Chapter 1

How on earth did we get here?

Introduction

Philip Ball

In 1638 two men met in a villa in Arcetri, near Florence. One was a precocious thirty-year-old Englishman, the other an ageing and grey-bearded Italian natural philosopher. Under house arrest by order of the Roman Church, Galileo was used to receiving visitors curious about his astronomical theory, and his young guest may have left little impression. But John Milton did not forget the meeting.

When twenty years later Milton began his most famous work, the epic poem *Paradise Lost*, the memory of Galileo must have haunted him. He had been appalled by the unjust treatment meted out to the sage of Pisa, and in his passionate defence of the freedom of speech, *Areopagitica* (1644), he had described how Galileo's imprisonment by the Inquisition 'for thinking in Astronomy otherwise than the Franciscan and Dominican licensers thought' had 'damped the glory of Italian wits'. Yet what is the universe of *Paradise Lost* but the conventional hierarchical cosmos of Ptolemy, endorsed by Christian theologians, with the heavens above and hell below a static earth?

Samuel Johnson criticized *Paradise Lost* for its 'harsh and barbarous' prose, but it is hard today not to feel more critical of Milton's decision to ignore Galileo's science. Perhaps he felt justified in taking poetic licence, retaining a stage design that fitted his narrative. But Galileo's universe, with the sun at its centre and the earth a mere planet in motion, probably left him deeply discomforted too. Certainly that seems to have been John Donne's feeling in 1611:

> And new Philosophy calls all in doubt,
> The Element of fire is quite put out;
> The Sun is lost, and th'earth, and no mans wit
> Can well direct him where to looke for it.

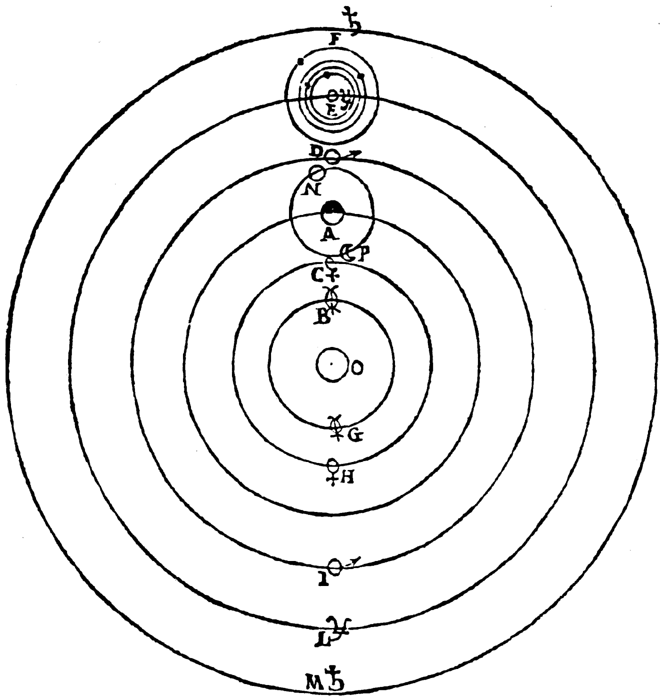
Today we find it intriguing and noteworthy when writers, poets, and artists look for inspiration and metaphor in science. In the 17th century that was a perfectly normal and deeply serious enterprise: John Donne, for all his misgivings, travelled to remote Linz in Austria to visit Johannes Kepler.

Clearly, those of a literary or artistic persuasion did not always like what they found in science; but that did not exempt them from the obligation to be appraised of the metaphysical implications of new discoveries. Milton's dilemma exemplifies the tensions between (to put it in stereotypical terms) the personal world-view of the artist and the objective perspective of the scientist; for Milton realized, even if he could not bring himself to articulate it, that things are not always as they seem, or as people believe them to be – or indeed, as we would like them to be.

In cosmological terms that lesson is still being learnt, while things have gone on getting ever stranger. Even Albert Einstein found himself misled by preconceptions when, in 1917, he fudged his equations describing a mathematical model of the universe to make it static and unchanging, as he though it should be. When, 12 years later, Edwin Hubble discovered that the universe is expanding, Einstein admitted his 'blunder' – if he'd not been blinkered by expectations, he'd have been able to predict Hubble's finding.

That discovery, meanwhile, revised Galileo (and his predecessor Nicolas Copernicus) once again. Astronomers had long since displaced the sun from the centre of the universe: it is merely the centre of our solar system, on the fringes of our galaxy, in an undistinguished corner of an immeasurably vast cosmos. But now this universe had a beginning. Play the Hubble expansion backwards and all converges to a point: the eye of the Big Bang, as maverick astronomer Fred Hoyle dismissively named this moment of creation.

For astronomy, the post-Copernican era had been a voyage into both revelation and ignorance. We know our place now; but the



1. Galileo's presentation of the Copernican universe in his *Dialogue*. Unlike in Copernicus' representation, the earth is not alone in carrying a satellite.

cosmos is as mysterious as ever, arguably even more so. We know (or think we know) that most of the mass in the universe is invisible to us, and of unknown and exotic nature. Thanks to observations made over the past decade, we know (or think we know) that the universe is not just expanding but accelerating, seeming to imply that all of space is filled with some 'dark energy' that counteracts gravity and pushes everything apart. One interpretation is that Einstein was right after all to add a fudge factor (called the cosmological constant) to his equations – it was no blunder. We know, in other words, not to be too certain about anything.

Indeed, fundamental physics is more wide open a field than it has been for decades. At the scales of the very big and the very small our finest theories are not only glaringly incomplete but inconsistent. That is why Einstein himself now needs revising, although there is nothing like a consensus about how to do it. String theory and its rivals work beyond the horizons of what is readily testable, and so remain as yet closer to abstract mathematics than to science.

Even the understanding of our own planet has been altered almost beyond recognition in the past one hundred years. The ground on which we stand, the archetype of solidity, has become a constantly shifting mosaic thanks to the theory of continental drift introduced (to much derision, if not exactly Galilean persecution) by Alfred Wegener in the 1930s. The continental plates are merely a veneer, riding on a mantle of hot, extremely viscous rock that churns in great overturning rolls in the earth's bowels, rearranging the face of the planet over millions of years. In other words, not only our cosmic maps but even our world maps are but snapshots, destined one day for redundancy.

By the same token, we are forced to accept the contingency of our climate, our seas, and our atmosphere. The ice ages, first identified by Swiss geologist Louis Agassiz in the 1830s, forced scientists to take a dynamic view of the natural environment, culminating in the 'astronomical theory' of climate change due to Serbian mathematician Milutin Milankovitch in the 1920s. Periodic changes in the shape of the earth's orbit around the sun lead to 'Milankovitch cycles' which, as they phase in and out of step with one another, create a complex but predictable change in the temperatures of the earth's surface. Climate science has been one of the most revolutionary of the earth sciences over the past two decades, revealing natural processes that, riding on the back of the orbital variations, can transform the global climate in a matter of decades, melting the ice caps entirely or plunging the globe into cold storage.

But surely nothing would have unsettled Milton and his contemporaries as much as the discoveries of the past two centuries in the life sciences. Milton's Adam became first the descendant of an ape, as the Victorians crudely put it (that descent is still being painstakingly traced from a sparse yet constantly surprising fossil record), and then a 'machine created by our genes': an automaton at the mercy of segments of the DNA molecule. This seems to be the new frontier at which the debates between science, art, belief, and society will unfold. Arguably this frontier now has its milestone, comparable to Copernicus's *De revolutionibus* or Darwin's *Origin of Species*: the (more or less) complete sequence of the human genome, unveiled in 2001. (But let's not forget that this was a technological, not an intellectual, triumph.) Today questions about how much of our personality and our health are determined by our genetic inheritance, or how much of our personality and our health are determined by our genetic inheritance, or how a web of neurons becomes conscious of itself, seem to hold within them fundamental clues about what it is to be human. We would surely all appreciate a short introduction to that.

EVERYTHING

A Very Short Introduction

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