Fundamentals of Modern Science

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Why are you here?

- I know many of you have worked hard to get to university. But have you thought about why are you here?
- University is *not* a diploma mill. You are here not to just to get a degree or a certificate, but to learn and be educated.

What is a university?

- HKU is *not* a trade school. The goal of a university is not to provide vocational training.
- The goal of a university is to develop the student as a person, to prepare him/her how to think and for life-long self learning and self improvement

Science foundation courses

•To give students a broad view of science in terms of its nature, its history, its fundamental concepts, its methodology, and its impact on civilization and society.

•To emphasize the inter-connection between different disciplines of science

•What is mathematics, what kinds of mathematics are there, and what can mathematics do for different disciplines of inquiry

Science Foundation 2: Fundamentals of Modern Science

- To provide students an overview of the web of knowledge that makes up science
- An integrated approach that encompasses physics, astronomy, earth sciences, chemistry and biology
- to introduce the general principles and unifying concepts to describe the diverse phenomena in the natural world.

What is science?

- Why do we need to study science?
- What has science done for society? (not just serving as basis of technology, but is responsible for the conceptual changes of who we are)

What is NOT science

- What is the name of this bird (or plant)?
- What are the names of the planets?
- What was before the beginning of the Universe (the Big Bang)?

Different languages have different names for a bird

Not a question that can be answered by empirical means

Science is not a collection of facts

What is a scientific question

- What is the shape of the Earth?
- Why is the sky blue?
- Why is it hot in the summer?
- Why are leaves green?
- How did life begin?
- Why is the ocean salty?
- Where did water on Earth come from?

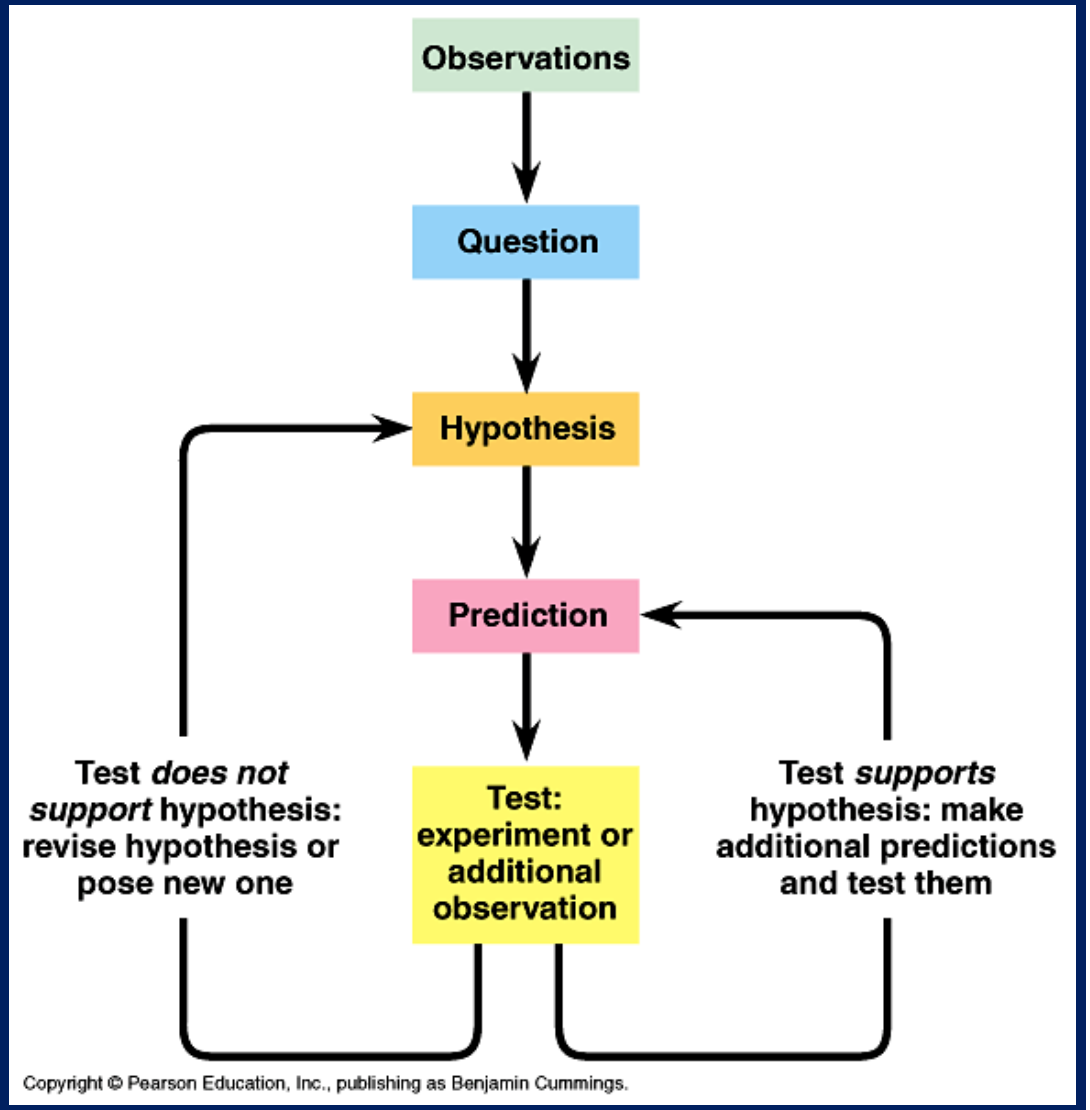
Ways of reasoning before science

- Metaphysics: it is the way it should be (e.g., planetary orbits should be circles because circle is the perfect shape, Aristotle)
- Authority: because the Pope tells me so

Science as a driver for social change

The scientific method

- Observations (qualitative and quantitative)
- Formulation of patterns
- Hypothesis to explain the observed patterns
- Deduction from the hypothesis and prediction of new phenomena or behavior
- Testing of prediction with new observations
- Revision of hypothesis



Scientific theories

Very powerful!

- A theory is an explanation for a very general class of phenomena.
- Example: the Newtonian theory of gravitation explains how objects on Earth and planets in the heavens move; the theory of evolution explains where different organisms come from.

A theory is the best that science can do as there is no absolute truths, just approximation to the truths.

A successful theory is the best that science can do

What is a good scientific theory?

- Self consistency
- Ability to explain known phenomena and prediction of unknown phenomena
- Simplicity (Occam's razor)
- Ability to explain a wide variety of phenomena with minimal hypotheses

When there are multiple explanations, the simplest is preferred

Can theories be overthrown?

- Theories can change as new observations are taken, or as more fundamental theories are formulated
- Examples: Newton's theory of motion replaced by Einstein's theory of special relativity; Newton's theory of gravity replaced by Einstein theory of gravity

Unification and integration

- Isaac Newton: unified the phenomena of moving objects on Earth and in the Heavens.
- James Clerk Maxwell: unified the phenomena of electricity and magnetism
- Albert Einstein: unified the theories of electromagnetism and moving objects

Why is science important

- Diseases are of spiritual origin (now known of be of physical origin)
- “vitality” separates living and non-living matter (biomolecules can be synthesized from inorganic molecules and all biological functions can be reduced to biochemistry)

Science as a driver for change in societal and philosophical perceptions

Are humans just machines?

Science as a driver for change in societal and philosophical perceptions

- The Earth is unchanging (rising mountains and drifting continents)
- The Earth is young (6000 yrs old , now known to be 4.6 billion years old)
- Men occupy a central place in the Universe (we are living on one of 8 planets around an ordinary star, which is one of 100 billion stars in the Milky Way galaxy, which in turn is one of 100 billion galaxies)

Are there intelligent life elsewhere?

Different kinds of science

- Basic science: physics, chemistry, biology
- Applied science: engineering, medicine, astronomy, geology
- Human behavior: history, economics, sociology, anthropology, psychology

Hierarchy of science

- *from bottom up*:
- Physics: basic structure of matter and fundamental laws of nature (elementary particles, atoms)
- Chemistry: rules governing the relationship between atoms and formation of matter
- Biology: structures and rules governing living matters, molecules as the basics for life

Applied science

- Astronomy: applied physics, chemistry and biology in the context of extraterrestrial environment
- Geology: applied physics, chemistry and biology in the Earth environment
- Engineering: applied physics, chemistry and biology for practical devices
- Medicine: applied chemistry and biology in the context of the human body

Applied sciences as motivation of fundamental discoveries

- The need of agriculture and navigation to understand celestial motions led to the formulation of theories of mechanics and gravitation
- Transmission of human diseases and the desire for cures leading to better understandings of microorganisms and genetics

Social sciences

- Application of the scientific method in the understanding of individual and collective human behavior
- Economics, sociology, anthropology, history

What is not science

- Languages: self consistent expressions for communication
- Artistic expressions: music, art, drama are not subjected to scientific testing
- Criteria: efficiency, beauty, expressiveness (power)

Only good or bad, no right or wrong

Pseudo science

- Astrology: is a legitimate theory but proven to be wrong
- UFO (unidentified flying objects): lack of supporting evidence
- ESP (extra-sensory perception): lack of supporting evidence
- Feng Shui (風水): can be falsified

What do we do?

- Exploration of uncharted territory: science is about the unknown
- Application of known principles to solve diverse problems in the real world

Discovery often the result of serendipity, not following a fixed recipe

Training in science

- Mastery of the scientific method and techniques of quantitative logic
- Mastery the method of solving problems through learning of previous work
- Free, bold, independent, and creative thinking
- Ability to make rational judgment, rise above ignorance and prejudice

Quantitative!

Quality of a scientist

- Curious, always asking questions
- Suspicion of authority, non-conformity
- Creative thinking
- Perseverance (nothing worthwhile is easy)

A student educated in science should be

- Knowledgeable (aware of the state of nature and the way it works)
- Able to think analytically
- Open minded
- Creative
- Independent (from conformity and public opinion)
- Versatile (can take on any job or vocation)

The Faculty of Science

- To train you as a person of intellect, not as a trainee to a vocation
- To lay the ground work for life long learning (encouragement of curiosity, development of rational thinking)

How much you get out of university is up to YOU

Summary

- Studying science is to understand the underlying principles (why and how things work), not memorization of facts
- A science education provides you with a way of thinking and methods of solving problems under diverse situations.
- A science education is the most powerful and enriching education a modern student can have

Are you ready for this challenge?