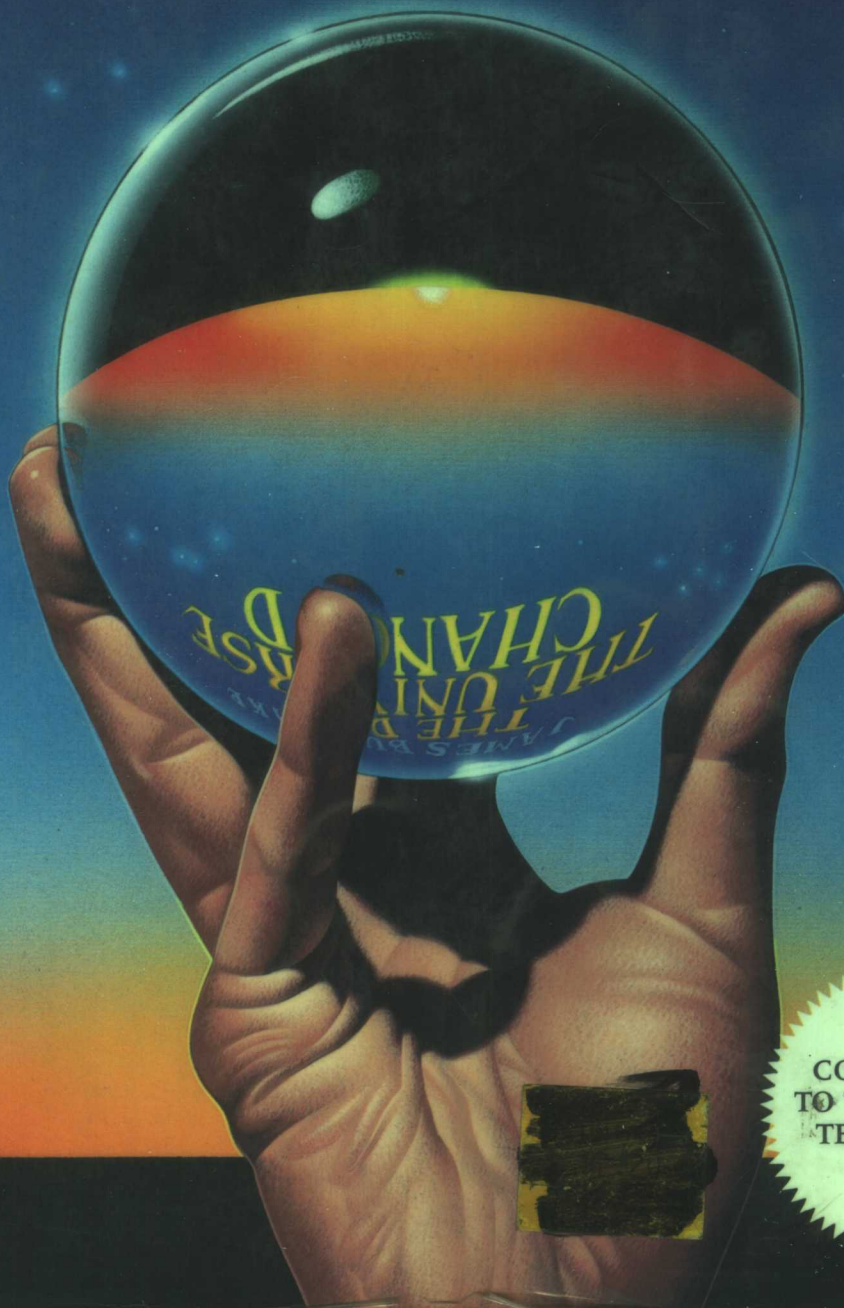


JAMES BURKE



THE DAY THE UNIVERSE CHANGED



COMPANION
TO THE PUBLIC
TELEVISION
SERIES

THE D UNIVERSE CHANGED

James Burke



Little, Brown and Company

BOSTON TORONTO LONDON

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JAMES BURKE
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Preface

You are what you know. Fifteenth-century Europeans 'knew' that the sky was made of closed concentric crystal spheres, rotating around a central earth and carrying the stars and planets. That 'knowledge' structured everything they did and thought, because it told them the truth. Then Galileo's telescope changed the truth.

As a result, a hundred years later everybody 'knew' that the universe was open and infinite, working like a giant clock. Architecture, music, literature, science, economics, art, politics – everything – changed, mirroring the new view created by the change in the knowledge.

Today we live according to the latest version of how the universe functions. This view affects our behaviour and thought, just as previous versions affected those who lived with them. Like the people of the past, we disregard phenomena which do not fit our view because they are 'wrong' or outdated. Like our ancestors, we know the real truth.

At any time in the past, people have held a view of the way the universe works which was for them similarly definitive, whether it was based on myths or research. And at any time, that view they held was sooner or later altered by changes in the body of knowledge.

This book examines some of those moments of change, in order to show how the changes of view also generated major institutions or ways of thought which have since survived to become basic elements of modern life.

Each chapter begins at the point where the view is about to shift: in the eleventh century before the extraordinary discoveries by the Spanish Crusaders; in the Florentine economic boom of the fourteenth century before a new way of painting took Columbus to America; in the strange memory-world that existed before printing changed the meaning of 'fact'; with sixteenth-century gunnery developments that triggered the birth of modern science; in the early eighteenth century when hot English summers brought the Industrial Revolution; at the battlefield surgery stations of the French revolutionary armies where people first became statistics; with the nineteenth-century discovery of dinosaur fossils that led to the theory of evolution; with the electrical experiments of the 1820s which heralded the end of scientific certainty.

The last chapter examines the implications of this approach to knowledge and what it means. If all views at all times are valid, which is the right one? Is there any direction to the development of knowledge, or merely substitution of one form for another? If this is the case, can there be any permanent and unchanging values or standards? Has the course of learning about the universe been, as science would claim, a logical and objective search for the truth, or is each step taken for reasons related only to the theories of the time? Do scientific criteria change with changing social priorities? If they do, why is science accorded its privileged position? If all research is theory-laden, contextually determined, is knowledge merely what we decide it should be? Is the universe what we discover it is, or what we say it is? If knowledge is an artefact, will we go on inventing it, endlessly? And if so, is there no truth to seek?



The Way We Are

Somebody once observed to the eminent philosopher Wittgenstein how stupid medieval Europeans living before the time of Copernicus must have been that they could have looked at the sky and thought that the sun was circling the earth. Surely a modicum of astronomical good sense would have told them that the reverse was true. Wittgenstein is said to have replied: 'I agree. But I wonder what it would have looked like if the sun *had* been circling the earth.'

The point is that it would look exactly the same. ~~When we observe nature we see what we want to see, according to what we believe we know about it at the time. Nature is disordered, powerful and chaotic, and through fear of the chaos we impose system on it. We abhor complexity, and seek to simplify things whenever we can by whatever means we have at hand. We need to have an overall explanation of what the universe is and how it functions. In order to achieve this overall view we develop explanatory theories which will give structure to natural phenomena: we classify nature into a coherent system which appears to do what we say it does.~~

This view of the universe permeates all aspects of our life. ~~All communities in all places at all times manifest their own view of reality in what they do. The entire culture reflects the contemporary model of reality. We are what we know. And when the body of knowledge changes, so do we.~~

Each change brings with it new attitudes and institutions created by new knowledge. These novel systems then either oust or coexist with the structures and attitudes held prior to the change. ~~Our modern view is thus a mixture of present knowledge and past viewpoints which have stood the test of time and, for one reason or another, remain valuable in new circumstances.~~

In looking at the historical circumstances which gave birth to these apparently anachronistic elements, which this book will attempt to do, it will be seen that at each stage of knowledge, the general agreement of what the universe is supposed to be takes the form of a shorthand code which is shared by everyone. Just as speech needs grammar to make sense of strings of words, so consensual forms are used by a community to give meaning to social interaction. These forms primarily take the shape of rituals.

An Egyptian wall-painting from a tomb of the 18th dynasty (1567-1320 BC). The figure top right is the surveyor, playing out his measuring string as he and other officials walk the boundaries of a field. The small figures are peasant workers.

Rituals are condensed forms of experience which convey meanings and values not necessarily immediately obvious or consciously understood by the people performing them. They relate to those elements of the culture considered valuable enough to retain. Involvement in them implies that the participants are not maverick. They conform by acting out the ritual. Each participant has a specific role to play, and one that is not invented or elaborated but laid down prior to the event.

A wedding, for instance, is a typically structured ritual act. In the Anglo-Saxon countries it represents a transition for the protagonists from one social state to another, from being members of a family to taking on the responsibility of creating another. The wedding formalises the transition, the change of state, within clearly understood terms and limits, which are witnessed by members of the public and officials of the community.

Much of the ritual is apparently anachronistic: the bride wears white; the service, whether religious or civil, involves archaic language and concepts which include the role of the woman as a chattel, to be given away. The event is infused with symbols. Flowers represent fertility, the ring is both a sexual and a business token, implying union in both senses. The bridesmaids intimate the state of virginity which the bride is about to leave. Both participants sign the contract, implying equality before the law. The honeymoon was a time when the bride and groom were removed from the pressures of daily life in order to begin their new family.

None of these elements may any longer be of direct value or meaning to the bride and groom today, but the fact that they are retained shows that marriage is still a socially important ritual. This indicates that the community considers formal and binding relationships between the sexes a necessary part of the continuity and stability of the group. The ritual remains for that reason.

Rituals which are performed widely and generally enough become institutionalised. These institutions are staffed by members of the society who are given authority and responsibility for social acts which are considered vital to the continued security and operation of the community. The institutions perform the function of social housekeepers, taking on the routine services which are necessary for the day to day functioning of the group. In some cases, such as that of government, the institution will confer real power on its members to make and enforce decisions about the future behaviour of the whole society.

In the case of the modern West, the primacy of money and possessions is indicated by the power and the institutionalised forms of those organisations whose job it is to ensure the continuity of finance and commercial transactions. Banks safeguard the means of exchange by formalising the ways in which it can be moved around. Although electronic fund transfer now makes the physical presence of bills of exchange and letters of credit unnecessary, the new medium still adheres to the system developed originally to handle the paper activity. The system is still that of seventeenth-century banking, because our society considers it to be sufficiently effective as a means of financial regulation to be retained almost unchanged.

The law is probably the institution that changes least in any society. In its codes it enshrines and protects the basic identity of the community. In its power to punish, it delineates the permitted forms of activity, those considered valuable, such as the act of innovation which is protected by patent legislation, and those which are considered to be so detrimental to the safety of the group at large that the punishment for transgression may be death. The particularly anachronistic way in which legal proceedings are carried on today – in dress, modes of speech, jury numbers, courtroom seating, and so on – indicates the value society places on the institution. The visible evidence of a continuing legal tradition enhances the impression of a community living under a permanent and consistent rule of law.

One of the principal aims of the institutions is that they free the majority of the group to do other things considered necessary for the welfare of all, such as the production of wealth, the maintenance of physical well-being and, above all, the inculcation of the community's view of life in the young. Humanity is unique in the length of time its offspring spend learning before they begin to take on adult responsibilities. Language gives us the unique ability to pass on information from one generation to another in the form of education.

The content of this kind of instruction indicates the social priorities of the group concerned, reveals in what terms it regards the world around it, and to a certain extent illustrates the direction in which a community considers that its own development should go. The very existence of formal educational institutions indicates that the community has the means and the desire to perpetuate a particular view, and shows whether that view is progressive and optimistic or, for example, static and theoretical in nature.

In our case, we use instruction to train young members of our society to ask questions. Education in the West consists of providing intellectual tools to be used for discovery. We encourage novelty, and this attitude is reflected in our educational curricula. Apparent anachronisms such as the titles of qualifications and of the teachers, as well as the conferring of formal accoutrements on the graduating student, recall the medieval origins of the organisation and at the same time show the importance our society attaches to standardised education. It is this quality-control approach to the product of the educational system that permits us to set up and encourage groups or organisations peculiar to modern Western culture, whose purpose is to bring change. In the main these take the form of research and development subdivisions of industrial or university systems. Their members are, in a way, the modern equivalent of the hunters and food-gatherers of early tribes.

In the West the most unusual characteristic of their existence is the extent to which they are autonomous. As a social sub-unit they are, of course, constrained by the same general regulations and limitations placed on all its members by society. However, thanks to the Western view of knowledge and its application, these change-makers usually work in highly specialised areas, isolated from the mainstream of social interaction by the esoteric nature of their activity, and above all by language. Their autonomy depends upon the success of their product in the market-place. Today, the products are technological and

scientific in nature, and predominantly oriented towards service and information systems, an indication that our society has moved beyond the stage of concentration on heavy industrial production. We now have the tools with which to reorganise production, and with it life-styles, along more autonomous, less rigid but socially fragmented lines.

The most significant point about these sources of modern technology in the West is that they are entirely directed towards the production of the means of constant change. Whereas other societies in the past adopted the same social structures as we do in order to ensure their stability, and others in the contemporary world still do so, we use those structures to alter our society unceasingly.

This extraordinary, dynamic way of life is the product of a particular, rational way of thought that had its origins in the eastern Mediterranean nearly three thousand years ago.

In about 1000 BC mainland Greeks started to emigrate eastwards, to Ionia, and settled on the islands and the Aegean coastline of Asia Minor. The new arrivals were pioneers, ready to adapt to whatever circumstances they encountered and to make use of anything that might make their existence easier. They were pragmatic people with a hard-headed, practical view of life.

The conditions they found in Ionia were difficult. For the most part they founded their small walled towns on narrow coastal strips of indifferent land, and supported themselves with dry farming capable of producing only some olives and a little wine. Backed by inhospitable mountain ranges that blocked all exits to the hinterland, the Ionians turned to the sea for survival. They began to travel all over the eastern Mediterranean, and discovered almost immediately that they were in close proximity to two great empires, the Babylonian and the Egyptian.

Both these ancient river-valley cultures had been the first, almost simultaneous examples of urban civilisation. Their societies were theocratic, ruled by kings with magical powers. There had been little scientific or technological novelty, due to the extreme regularity of their physical environment and the rigidity of their social structures, which were based on the need to build and maintain vast irrigation systems. The civilised world, for both the Egyptians and the Babylonians, was encompassed by their own frontiers. All that needed to be known related to their immediate practical needs. Babylonian mathematics and astronomy were restricted subjects whose study was permitted only to the priesthood. Egyptian geometry served exclusively to build pyramids and measure the area of inundated land or the volume of water reservoirs.

Both cultures developed mythical explanations for Creation which, they felt, had happened not long before each of them had come into existence. With gods responsible for all aspects of the world and with minimal science and technology developed for practical necessities, their simple cosmology was complete. The environment made no demands on them which they were not able to meet.

Not so the Ionians. The uneven nature of their physical environment, with marginal agricultural productivity, little room for landward expansion, hostile



A ninth-century BC clay tablet from Babylonia shows the Sun God and his servants. The magic symbols of divination are present: the sun symbol rests on the stool in front of the god, and in the sky under his canopy are the moon, the sun and Venus. The temple rests on the heavenly ocean, the source of life.

neighbours, and the need to trade, made the colonial Greeks dynamic in outlook. Without theocratic traditions to hold them back they rejected monarchies at an early stage, opting for republican city-states in which a relatively small number of slave-owners governed by mutual consent.

It may have been because of their economic circumstances that the Ionians took a radically new view of the world. Whereas Babylonian astronomy had aided priests to make magic predictions, it now served the Ionians as an aid to maritime navigation. The major advance represented by the use of the Little Bear as an accurate positional aid is attributed to one of the early Ionians, Thales of Miletus, who flourished at the end of the sixth-century BC. Little is known of him, none of it contemporary. He almost certainly visited Egypt and may have been instrumental in the introduction of Egyptian geometry to Ionia. He is also reputed to have been able to use Babylonian astronomical techniques to predict eclipses.

Thales and the two generations of students that followed him are credited with the invention of philosophy. These Ionians began, ahead of all others, to ask fundamental questions about how the universe worked. Where the older cultures had been content to refer to custom, edict, revelation and priestly authority, Thales and the others looked to naturalistic explanations for the origin of the world and everything in it. They began to find ways of exploring nature, in order to explain and control it, the better to ensure their survival.

By the time of Thales, the Ionians, due in part to their invention of gold and silver coin, were trading all over the eastern Mediterranean, dealing in a variety of commodities from corn to millstones, silk, copper, gum, salt. They had colonies all along the shores of the Black Sea and were keen explorers, ranging north to the Russian steppes, south to Nubia, and west to the Atlantic, and producing the first maps known to the West to aid them.



The Ionians are credited with the invention of assaying techniques and thence the first use of standard precious metal coins as currency, such as this stater. It shows a man carrying a spear and a bow.

The Ionian interest in practical answers to questions about the world led to the first, crude attempts to find mechanisms, rather than gods, responsible for natural phenomena. Thales thought that the material basic to all existence was water, whose presence was evidently essential to life. He and his students examined beaches, clay deposits, phosphorescence and magnetism. They studied evaporation and condensation, as well as the behaviour of the winds and the changes in temperature throughout the year, from which they deduced the dates of the seasons.

One of Thales' pupils, Anaximander, observed that nature was composed of opposites: hot and cold, wet and dry, light and heavy, life and death, and so on. He also stated that everything was made up of differing amounts and combinations of four elements: earth, water, air and fire. Anaximenes, another student, observed the behaviour of air, as it condensed to make water which froze as ice and then evaporated as air.

These simple analyses of phenomena and the observation of the presence of opposites combined with the political and economic structure of the Ionian society to produce the dominant intellectual structure in Western civilisation. In their small frontier cities all decisions were taken publicly and after debate. Their first experiences in trading may have given them a tendency to argue their way to compromise. Their circumstances led them to adapt particular techniques for more general use.

The Ionians took the geometry developed by the Egyptians for building their pyramids and made it a tool with many applications. Thales himself is said to have proved that a circle is bisected by its diameter, that the base angles of an isosceles triangle are equal and that opposing angles of intersecting lines are equal. Be that as it may, the Ionians were soon able to use geometry to work out, for instance, the distance from the coast of a ship at sea. Geometry became the basic instrument for measuring all things. All natural phenomena including light and sound, as well as those of astronomy, existed and could be measured in exclusively geometrical space.

Geometry rendered the cosmos accessible to examination according to a common, standard, quantitative scale. Together with the concept of pairs of opposites, geometry was to become the foundation for a rational system of philosophy that would underpin Western culture for thousands of years. The systems of Plato and Aristotle, the apotheosis of Greek thought at the end of the fourth century BC, were based on the use of opposites in argument and the self-evident nature of geometric forms.

Rational discussion followed a new logical technique, the syllogism, developed by Aristotle, which provided an intellectual structure for the reconciliation of opposing views. The self-evident axioms of geometry, such as the basic properties of a straight line or the intersection of two such lines, could lead via deduction to the development of more complex theorems. When this technique was applied to rational thought it enhanced the scope of intellectual speculation.

In this way Aristotle produced a system of thought that would guide men from the limited observations of personal experience to more general truths.



The Parthenon. The perfect physical manifestation of the union of logic and geometry is to be found in Greek architecture. It represents the desire for balance and symmetry basic to Western rational thought.

about nature. Plato examined the difference between the untrustworthy and changing world of the senses and that of the permanent truths which were only to be found through rational thought. The unchanging elements of geometry were the measures of this ideal, permanent thought-world with which the transitory world of everyday existence could be identified, and against which it might be assessed. This union of logic with geometry laid the foundations of the Western way of life. ✱

This book examines what happened at particular points in history when man applied such a rational approach to nature. It looks at the ways in which a questioning system of thought brought us to today's world, in which change is the only constant. Above all, it seeks to show how the attitudes of Western culture, and the institutions which accompany these attitudes, are generated at times when major changes occur in the way society sees itself, as a result of advances in the body of knowledge.