

# Contents

Introduction . . . . .	1
<b>THE NATURAL WORLD . . . . .</b>	<b>3</b>
Zeno's Paradox of Achilles and the Tortoise (c.420 BCE) . . . . .	3
Galileo's Balls (1628) . . . . .	9
Newton's Cannon (1687) . . . . .	13
The Watch on the Heath (1802) . . . . .	17
Laplace's Demon (1814) . . . . .	21
Darwin's Imaginary Illustrations (1859) . . . . .	25
Maxwell's Demon (1867) . . . . .	30
What Would It Be Like to Chase a Beam of Light? (1895) . . . . .	34
A Man Falling From a Roof (1907) . . . . .	40
The Grandfather Paradox (post-1915) . . . . .	45
The Ontological Paradox (post-1915) . . . . .	50
Schrödinger's Cat (1935) . . . . .	54
<b>HOW DOES THE MIND WORK? . . . . .</b>	<b>59</b>
Leibniz's Mill (1718) . . . . .	59
The Missing University (1949) . . . . .	63
Turing's Imitation Game (1950) . . . . .	66
Beetles in Boxes (1953) . . . . .	69
What Is It Like to Be a Bat? (1974) . . . . .	73
The Chinese Room (1980) . . . . .	76
Mary the Colour Scientist (1982) . . . . .	83
Philosophical Zombies (1996) . . . . .	86

<b>HOW TO BE GOOD</b> .....	93
Buridan's Ass (c. seventeenth century) .....	93
Pascal's Wager (1662) .....	96
Locke's Locked Room (1690) .....	99
The Prisoner's Dilemma (1950) .....	102
The Trolley Problem (1967) .....	105
What's the Fairest Way to Cut a Cake? (1971) .....	110
Judith Jarvis Thomson's Unconscious Violinist (1971) .....	114
Lifeboat Earth (1974) .....	118
Take My Leg... Please! (1980) .....	123
Minority Report (2001) .....	128
 <b>WHAT CAN WE KNOW?</b> .....	 133
Plato's Allegory of the Cave (c.380 BCE) .....	133
Descartes' Evil Genius (1641) .....	137
Molyneux's Blind Man Made to See (1688) .....	141
The Surprise Examination Paradox (1943–4) .....	145
Newcomb's Paradox (1960) .....	148
 <b>WHAT MAKES US WHO WE ARE?</b> .....	 153
The Sorites Paradox (4 BCE) .....	153
The Ship of Theseus (1 CE) .....	156
Putnam's Twin Earth (1973) .....	160
Robert Nozick's Experience Machine (1974) .....	163
The Teleporter Duplicate Paradox (1984) .....	166
 <i>Further Reading</i> .....	 171
<i>Index</i> .....	177

# THE NATURAL WORLD

The roots of science lie in natural philosophy (the study of the natural world), from the mathematics of motion to the mysteries of space and time. Thought experiments have proved to be powerful and essential tools in natural philosophy, helping to spark extraordinary bursts of creativity and profound insights into the nature of reality.

## Zeno's Paradox of Achilles and the Tortoise (c.420 BCE)

*If the tortoise has a head start on Achilles in a race between the two, then by the time Achilles reaches where the tortoise was, it will have moved on; since Achilles has always first to reach where the tortoise was, he can never catch up with where it is now.*

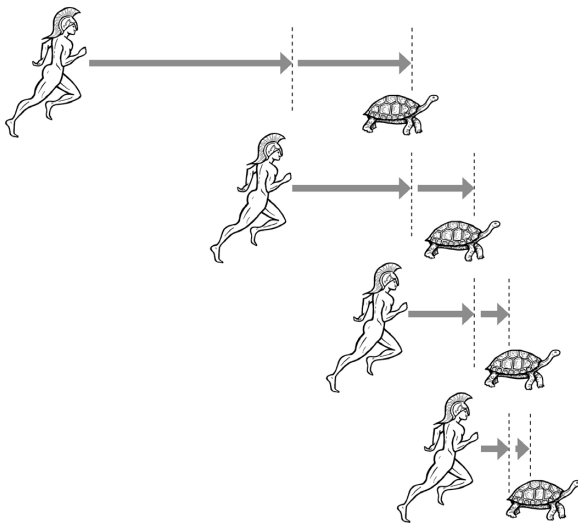
This paradox, which apparently proves that fleet-footed Achilles could never catch a ponderous tortoise, was one of many attributed to Zeno of Elea. Although little is known for certain of his life or work, the ancient Greek philosopher is thought to have lived and died in Elea, a Greek colony in southern Italy, between around 490–425 BCE. Zeno is said to

## The Infinite Tortoise

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have stated the paradox, popularly known by the title ‘Achilles’, in this fashion:

The slower when running will never be overtaken by the quicker; for that which is pursuing must first reach the point from which that which is fleeing started, so that the slower must necessarily always be some distance ahead.



*The tortoise is always one step ahead.*

### **Tiny steps**

An elaboration of the paradox imagines a dialogue between Achilles and a tortoise, in which the ancient Greek hero laughs when challenged to a race by the cunning chelonian and readily agrees to allow it a 10-metre head start. Since their respective running speeds are 10 m/s and 1 m/s,

Achilles calculates that he will overtake the tortoise in just over a second, won't he?

'Not so,' cries the tortoise, 'for given a head start I have you beaten.' He goes on to explain why. After 1 second of running, Achilles will reach the 10-metre mark where the tortoise started, but by this point the tortoise will be at the 11-metre mark. It will take Achilles another 0.1 seconds to reach the 11-metre mark, but by this time the tortoise will have travelled another 0.1 metres. In the 0.01 seconds it takes Achilles to cover this distance, the tortoise will have gone a further 0.01 metres, and so on. Every time Achilles reaches the spot where the tortoise last was, the reptile will have moved infinitesimally further on. Flummoxed, the great warrior concedes defeat to his testudinal foe.

### **Being and change**

This paradox was one of forty Zeno was said to have described in a book, although only a few survive and are known only through mentions in other people's work. The paradoxes were probably intended to defend the theory proposed by Zeno's mentor Parmenides, who had founded the Eleatic School, one of the leading philosophical studios of the ancient Greek world in the early fifth century BCE. Parmenides argued for a philosophy of monism, claiming that 'all is one', and that all reality is a single, constant, unchanging, eternal Being. All appearance of change and variety in the universe is illusory; change and division would be forms of non-Being, and hence impossible.

Since motion is a form of change, Zeno devised several paradoxes to prove it impossible; the paradox of Achilles