Unit 01 : Science, Nonscience, Pseudoscience

I. What is science?

A. one definition
observation
identification
description
experimental investigation
theoretical explanation
of natural phenomena
B. another definition

"The whole of science is nothing more than a refinement of everyday thinking."
Albert Einstein

II. The goals of science

A. to discover order in the natural world
(i.e., what makes the Universe tick?)
B. to make predictions about what should be expected to occur
(a test of your understanding)

III. Assumptions underlying science

A. Principle of Common Perception
1. we perceive with our basic senses
a. visual
b. auditory
c. olfactory
d. taste
e. tactile
f. other
2. what we perceive represents [the existence of] an objective reality
B. Principle of Uniformity
1. objective reality
a. obeys certain basic principles & natural laws
b. which remain consistent through time and space
2. fundamental natural laws do not change capriciously
C. Principle of Natural Causality
1. every event has an explainable natural cause
2. every event, in turn, will cause other events
D. conclusion
using our powers of observation, manipulation, and reason
we can discover basic principles and natural laws which govern the Universe

IV. Limitations of science

A. can investigate / explain natural phenomena
B. not applicable to
    1. supernatural phenomena
    2. aesthetic, moral, ethical dilemmas
C. falsifiable hypotheses are required
    1. if the hypothesis is false, it must be capable of being shown to be false
    2. alternative (negative) meaning of falsification
        a. data fabrication
        b. data manipulation
        c. other forms of intellectual dishonesty

V. Falsifiability

A. science can never 'prove' that something is true
    only demonstrate that an idea is false (disprove)
B. onion model
    truth may reside in what remains after 'false' is peeled away
C. analogies
    1. look to the law
        a. defendants are found to be guilty or not guilty
        b. innocence is much harder, perhaps impossible, to prove
    2. look to product safety
        a. products are deemed to be unsafe or not unsafe
            only a few observations of danger are necessary
        b. products can never be deemed absolutely safe
D. example
    1. test new drug on every human on the planet
        even with no harmful effects, you still not have proven it safe
    2. the next individual born might succumb to negative side-effects
    3. weigh potential benefits against potential risks

VI. Hallmarks of pseudoscience

A. relationship between science and pseudoscience is highly suspect
    1. attempt to use scientific knowledge to bolster claims
        claims often violate known scientific principles
    2. scientific jargon is favored over the scientific method
        "The hallmark of pseudoscience is new terminology."
B. pseudoscience does not advance / progress
    1. good science should be predictive and permit progress
    2. pseudoscience is often built upon older, untested claims
C. a feature shared with nonscience
    1. dogmatic approach to knowledge
        characterized by uncritical belief
    2. response to disagreement or contradictory evidence
        hostility, paranoia, ad hominem attack
D. tendency to ignore or distort contradictory evidence
    confirmation bias - the only evidence sought or brought to light confirms a claim
E. tends toward claims which are not readily testable or refutable by scientific means
    1. subjective
    2. invoke supernatural causes
F. data of questionable validity are frequently accepted as proof
    1. claims based on
        a. ancient manuscripts
        b. dubious observations
    2. which cannot be independently verified
G. reliance on anecdotal evidence
    1. preferable approach
        a. systematic observations
        b. controlled experiments
    2. example :
    photographs captured via hidden cameras and tripwires
        versus
    anecdotal reports of Bigfoot sightings
H. fragile phenomena
    1. disappear when subjected to
        a. controlled conditions / properly-controlled experimentation
        b. nonbelievers (negative energy)
    2. shift the burden of proof
        a. nonbelievers cannot perceive the 'signals'
        b. cameras and bright lights disrupt the phenomenon

I. unsolved mysteries are intriguing to everyone
1. scientific approach
a. generate explanatory / predictive hypotheses
b. test these hypotheses
2. pseudoscientific approach
mysteries are explanations in and of themselves
3. example :
Nostradamus 'foretold' of so many events in such general terms that, sooner or later, some event will seem to have been predicted
logical fallacy : The Fallacy of Positive Instances
simple coincidence is disregarded
ignoring all of the false predictions never hurts either

J. pseudoscience
1. explanation by construction of scenario after the facts are known
2. stagnation of thought
a. lack of scientific prediction
b. lack of accumulation of new knowledge

VII. Good Science

A. testable
B. falsifiable hypotheses
C. verifiable / repeatable
D. progressive
E. predictive
F. tentative truths

VIII. Scientific method

A. There is no single scientific method
no single step-by-step recipe followed by scientists
rather, a rigorous process by which new ideas are put to the test
B. classical scientific method
nonscientists tend to perceive a linear sequence of steps that must be followed
scientists recognize that steps are cyclical ... start anywhere in the sequence
1. observe (carefully)
a. keep good field or lab notes
b. keep data backed-up (physical and digital backups)
c. store in multiple, safe locations
2. hypothesize
a. create explanation for your observations that is
i. testable
ii. tentative
iii. causal
b. Ockham's Razor (also spelled Occam's Razor)
i. William of Ockham (ca. 1288 – ca. 1348)
ii. Principle of parsimony [Bertrand Russell]
iii. If one can explain a phenomenon without assuming some hypothetical entity, then there is no ground for assuming it.
iv. the best among competing explanations explains all observations, with fewest unwarranted assumptions.
3. test hypothesis
a. via
i. properly-controlled physical experiment
ii. thought experiment
iii. computer simulation
iv. etc.
b. manipulation is required
4. draw conclusions based on experimental data / results
a. were predictions (based upon your hypothesis) realized?
b. if the preponderance evidence
i. refutes hypothesis, then hypothesis is false
reject hypothesis
ii. supports hypothesis, then fail to reject hypothesis
"accept" hypothesis ss tentatively true
iii. if hypothesis is neither rejected nor failed to be rejected
revise the hypothesis
retest hypothesis (repeat experiment - never reuse data)

5. publish results
    a. media
        i. traditionally : print-media publication
        ii. increasing number of online publishing options
    b. manuscript is submitted to an appropriate journal
        i. subject matter should closely match your research
        ii. send manuscript to editor
        iii. editor selects 2-5 anonymous reviewers (referees)
        iv. author(s), affiliation(s), or acknowledgements stripped from manuscript
            why?
    c. referees
        i. expert in closely-related field
        ii. critique manuscript and recommend to the editor
            a) publish as-is
            b publish with modification
            c) reject
        iii. editor notifies you of decision
        iv. referees remain anonymous
        v. comments / critiques are provided to you
    d. peer-review
        i. disadvantages
            slow - delay of months before publication
        ii. advantages
            a) likely to spot flaws in data analysis, logic
            b) likely to detect hidden biases
6. example
    a. a new teaching method, artificial expert system (AES), is proposed
        i. hypothesis : AES superior to standard lecture-response method (SLR)
        ii. test : split class into male and female subclasses
            a) females taught by AES method
            b) males taught by SLR
            c) compare class averages when semester ends
            d) females exhibit higher class average
        iii. what conclusion do you draw? why?
            females are brighter than males? AES is superior to SLR?
            gender, teaching method are confounded
            we cannot tell which, if either, is REALLY responsible
        iv. how could we do this better?
            a) randomly assign students to teaching method
                what other factors might affect the outcome?
                    age? socioeconomic status?
                    quality of high school education?
                    professor's teaching style?
            b) pre-testing / post-testing