

8 Robert Boyle and the Mechanical Philosophy

FOR TEACHERS

Lesson Title: *Robert Boyle and the Mechanical Philosophy*

Area of Learning: chronology, states of affairs

Aims. Pupils should be able to: **Gain factual knowledge** and understanding of the history of Britain; use their knowledge to **describe past societies**; use their knowledge to **make links between features** within and across different periods; **identify and evaluate sources of information** which are used to reach and support conclusions; select, organise and deploy relevant information to produce structured work, making appropriate use of dates and terms.

Vocab: vacuum, matter, properties, body, analysis, Torricellian experiment, corpuscular, atomistic, constituted, Aristotle

Time frame: at least one hour.

Resources: worksheet given below

Pupil tasks: Pupils will be best able to tackle this lesson if they have already done other lessons on Boyle, particularly Lesson 1, which includes Science and Natural Philosophy before the 17th century, and Lesson 7 on Boyle's experiments on pneumatics. It can be done in parallel with Lesson 11.

In section A, pupils are encouraged to think themselves back into the mindset of an Aristotelian. This should not take too long though it could be enriched by the involvement of a science teacher.

In section B, pupils need to read through the text carefully, with frequent pauses to ensure that they have understood the ideas involved.

Cross-curricular links: physics teachers could be encouraged to explain atomic theory and the structure of air; action of burning; the creation of a vacuum and the Torricellian experiment *before* history teachers tackle this topic.

8 Robert Boyle and the ‘Mechanical Philosophy’

Section A: Aristotle’s theory of ‘forms and qualities’

Like most natural philosophers before him, Boyle was interested in the nature of *matter*, as he himself, and everything surrounding him, was made up of matter. The ancient Greek philosopher **Aristotle** had said that all matter was *uniform* (i.e. identical) and *continuous*; he also argued that there was no part of space which did not contain matter. This continuous matter could be differentiated (grouped) into four elements – earth, air, fire and water. He argued that the **properties** of a **body** were explained by the proportion of each element it contained, and further conditioned by the ‘**form**’ it took and the mixture of its ‘**qualities**’ (the principal ones being hot, dry, cold and wet). As time went on Aristotle’s many followers continued to develop new and increasingly complicated theories of forms and qualities. For example, they added the idea of hidden or *occult* qualities to explain the wide range of **phenomena** observed.

Aristotle also said the form and qualities of a body determined its ‘purpose’ and goal. Matter had **intent**, which determined its actions. For example, matter in the form of an arrow ‘naturally’ sought a target – that was its end and purpose. A stone, being made of the element earth, would always by its nature ‘seek’ the centre of the earth and would thus *fall down* to the ground as soon as it could. The theory of forms and qualities could lead to circular arguments. The answer of an Aristotelian, for example, to the question ‘*why is snow white?*’ would be ‘because of the quality of whiteness in it’. A modern scientist would explain this very differently, with reference to the physical properties of ice, the behaviour, perception and transmission of light and the anatomy of the eye, optic nerve and brain.

Questions

1. How would a follower of Aristotle explain the action of flames in a fire? (hint – think of the sun and where it is in relation to a flame). How would a modern chemist explain what happens in a flame?
2. Why did the Aristotelians say that a stone fell to earth? How would a modern physicist explain this?
3. How would a follower of Aristotle explain why a marble was coloured blue? How do you think a modern scientist would explain this? (You may wish to ask your physics teacher to help you complete this question.)

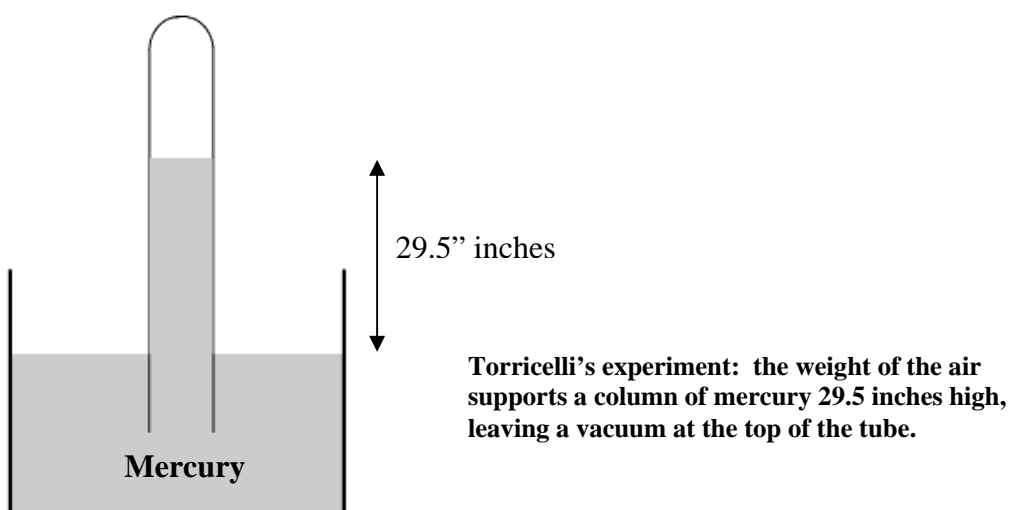
Section B: Boyle’s ‘Mechanical Philosophy’ and his rejection of Aristotle’s theory of ‘forms and qualities’

Boyle did not accept the Aristotelian theory of forms and qualities, as he felt that it had become excessively complicated. Instead he preferred the ideas of other natural philosophers of the 1630s and 1640s, who adapted a **mechanical** view of nature, and particularly those – notably Pierre Gassendi (1592-1655) – who developed ‘**atomistic**’ theories of matter. Aristotle said that all matter was continuous and that various objects appeared different because of their individual forms and qualities. Gassendi followed other ancient Greek philosophers such as Democritus (c. 460-c. 370 BC) and Epicurus (341-270 BC) who theorized that matter was made up of tiny individual, and separate, bodies called ‘**atoms**’ (from the Greek for ‘indivisible’). Boyle called these bodies ‘**corpuscles**’ and he developed what he called a

corpuscularian theory. These tiny bodies were thought to bring about large-scale phenomena by moving around and interacting in specific ways. Pierre Gassendi wrote a book defending the ideas of Epicurus, whose atomistic theories had long been considered dangerous to Christian doctrine. These ideas were popularised in England by a doctor, Walter Charleton (1619-1707), in his work *Physiologia Epicuro-Gassendo-Charltoniana, or a Fabrick of Science Natural upon the Hypothesis of Atoms* (1654). Boyle knew Charleton's work and he became more convinced that matter came in separate units by his knowledge of an experiment described in detail in Charleton's work, the demonstration of a **vacuum** performed in 1644 by the Italian Evangelista Torricelli (1608-47). This experiment involved a tube filled part way with mercury which was turned upside down in a basin of mercury. The empty space remaining at the top of the tube once it was turned over proved the existence of a vacuum – a space where there was no matter.



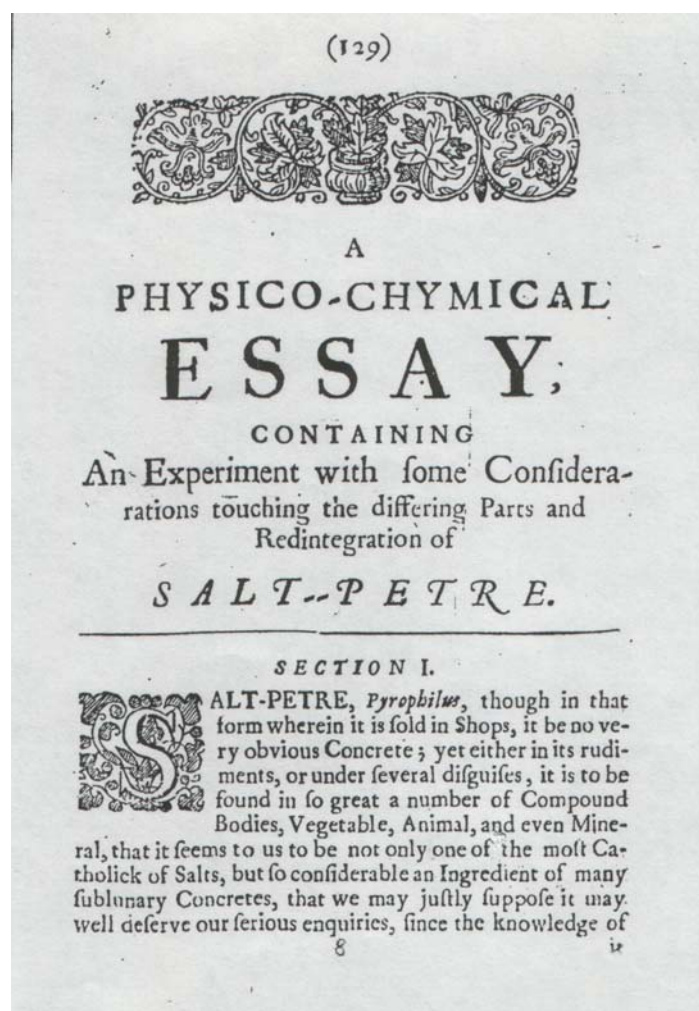
Walter Charleton



(Torricelli's demonstration, which gave rise to the modern barometer, can be explained by your physics or chemistry teacher). Boyle's interest was further stimulated by the proof of the elasticity ('spring' as he called it) of the air through his own experiments with the air pump.

One of Boyle's earliest experiments which he felt proved the corpuscular theory was his **analysis** and **redintegration** of **nitre** (saltpetre or potassium nitrate). In this experiment, which was achieved by heating a piece of saltpetre in a crucible, the nitre was separated into its component parts (*analysis*), and then put back together again (*redintegration*). Boyle later wrote this experiment up as 'A Physico-Chymical

Essay Containing an Experiment with some Considerations touching the differing Parts and Redintegration of Salt-Petre', part of his published *Certain Physiological Essays* (1661). Through this experiment Boyle was able to show that matter could be divided into separable parts and then reassembled. Nitre did not have its qualities because of its 'form' as the Aristotelians would have argued, but because of the different corpuscles that constituted it.



Title page of 'A Physico-Chemical Essay' from *Certain Physiological Essays* (1661). © The Royal Society

To Boyle, corpuscles had their effects through their individual shapes and motions. Like Aristotle, Boyle believed that all matter was made of the same substance. However his theory was very different from Aristotle and the theory of forms and qualities in that he argued that matter was made up of **discrete** units (corpuscles) and was not continuous. Furthermore, the tiny corpuscles had their effects through their distinctive shapes and motions. The nature of objects were not determined by forms and qualities but by the interaction of a host of corpuscles, each differentiated by its unique shape and motion. Boyle set out in a number of his works to devise 'mechanical' explanations of the Aristotelian qualities. Therefore Boyle's 'corpuscular hypothesis' was an expression of the 'mechanical philosophy'. It is 'mechanical' in that according to this way of thought nature is like a machine. Just as a clock is made up of tiny units of different shapes and sizes working and interacting together to create a functioning machine, so the mechanical philosophy could see

nature as a set of discrete ‘cogs’ interacting to make it function. Furthermore, nature can be seen as ‘mechanical’ in that this matter is unthinking and inanimate of itself.

To return to the clock **metaphor** – one frequently used by the natural philosophers of the seventeenth century themselves – just as the clock looks like a living being whose hands move as if by the clock’s own will, the mechanical philosopher knows that the seeming life of the clock is actually caused by very dead cogs and wheels and springs inside. To Boyle matter is unthinking and does not have intentions and goals as in Aristotle’s thought. Furthermore corpuscles are **imbued** with no qualities apart from shape and motion, and all natural phenomena can be explained by the interactions of the individual corpuscles with their own individual shapes and motion. But, and this is VERY important, Boyle believed that the all-important quality of the corpuscles’ motion is imparted to matter by God alone. Boyle regarded the idea that matter was innately endowed with motion as blasphemous, and thought that motion must have been initially impressed on matter by God. Nor would Boyle believe that the comparison often made between nature and a clock would suggest that God wound up the clock at the beginning of time and then just sat back to watch it run. A ‘mechanical’ universe did not mean to Boyle one without the constant action and involvement of God.

Why was Boyle’s Mechanical Philosophy’ important?

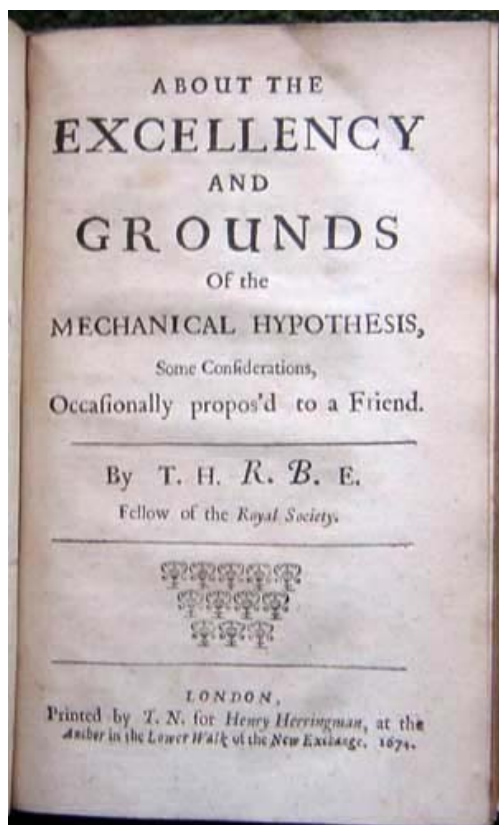
In many respects, Boyle’s ‘corpuscular philosophy’ was the precursor to modern atomic theory used by scientists today. Both are based on a model that sees matter consisting of tiny individual particles. Boyle was crucial in offering experimental support for this mechanical view of nature, initially in his ‘Physico-Chymical Essay’, and subsequently in many of his other books. Of course, since then scientists have moved to much more sophisticated positions, which Boyle could only dream of, and atomic theory has changed dramatically since his time. To Boyle, corpuscles are made of the same substance and only differentiated by *shape* and *motion*. In contrast, modern atomic theory posits a radical difference between many different types of elements. Yet, without the work of pioneers like Boyle, we would not be where we are today.

Questions

1. Which theories of matter did Boyle favour – those of Aristotle or those of Epicurus and Democritus?
2. What was the name of the experiment that Boyle used to prove his corpuscular theory?
3. Below are listed a number of books written by Robert Boyle:

- a) *The Excellency of the Mechanical Hypothesis* (1674)
- b) *Some Considerations about the Reconcilableness of Reason and Religion* (1675)
- c) *Occasional Reflections upon several Subjects* (1665)
- e) *The Origin of Forms and Qualities, (According to the Corpuscular Philosophy)* (1666-7)

If you were a historian searching for information on Boyle's development of the corpuscular or mechanical philosophy, which books do you think might include some relevant information and why do you think this?



Titlepage of *The Excellency of Theology* (1674) © The Royal Society

Source A: In 1674 Boyle included as part of his book *The Excellency of Theology* an essay titled 'About the Excellency and Grounds of the Mechanical Hypothesis'. In this essay he describes how excellent his mechanical hypothesis is. Some of the points he makes are listed below:

- 1) The first advantage is the clearness of mechanical principles ... but amongst the Aristotelians there are many disputes about certain points
2. [The mechanical philosophy] contains two grand principles of matter and motion ... there cannot be any physical principles more simple than matter and motion
3. The next thing I shall name to recommend the Corpuscularian principles is their great comprehensiveness.

(Adapted from Robert Boyle, 'About the Excellency and Grounds of the Corpuscular or Mechanical Philosophy' (*Works of Boyle*, vol. 8, pp. 104-6))

Read source A. What does source A reveal about why Boyle thought his mechanical philosophy was better than Aristotelian theories?

Source B: 'It more sets off the wisdom of God in the fabric of the universe, that he can make so vast a machine perform all those many things which he designed it should, by the mere contrivance of brute matter managed by certain laws of motion and upheld by his ordinary and general involvement'

Adapted from Robert Boyle, *A Free Enquiry into the Vulgarly Received Notion of Nature* (1686), sect. 1 (edited by Michael Hunter and Edward B. Davis (Cambridge, 1996))

Read source B. What does it reveal about Boyle's views on the role of God in the world? Why, as a scientist, was Boyle concerned about including God in his theories? Do modern chemists and physicists include ideas about God and religion in their writings do you think? If not, why not?