Paradigm shifts

In his book *The Structure of Scientific Revolutions* (1962) Thomas Kuhn claimed that scientific knowledge could be described as a series of scientific revolutions in which scientific paradigms, or ways of thinking, are entirely replaced by others. He called these revolutions *paradigm shifts* and suggested that they follow five phases

Phase 1: pre-paradigmatic state

The **pre-paradigmatic state** refers to a period before a scientific consensus has been reached. In modern science we have well-formulated theories in areas such as:

- the structure of the cosmos
- the evolution of organisms
- theories of disease and their treatment
- the chemical composition of matter

In ancient times there was no clear understanding of how such things worked and scientific experimentation did not yet exist. If humans believed anything about these elements of the natural world it was likely to be ascribed to a supernatural creator or addressed as a practical necessity, for example the use of certain herbs to treat ailments, gathered from experience.

Phase 2: normal science

Before modern science existed, many societies (for example in Greece and in the middle east) had an established class of natural philosophers who tried to understand the world. They developed theories that became widely accepted. A consensus was reached and a paradigm was established. New knowledge was incorporated into the paradigm.

Examples of early scientific paradigms are:

- **Geocentric view of the heavens**: the Sun and planets exist on a series of concentric spheres, centred on the Earth, which rotate, causing planetary motion.
- **Lamarckian evolution**: understood as a goal-oriented process in which organisms 'try' to adjust to their surroundings.
- **Humour theory of disease**: the body is filled with four substances called *humours*. Ill-health arises from an imbalance of these substances. Treatment is based on attempts to restore the balance, for example by bleeding the patient to remove excess blood.
- **Aristotelian physics**: objects move according to their 'nature'. If they are mostly made of 'earth' they will fall. If mostly composed of 'air' they will rise.

The paradigm provides natural philosophers with a way of thinking about a concept. They then work on the details and use the paradigm to rationalise more natural phenomena. Kuhn called this process of elaboration **normal science**.

Phase 3: crisis

The scientists engaged in normal science will make observations that cannot be easily explained. For example, simple geocentrism could not explain the 'wandering' of planets in their orbits.

Galileo also challenged Aristotelian physics when he devised a series of experiments into the motion of objects. Most famously he dropped two spheres of different weights from the leaning tower of Pisa and observed that they hit the ground at the same time. Aristotle had claimed that the heavier one should fall faster.

During the crisis, modifications may be proposed to allow the observations to fit. The geocentric model was adapted by the addition of epicycles – smaller rotating spheres upon the major spheres, which allowed the planetary wandering to be explained.

Is Kuhn's theory valid?

Kuhn has been accused of being a relativist. Maybe all the theories are equally valid? Why should we believe today's science when it might be overturned in future? Kuhn vigorously rejected this, claiming that scientific revolutions have always led to new, more accurate theories, and represent true progress.

However, each successive paradigm is the best available at the time and frequently older paradigms did make useful predictions. In its final stages, the geocentric paradigm, although complex and rather inelegant (spheres upon spheres upon spheres), did accurately describe planetary motion.

Perhaps in future we will have new theories in physics that will better explain and unify the worlds of quantum mechanics and relativity, but the theories as they stand today are predictive and useful. Science tries to describe the natural world as accurately as possible. Successive paradigms illustrate scientists' willingness to be proven wrong, and their commitment to objective truth in their endeavours.

Phase 4: revolution

This is where the paradigm shift occurs. Eventually the challenges to the paradigm become insurmountable. A number of competing theories may be proposed that seem to offer a better explanation. A 'tipping point' is reached, whereby the consensus view moves towards a new paradigm.

Examples of paradigm shifts include:

- The geocentric model was replaced with a **heliocentric model**, in which the planets are understood to orbit the Sun in elliptical orbits.
- Lamarckian evolution was replaced with Darwin's theory of **evolution by natural selection**. The long neck of the giraffe was explained not as a result of efforts by the giraffe to 'reach' for food in high trees, but instead as a process of gradual change in which those giraffes with longer necks were better able to survive until reproductive age.
- **Germ theory of disease**: sickness is caused not by an internal balance of humours but by external vectors — microorganisms transferred from person to person. Disease prevention should be focused on the prevention of transmission of these microorganisms.
- Einstein's paper on Brownian motion in 1905 proved that **matter consists of discrete particles**, and is not continuous.

It is important to remember that Kuhn does not see a paradigm shift as a mere choice between equally credible theories. A scientific revolution occurs when:

- the new paradigm is incommensurate with the old (you cannot simultaneously believe that the Earth is central to the heavens, and that the Sun is central)
- the new paradigm better explains the observations, and offers a model that is closer to the objective, external reality. Often, improved technology (e.g. telescopes, microscopes) helps confirms the model

Phase 5: return to normal science

Once the new paradigm has been established, normal science resumes. Newton formulated his laws of planetary motion assuming a heliocentric view. Thomson and Rutherford, among many others, developed the atomic model and demonstrated the existence of subatomic particles.

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