Topic 1: Early forms of scientific methods

Objectives

After completing this chapter, you should be able to:-

- Identify the history of the early forms scientific methods.
- The early philosophers and scientists views about the scientific methods.
- Identify how to test the scientific theories by applying the scientific methods.

The Ancient Egyptian methodology.

- There are few discussions of scientific methodologies in surviving records from early cultures, especially in the descriptions of early investigations into nature.

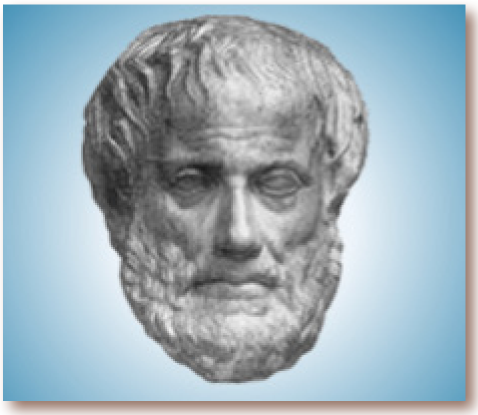
- Some Egyptian medical textbooks apply the basic components of scientific method: examination, diagnosis, treatment and prognosis, to the treatment of disease.

- Imhotep (This name means “the one who comes in, with peace") one of the ancient Egyptians who used the early forms of scientific methods.
- He is considered to be the first engineer architect and physician in history known by name.
- Imhotep is credited with being the founder of Egyptian medicine and with being the author of a medical treatise remarkable for being devoid of magical thinking.

The ancient Greek methodology (Aristotle).

- Aristotle (384 BCE-322 BCE or BC) ancient Greek philosopher.

- Aristotle, more than any other thinker, determined the orientation and the content of Western intellectual history. He was the author of a philosophical and scientific system that through the centuries became the support and vehicle for both medieval Christian and Islamic scholastic thought.



- Until the end of the 17th century, Western culture was Aristotelian. And, even after the intellectual revolutions of centuries to follow, Aristotelian concepts and ideas remained embedded in Western thinking.

- Aristotle was so famous that his work influenced thinking in the Western world from his time to the present. This was fine when he was right. But he was so influential that his mistakes were never noticed.

- Aristotle and his contemporaries believed that all problems could be solved by thinking about them. Sometimes this worked, other times it did not.
- For example, Aristotle thought that heavy objects would fall faster than lighter ones. Now that does seem reasonable at first. And this is how "science" was done in ancient times.

- But what did Aristotle not do? He never tested his ideas! The world would have to wait almost 2000 years for that to happen.

- **Aristotle provided another form of scientific tradition:** empiricism.

- For Aristotle, universal truths can be known from particular things by induction. To some extent then, Aristotle reconciles abstract thought with observation.

- Aristotle did not accept that knowledge acquired by induction could rightly be counted as scientific knowledge.

- Nevertheless, induction was a necessary introduction to the main business of scientific enquiry, providing the primary premises required for scientific demonstrations.

- Aristotle largely ignored inductive reasoning in his treatment of scientific enquiry.
- It was therefore the work of the philosopher to demonstrate universal truths and to discover their causes.
- While induction was sufficient for discovering universals by generalization, it did not succeed in identifying causes.

- The tool Aristotle chose for this was deductive reasoning in the form of syllogisms.

  For example:
    - Socrates is a man.
    - All men are mortal.
    - Therefore, Socrates is mortal.

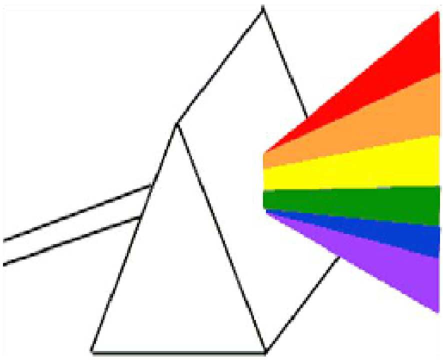
- Using the syllogism, scientists could infer new universal truths from those already established.

- Aristotle brings us somewhat closer to an empirical science than his predecessors.

The Arabic treatment of methodology (Ibn al-Haytham).

- Ibn Al-Haytham is regarded as the father of optics for his influential Book of Optics. His book correctly explained and proved the modern intromission theory of vision, and for his experiments on optics, including experiments on: Lenses – Mirrors - The Dispersion of light into its constituent colors.

- **Due to his formulation of a modern quantitative, empirical and experimental approach to physics and science, he is considered:**
  - The pioneer of the modern scientific method
  - The originator of experimental science and experimental physics.
  - Some have described him as the "first scientist" for these reasons.



- His Book of Optics has been ranked alongside Isaac Newton's Philosophiae Naturalis Principia Mathematica as one of the most influential books in the history of physics, for initiating a revolution in optics and visual perception.

- Ibn Al-Haytham gave the first clear description and correct analysis of the camera obscura.

- Discovered Fermat's principle of least time, and early ideas relating to inertia.
- Discovered the concept of momentum (part of Newton's second law of motion).

- Described the attraction between masses and was aware of the magnitude of acceleration due to gravity at a distance.

- Discovered that the heavenly bodies were accountable to the laws of physics.

- His optical research laid the foundations for the later development of telescopic astronomy, as well as for the microscope.

- In geometry, Ibn al-Haytham developed analytical geometry and established a link between algebra and geometry.

- Ibn al-Haytham also discovered a formula for adding the first 100 natural numbers (which may later have been intuited by Carl Friedrich).
- Ibn al-Haytham used a geometric proof to prove the formula.

- His contributions to number theory includes his work on perfect numbers.

- During the Middle Ages (or Islamic Golden Age), early Islamic philosophy developed in scientific debates.

- Muslim scientists used experiment and quantification to distinguish between competing scientific theories, set within a generally empirical orientation.

- Several scientific methods thus emerged from the medieval Muslim world by the early 11th century, all of which emphasized experimentation as well as quantification to varying degrees.

- The first of these experimental scientific methods was developed by the prominent Iraqi Muslim and scientist Ibn al-Haytham (Alhazen), who used experimentation and mathematics to obtain the results in his Book of Optics(1021).

- In particular, he combined observations, experiments and rational arguments to support his intromission theory of vision, where rays of light are emitted from objects rather than from the eyes.

- He used similar arguments to show that the ancient emission theory of vision supported by Ptolemy and Euclid (where the eyes emit rays of light), and the ancient intromission theory supported by Aristotle (where objects emit physical particles to the eyes), were both wrong.
- Ibn al-Haytham's scientific method was similar to the modern scientific method and consisted of the following procedures.

1. Explicit statement of a problem, tied to observation and to proof by experiment.
2. Testing and/or criticism of a hypothesis using experimentation.
3. Interpretation of data and formulation of a conclusion using mathematics.
4. The publication of the findings.

- Ibn al-Haytham also employed **scientific skepticism** and emphasized the role of **empiricism**.

- He also explained the role of induction in syllogism, and criticized Aristotle for his lack of contribution to the method of induction, which Ibn al-Haytham regarded as superior to syllogism, and he considered induction to be the basic requirement for true scientific research.

- The concept of Ockam's razor is also present in the Book of Optics.

- For example, after demonstrating that light is generated by luminous objects and emitted or reflected into the eyes, he states that therefore "the extramission of [visual] rays is superfluous and useless".

- He was also the first scientist to adopt a form of positivism in his approach, centuries before a term for positivism was coined.

- He wrote that "we do not go beyond experience, and we cannot be content to use pure concepts in investigating natural phenomena", and that the understanding of these cannot be acquired without mathematics.

- After assuming that light is a material substance, he does not discuss its nature any further but confines his investigations to the diffusion and propogation of light.

- The only properties of light he takes into account are that which can be treated by geometry and verified by experiment.

Topic 2: The Modern Methodology

Objectives

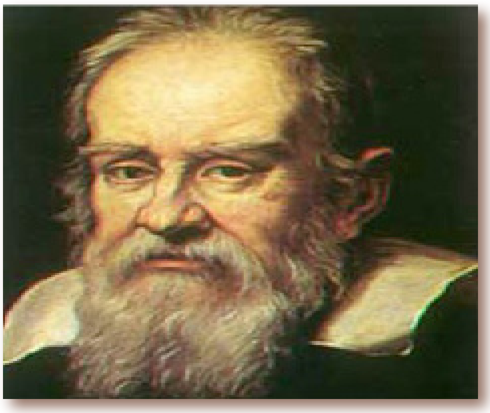
After completing this chapter, you should be able to:-

- Identify the Modern Scientific Methods.
- Identify the Modern Philosophers and Scientists views about the Scientific Methods.
- Identify the Modern views of methodology.
- Identify how to test the Scientific Theories by applying the Scientific Methods.

Galileo Galilei

- Galileo (1564-1642 AD or CE). Lived in what is today Italy.

- **Galileo Is considered to be the first true scientist. Why?**
    - Because he actually did the experiment.
    - Aristotle said that heavy objects fall faster than lighter ones.
    - So Galileo asked, “How much faster?”



- So he sent students up to the top of a building and had them drop a heavy ball and a lighter one off at the same time. He had other students waiting below to measure the difference in time between the two hitting the ground.

- Today of course we know what happened.

- Much to everyone’s surprise both balls hit the ground at about the same time!
- This shows that it is much preferred to test your ideas rather than merely think about them.

- One test is worth a thousand expert opinions.

- When conducting an experiment, change one factor and keep everything else exactly the same. The one thing you change is called the variable.
    - All the things you keep the same are called controls.
    - What was the variable in Galileo’s experiment?

- **What was the variable in Galileo’s experiment?**
- The weight of the balls.

- What were some controls?

- Dropped from same height.

- Dropped at same time.

- Balls had same shape/size.

- So the theory of gravity, theory of electricity, the germ theory of disease, and the theory of evolution are tested, accepted explanations for events that occur in nature.

- Theories can really never be completely proven, only disproven.

- When new evidence comes along, we must modify our theory or at times even get rid of it and start over again.

- Galileo is considered to be a father of the scientific method.

- Because Galileo thought the way some of his predecessors thought and also anticipated the thinking of some of his successors, his views are of special interest in understanding scientific method.

- He sought respectable authority for his way of establishing conclusions in the writings of ancient Greek philosophers and mathematicians, and there are, too, connections between his ideas and those of his more immediate predecessors and contemporaries in Italy.

- But he also helped to develop the role of experiment, particularly as a useful means for discovering and exploring new connections in nature, and partly because of this we detect in him ideas and methods which were further developed by his successors.

- There is no doubt that his claims about what is true and why it is true were particularly influential in the seventeenth century.

- His ideas played an important part in the early development of scientific method although, as we shall see, the differences between Galileo's views and those familiar to us are at least as significant as the similarities.

- The question of how motion should be studied was answered by Galileo's contemporaries in a different way than it would be answered today.
- We think that the scientific study of motion is an experimental and mathematical undertaking.

- We think, that is, that our knowledge of the laws governing the behaviour of objects in motion must in some way be founded on our knowledge, gained by means of experiment, of moving objects, and that these laws should be expressed in the precise language of mathematics. For example, we observe and measure various characteristics of objects as they roll down inclined planes, and on that basis we develop general laws which will be expressed in a mathematical form.

Francis Bacon

Scientific Method

- If Galileo had shied away from the role of experimenter, the opposite can be said for his English contemporary Francis Bacon.
- Bacon attempted to describe a rational procedure for establishing causation between phenomena based on induction.
- It was a radically different form of induction to that employed by the Aristotelians.
- Bacon believed his method would produce certain knowledge rather than tentatively justify adherence to knowledge claims.
- Bacon explains how his method is applied in his Novum Organum (published 1620).

Rene Descartes

- Descartes is often regarded as the first modern thinker to provide a philosophical framework for the natural sciences as these began to develop.

- In his Discourse on the Method he attempts to arrive at a fundamental set of principles that one can know as true without any doubt.

- **To achieve this, he employs a method called hyperbolical/metaphysical doubt, sometimes also referred to as methodological skepticism:**
  - he rejects any ideas that can be doubted, and then reestablishes them in order to acquire a firm foundation for genuine knowledge.

- **Initially, Descartes arrives at only a single principle:**
  - thought exists. Thought cannot be separated from me, therefore, I exist (Discourse on the Method and Principles of Philosophy).

- Most famously, this is known as cogito ergo sum (Latin: "I think, therefore I am").

- Therefore, Descartes concluded, if he doubted, then something or someone must be doing the doubting.
- Therefore the very fact that he doubted proved his existence. "The simple meaning of the phrase is that if one is skeptical of existence that is in and of itself proof that he does exist."

- Descartes concludes that he can be certain that he exists because he thinks.

- But in what form?

- He perceives his body through the use of the senses; however, these have previously been proven unreliable.

- So Descartes concludes that the only indubitable knowledge is that he is a thinking thing.

- Thinking is his essence as it is the only thing about him that cannot be doubted.

- Descartes defines "thought" (cogitatio) as "what happens in me such that I am immediately conscious of it, insofar as I am conscious of it".

- Thinking is thus every activity of a person of which he is immediately conscious.

- To further demonstrate the limitations of the senses, Descartes proceeds with what is known as the Wax Argument.

- He considers a piece of wax; his senses inform him that it has certain characteristics, such as shape, texture, size, color, smell, and so forth.

- When he brings the wax towards a flame, these characteristics change completely.

- **However, it seems that it is still the same thing:** it is still a piece of wax, even though the data of the senses inform him that all of its characteristics are different.

- Therefore, in order to properly grasp the nature of the wax, he cannot use the senses. He must use his mind.

- **Descartes concludes:** “And so something which I thought I was seeing with my eyes is in fact grasped solely by the faculty of judgment which is in my mind”.

- In this manner, Descartes proceeds to construct a system of knowledge, discarding perception as unreliable and instead admitting only deduction as a method.

- In the third and fifth Meditation, he offers an ontological proof of a benevolent God (through both the ontological argument and trademark argument).

- Because God is benevolent, he can have some faith in the account of reality his senses provide him, for God has provided him with a working mind and sensory system and does not desire to deceive him.

- From this supposition, however, he finally establishes the possibility of acquiring knowledge about the world based on deduction and perception. In terms of epistemology therefore, he can be said to have contributed such ideas as a rigorous conception of foundationalism and the possibility that reason is the only reliable method of attaining knowledge.
- In Descartes' system, knowledge takes the form of ideas, and philosophical investigation is the contemplation of these ideas.

- This concept would influence subsequent internalist movements as Descartes' epistemology requires that a connection made by conscious awareness will distinguish knowledge from falsity.

- As a result of his Cartesian doubt, he viewed rational knowledge as being "incapable of being destroyed" and sought to construct an unshakable ground upon which all other knowledge can be based. The first item of unshakable knowledge that Descartes argues for is the aforementioned cogito, or thinking thing.

- Descartes also wrote a response to skepticism about the existence of the external world.

- He argues that sensory perceptions come to him involuntarily, and are not willed by him.

- They are external to his senses, and according to Descartes, this is evidence of the existence of something outside of his mind, and thus, an external world.

- Descartes goes on to show that the things in the external world are material by arguing that God would not deceive him as to the ideas that are being transmitted, and that God has given him the "propensity" to believe that such ideas are caused by material things.

- Descartes was also renowned for his work in producing the Cartesian Theory of Fallacies.
- **This can be most easily explored using the statement:** "This statement is a lie." While it is most commonly referred to as a paradox.

- the Cartesian Theory of Fallacies states that at any given time a statement can be both true and false simultaneously due to its contradictory nature.

- The statement is true in its fallacy.

- Thus, Descartes developed the Cartesian Theory of Fallacies, which greatly influenced the thinking of the time.

- Many would-be philosophers were trying to develop inexplicable statements of seeming fact, however, this laid rumors of such a proposition impossible.

- Many philosophers believe that when Descartes formulated his Theory of Fallacies, he intended to be lying, which in and of itself embodies the theory.

Topic 3: The new forms of Methodology

Objectives

After completing this chapter, you should be able to:-

- Identify the new forms of Methodology.
- Identify the contemporary philosophers and scientists views about the scientific methods.
- Identify the contemporary views of methodology, especially Karl Popper, and Thomas Kuhn.
- Identify how to test the scientific theories by applying the scientific methods.

Galileo Galilei

- Karl Popper is generally regarded as one of the greatest philosophers of science of the 20th century.

- **He was also**
  - a social and political philosopher of considerable stature
  - a self-professed ‘critical-rationalist’
  - a dedicated opponent of all forms of scepticism, conventionalism, and relativism in science and in human affairs generally
  - a committed advocate and staunch defender of the ‘Open Society’
  - and an implacable critic of totalitarianism in all of its forms.

- For Popper accordingly, the growth of human knowledge proceeds from our problems and from our attempts to solve them.
- These attempts involve the formulation of theories which, if they are to explain anomalies which exist with respect to earlier theories, must go beyond existing knowledge and therefore require a leap of the imagination.

- For this reason, Popper places special emphasis on the role played by the independent creative imagination in the formulation of theory.

- The centrality and priority of problems in Popper's account of science is paramount, and it is this which leads him to characterise scientists as ‘problem-solvers.

- Further, since the scientist begins with problems rather than with observations or ‘bare facts’, Popper argues that the only logical technique which is an integral part of **scientific method** is that of the **deductive testing of theories** which are not themselves the product of any logical operation.

- In this deductive procedure conclusions are inferred from a tentative hypothesis.

- These conclusions are then compared with one another and with other relevant statements to determine whether they falsify or corroborate the hypothesis.

- Such conclusions are not directly compared with the facts, Popper stresses, simply because there are no 'pure' facts available.

- all observation-statements are theory-laden, and are as much a function of purely subjective factors (interests, expectations, wishes, etc.) as they are a function of what is objectively real.
- **How then does the deductive procedure work?**

A. Testing of the internal consistency of the theoretical system to see if it involves any contradictions.

B. The axiomatising of the theory to distinguish between its empirical and its logical elements
  - In performing this step the scientist makes the logical form of the theory explicit.
  - Most scientific theories contain analytic (i.e.,a priori) and synthetic elements, and it is necessary to axiomatise them in order to distinguish the two clearly.

C. The comparing of the new theory with existing ones to determine whether it constitutes an advance upon them.
  - If it does not constitute such an advance, it will not be adopted.

D. The testing of a theory by the empirical application of the conclusions derived from it.
  - If such conclusions are shown to be true, the theory is corroborated (but never verified).
  - If the conclusion is shown to be false, then this is taken as a signal that the theory cannot be completely correct (logically the theory is falsified), and the scientist begins his quest for a better theory.

- Popper uses **falsification** as a criterion of demarcation to draw a sharp line between those theories that are scientific and those that are unscientific.
- It is useful to know if a statement or theory is falsifiable, if for no other reason than that it provides us with an understanding of the ways in which one might assess the theory.
- One might at the least be saved from attempting to falsify a non-falsifiable theory, or come to see an unfalsifiable theory as unsupportable.

- Popper claimed that, if a theory is falsifiable, then it is scientific; if it is not falsifiable, then it is not open to falsification.

Galileo Galilei

- In "The Structure of Scientific Revolutions" (SSR), Kuhn argued thatscience does not progress via a linear accumulation of new knowledge, but undergoes periodic revolutions, also called "paradigm shifts" in which the nature of scientific inquiry within a particular field is abruptly transformed. In general, science is broken up into three distinct stages. Prescience, which lacks a central paradigm, comes first. This is followed by "normal science", when scientists attempt to enlarge the central paradigm by "puzzle-solving".

- Thus, the failure of a result to conform to the paradigm is seen not as refuting the paradigm, but as the mistake of the researcher, contra Popper's refutability criterion.

- As anomalous results build up, science reaches a crisis, at which point a new paradigm, which subsumes the old results along with the anomalous results into one framework, is accepted.

- This is termed revolutionary science.

- According to Kuhn, scientific practice is divided into two phases, called normal science and revolutionary science.

- uring normal science, the dominant paradigm is neither questioned nor seriously tested.

- Rather, the members of the scientific community employ the paradigm as a tool for solving outstanding problems.

- Occasionally, the community will encounter especially resistant problems, or anomalies, but if a paradigm encounters only a few anomalies there is little reason for anxiety among its proponents.

- Only as the anomalies accumulate will the community pass into a state of crisis, which may in turn push the community into the phase of revolutionary science.

- During a period of revolutionary science, the scientific community actively debates the underlying principles of the dominant paradigm and its rivals.

- Thus, the business- as-usual of routine problem solving is suspended until a new paradigm (or perhaps the old one) establishes dominance.

- Thus, the business- as-usual of routine problem solving is suspended until a new paradigm (or perhaps the old one) establishes dominance.
- The most influential interpretation (one which Kuhn has spent much time disavowing) paints Kuhn as an arationalist.

- This interpretation makes much of Kuhn's use of the theory-ladenness of observation and various sorts of incommensurability.

- The supposed result of these features is that the proponents of different paradigms will often be unable to communicate with each other, and that, even when they can communicate, their standards of assessment will always favor their own paradigms.

- **Thus, there is no rational basis for choosing between paradigms:**
  - The switch from one worldview to another is not so much a reasoned matter as the scientific equivalent of a perceptual gestalt shift.
  - On this view, the transition between paradigms is best explained sociologically, in terms of institutional might, polemics and perhaps generational replacement.