peak in summer because winter is a hell of a time to lurk in alleyways

robberies show reverse because weapons are more easily concealed under winter clothing

remember occams razor

→ try to have only one dependent variable

eg Hawthorne Effect – >factory lighting > productivity

sometimes very difficult to separate correlation from cause/effect

eg. Haleys comet and price of ice cream:
for last ~15 yrs (since 1986) the further away it gets the higher the price of ice cream in cincinnati ohio

→ are they correlated? yes
→ is it cause and effect?

eg. 2003 study: people who shave less often are 70% more likely to die of stroke

→ correlated: yes
→ cause effect: no
→ both related to something else
slight decrease in testosterone levels: maybe

controls

some experiments compare an experimental treatment to a known control

eg. testing new drugs on market against placebo

but there is a true "placebo effect"

statistical analysis

the evidence from your experiments can be:
strong and convincing
suggestive
poor
→ need a way to test their strength

can statistics prove anything – no

statistics, used correctly can strengthen conclusions of experimental data

it takes in account normal variations

allows you to judge the original hypothesis with a certain degree of confidence
eg. 95% or 99% typically

statistics deals with **probabilities**, not certainties
there is no such thing as 100% certainty

even with all this conclusions are ALWAYS
tentative

must be repeatable by many others

eg. scientists publish in refereed journals

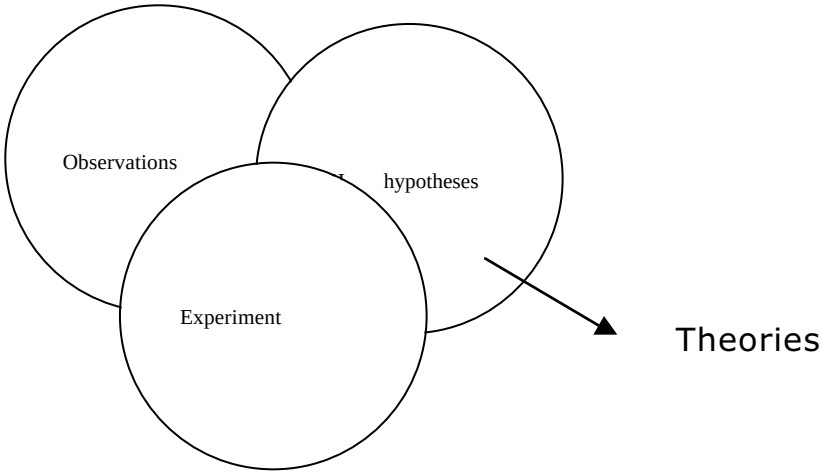
eg. "cold fusion"

one disproof invalidates it

observations or hypotheses that have been
verified repeatedly tend to become accepted as **scientific facts**

4. Develop Theories

the above processes may lead to theories



hypotheses that have been repeatedly verified and
not disproven may become theories

theories are not speculation
→supported by massive amount of evidence

but we haven't "proven" a thing
→**nothing has been (is ever) proven**
in science

but only need one disproof

these theories become Models:
helps focus and organize
helps simplify
leads to inferences and predictions

eg. medical discoveries used to cure diseases

most theories have a very short life span as originally proposed
→ they are only **temporary truths**

they don't necessarily become incorrect, just obsolete
eg Newton's gravity vs Einstein's relativity

as they are refined they become more inclusive and are able to make stronger predictions

replacing a theory that is wrong with one that is more subtly wrong

eg. "theory of agriculture"

seed sprouts
seed sprouts better with water
seed sprouts better under soil with water
add manure
prevent disease
root nodules
mycorrhizae
etc.

as theory is refined it becomes more and more accurate at predicting future events

eg. Heredity
something in cell transmits traits to offspring (Mendel)
it is in nucleus
it is in chromosomes
its either proteins or DNA
its DNA
specific genes identified

when we find exceptions to a current theory we are usually discovering new factors that might influence a particular outcome

a natural law implies there are NO exceptions

eg. an apple always falls to the ground
until the '50's anyway

→ one exception it must be trashed

eg. spontaneous generation
eg. gravity

very few Natural Laws in Biology