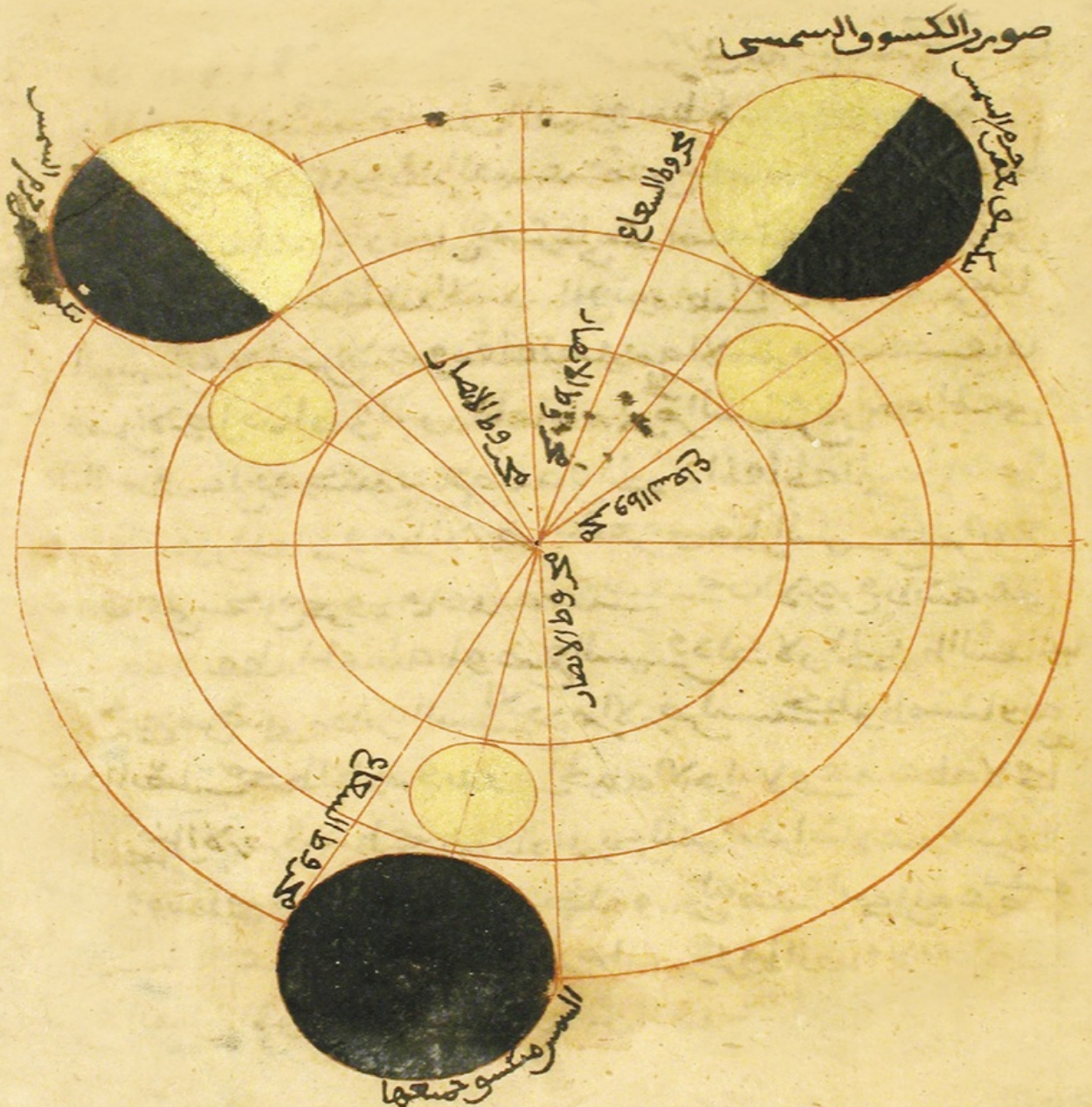


# Pathfinders

*The Golden Age of Arabic Science*



Jim Al-Khalili

---

JIM AL-KHALILI

Pathfinders

*The Golden Age of Arabic Science*



ALLEN LANE

*an imprint of*

PENGUIN BOOKS

---

ALLEN LANE

Published by the Penguin Group

Penguin Books Ltd, 80 Strand, London WC2R 0RL, England

Penguin Group (USA) Inc., 375 Hudson Street, New York, New York 10014, USA

Penguin Group (Canada), 90 Eglinton Avenue East, Suite 700, Toronto, Ontario,

Canada M4P 2Y3 (a division of Pearson Canada Inc.)

Penguin Ireland, 25 St Stephen's Green, Dublin 2, Ireland (a division of Penguin Books Ltd)

Penguin Group (Australia), 250 Camberwell Road, Camberwell, Victoria 3124, Australia

(a division of Pearson Australia Group Pty Ltd)

Penguin Books India Pvt Ltd, 11 Community Centre, Panchsheel Park,

New Delhi – 110 017, India

Penguin Group (NZ), 67 Apollo Drive, North Shore 0632, New Zealand

(a division of Pearson New Zealand Ltd)

Penguin Books (South Africa) (Pty) Ltd, 24 Sturdee Avenue, Rosebank 2196, South Africa

Penguin Books Ltd, Registered Offices: 80 Strand, London WC2R 0RL, England

[www.penguin.com](http://www.penguin.com)

First published 2010

Copyright © Jim Al-Khalili, 2010

The moral right of the author has been asserted

All rights reserved.

Without limiting the rights under copyright reserved above, no part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted, in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the prior written permission of both the copyright owner and the above publisher of this book

ISBN: 978-0-14-196501-7

---

To Julie

---

*He who finds a new path is a pathfinder, even if the trail has to be found again by others; and he who walks far ahead of his contemporaries is a leader, even though centuries pass before he is recognized as such.*

Nathaniel Schmidt, *Ibn Khaldūn*

---

# Contents

*List of Figures*

*List of Plates*

*Preface*

*A Note on Names, Pronunciations, Spellings and Dates*

*A Note on the Term 'Arabic Science'*

1. A Dream of Aristotle

2. The Rise of Islam

3. Translation

4. The Lonely Alchemist

5. The House of Wisdom

6. Big Science

7. Numbers

8. Algebra

9. The Philosopher

10. The Medic

11. The Physicist

12. The Prince and the Pauper

13. Andalusia

14. The Marāgha Revolution

15. Decline and Renaissance

*Notes*

*Glossary of Scientists*

*Timeline: The Islamic World from Antiquity to the Beginning of the Modern World*

*Index*

---

## *List of Figures*

Map 1. The Abbasid Caliphate at the beginning of the Ninth Century.

Map 2. The Middle East and Maghrib, towards the end of the Eleventh Century.

Fig. 1. Schematic map of early Abbāsīd Baghdad. Source: *Journal of the Economic and Social History of the Orient*, 9/1–2 (November 1966).

Fig. 2. Round City projected onto a map of modern Baghdad.

Fig. 3. An ancient Chinese method for proving Pythagoras' theorem.

Fig. 4. The evolution of Hindu-Arabic numerals.

Fig. 5. The first use of a decimal point, in *The Book of Chapters on Hindu Arithmetic* by al-Uqlīdisi.

Fig. 6. An example of a geometric problem requiring the solution of a quadratic equation, taken from Euclid's *Elements* (Book Two, Proposition Eleven).

Fig. 7. Ibn Sahl's diagram showing the law of refraction of light (through a plano-convex lens) for the very first time. Source: *Isis*, 81/3 (September 1990).

Fig. 8. The difference between the Greeks' version of the law of refraction and the correct one described by Ibn Sahl.

Fig. 9. Ibn Mu'ādh's method for calculating the height of the atmosphere.

Fig. 10. Conic sections.

Fig. 11. Al-Bīrūni's method for measuring the height of a mountain by geometric means.

Fig. 12. Al-Bīrūni's method for calculating the circumference of the earth.

Fig. 13. The Ptolemaic model of planetary motion around the earth.



Fig. 14. Comparison between diagrams of Copernicus and al-Tūsi

---

Fig. 15. The origin of the trigonometric sine of an angle as described by Hindu mathematicians.

---

## *List of Plates*

1. Abbasid Caliph Harūn al-Rashīd and King Charlemagne, oil painting by Julius Koeckert (1827–1918). (Maximilianeum Foundation, Munich)
2. Hārūn al-Rashīd and the barber in a Turkish bath, fifteenth-century oil painting. (British Library, London, UK/ © British Library Board. All Rights Reserved/The Bridgeman Art Library)
3. The author's great-great-great uncle, Muhammad Al-Khalili.
4. The author's paternal grandfather, Merza Muhammad Sādiq Al-Khalili.
5. Members of the Al-Khalili clan in Najaf, 1950.
6. Baghdad's al-Rashīd Street during a flood, 1950.
7. The Baghdad district of Karradat Merriam.
8. The author and his brother, mid 1960s.
9. The author as a child with his family, 1971.
10. The author during his last year of primary school in Saddat al-Hindiyya.
11. The ruins of the eighth-century Abbāsīd Palace of Ukhaidhir, south of Baghdad. ([alimdi.net/photographersdirect.com](http://alimdi.net/photographersdirect.com))
12. The ruins of the tenth-century palace-city complex Medinat al-Zahrā', outside Córdoba. (Medjai)
13. The spiral cone minaret of the Sāmarra mosque. (Thomas J. Abercrombie/Getty Images)
14. Brass astrolabe from Saragossa (c. 1079–80). (Germanisches Nationalmuseum, Nuremberg (Nuernberg), Germany/The Bridgeman Art Library)

15. Description of the eye in Hunayn ibn Ishāq's *Ten Treaties on the Eye*. (The Art Archive/Kharbine-Tapabor/Boistesselin)
16. A trickster in eleventh-century Baghdad; thirteenth-century painting. (Institute of Oriental Studies, St Petersburg, Russia/The Bridgeman Art Library)
17. Page from the *Canon of Medicine* by Ibn Sīna. (Wellcome Library, London)
18. Medieval Muslim surgical instruments, from *Kitab al-Tasrīf*.
19. Eleventh-century Balkhi-style map of northern Iraq. (The Art Archive/National Library Cairo/Gianni Dagli Orti)
20. Al-Idrīsī's twelfth-century map of the world.
21. Ptolemy's geocentric universe as it appears in the *Almagest*.
22. Copernicus' heliocentric universe. (Mansell/Getty Images)
23. Diagram of a solar eclipse, from an eleventh-century manuscript of al-Karkhi. (The Art Archive/Kharbine-Tapabor/Photo Boistesselin)
24. Ibn al-Shātīr's sundial, Umayyad Mosque, Damascus. (Billbl)
25. A map from the *Book of Routes and Provinces*.
26. The Banū Mūsa brothers' self-trimming lamp. (The Art Archive/National Library Cairo/Gianni Dagli Orti)
27. The Elephant Clock of al-Jazari.
28. The inner workings of the Elephant Clock.
29. Diagram of a system for pumping water into a basin, from the *Book of Knowledge of Ingenious Mechanical Devices*, by al-Jazari (1206). (Topkapi Palace Museum, Istanbul, Turkey/The Bridgeman Art Library)
30. Al-Birūnī's mountain, from which he measured the circumference of the earth.
31. The campus of King Abdullah University of Science and Technology (KAUST), Jeddah. (Matin Durrani/'Buying success, Saudi style', *Physics World*, November 2009)

---

## Preface

*Sargon, king of Akkad, overseer of Ishtar, king of Kish, anointed priest of Anu, king of the country; he defeated Uruk and tore down its walls. Lugalzaggisi, king of Uruk, he captured in this battle, and brought him in a dog collar to the gate of Enlil.*

Ancient text

An hour's drive south of Baghdad lies the town of Hindīyya. This was where I spent my last few happy teenage years in Iraq before leaving for good in 1979. The town takes its name from the Hindīyya Barrage, which was built across the Euphrates in 1913 by the soon to be departing Ottomans. I have an abiding and powerful memory of this bridge. On cool autumn days I would skip afternoon school with my three best friends, Adel, Khalid and Zahr il-Dīn, and walk across the Barrage to the riverside tourist resort on the opposite bank. We would buy a six-pack of *Farīda* beer and sit down by the water discussing football, philosophy, movies and girls.

Those happy days contrast dramatically with a second powerful image that is seared into my memory and which took place during the first Gulf War of 1991. I remember watching a CNN news report showing footage of a gun battle in Hindīyya in which a lone and terrified woman was trapped in crossfire while walking across the Barrage. For most viewers this would have been just another scene depicting the horrors of war in a far-off land. But for me, instantly recognizing the setting, it suddenly brought home the reality of the plight of the country I had left behind twelve years earlier. I had walked past the spot where this helpless woman now stood frozen in terror dozens of times.

But that was a world away. As I write, I have yet to return to Iraq. I say 'as I write' for I have not ruled out a brief visit at some point in the future when, coward that I am, I deem it

safe enough.

---

The year I left Iraq was a momentous one in the Islamic world. In 1979 Anwar Saddat of Egypt and Israel's Menachem Begin signed a peace treaty in Washington, the first Islamic republic was created in Iran after the deposed shah fled to Cairo, the holy city of Mecca witnessed a gun battle to put down a fundamentalist insurrection following the killing of hundreds of pilgrims, the Soviet Union invaded Afghanistan and the Iranian hostage crisis began in the US embassy in Tehran. During all this turmoil, Saddam Hussein had taken over the presidency of Iraq from Field Marshal Muhammad Hassan al-Bakr, thus making life a great deal grimmer for the vast majority of the population there. My family and I arrived in Margaret Thatcher's Britain at the end of July – exactly two weeks after Saddam had come to power. We had escaped just in time, as it turned out, for within months he had declared war on Iran. Had we not left that summer, my brother and I would undoubtedly have been conscripted to fight in that pointless and terrible conflict and I doubt that I would have lived to tell the tale. Having a British mother and a Shi'a Muslim father of Persian descent who had flirted with the Iraqi Communist movement in the 1950s marked my brother and me as 'undesirables', and certainly expendable frontline fodder.

And life in Iraq seems to have gone downhill ever since. Things have changed there dramatically since my childhood in the 1960s and 1970s when life for a kid from a middle-class background was comfortable and relatively easy. My father, a British educated electrician, had served as an officer in the Iraqi air force. His various postings around the country meant that we were used to moving house regularly. But in the early 1970s, the ruling Ba'ath party decreed that any Iraqis with British wives were suddenly no longer to be trusted in the armed services. So, having reached the rank of major, he now had to find work as a civilian for the first time in his adult life. He soon landed a job as the head of engineering at *Ma'mal al-Harir*, a chemical firm in Hindiyya that produced artificial rayon fibres. We lived in Baghdad for a few years before eventually moving to Hindiyya to spare my father the daily commute. This was fine with me. I made friends quickly, set up my new football team: the Rayon Dynamos (I still have the tatty number 9 shirt I wore) and, together with my brother, would tune in to the BBC World Service to catch the English football score on 'Sports Report' on Saturdays. Actually, the World Service was pretty much a constant background in our house. When possible, I would make regular visits to the British Council's library in Baghdad for my supply of English books. And I grew up knowing that living under

dictatorship was bearable, as long as you kept your head down and never criticized the government or the Ba'ath Party, even in private.

A fun day out for my family and me was to visit the Hanging Gardens of Babylon, an hour's drive south-east of Hindīyya. The ruins of this mythical place held no great mystique as I had often trudged around the site on school trips. But despite the less than impressive ruins and my indifference born of familiarity, the excitement of a day away from class never lost its appeal, and the site still radiated a powerful aura that whispered of past glories too ancient for me to comprehend. Once, while on a family picnic there when I was in my early teens, we came across two chunks of clay brick, each the size of a fist and each clearly marked with ancient cuneiform writing on one surface. It is still a source of a long-running and good-natured family dispute as to whether it was my brother, my mother or I who actually picked up these bricks. In any event, my mother hid them in the bottom of our food hamper and we smuggled them back home.

This probably sounds like an outrageous case of archaeological theft. Surely we should have handed over such national treasures to the local authorities or, probably more sensibly to the Iraqi Museum in Baghdad. But we kept them. In our defence, similar cuneiform-etched Babylonian bricks were strewn among the rubble all around us. And in comparison with the later damage wrought on the ruins of ancient Babylon – first by Saddam Hussein's astonishingly vulgar rebuilding of the Ishtār Gate in the 1980s, and more recently by the US forces in 2003 who levelled a whole section of one of the world's most precious archaeological sites to create a landing area for helicopters and a parking lot for heavy military vehicles – our theft seems pretty tame.

It was only recently that I asked an acquaintance, Irvine Finkle, the Curator of Ancient Mesopotamia at the British Museum, to take a look at the two bricks. He confirmed that they date back to the seventh century BCE and the reign of King Nebuchadnezzar II, when the Hanging Gardens were built. Apparently, the symbols are fragments of a common inscription that reads: 'Nebuchadnezzar, King of Babylon, who provides for Esagila and Ezida [the temples of two Babylonian gods Marduk and Nabu], the eldest son of Nabopolassar'.

The seventh century BCE may sound quite ancient to Europeans, and even more so to Americans, but by Iraqi archaeological standards the period of Nebuchadnezzar's reign is practically the Middle Ages. It is sometimes hard to imagine that the heritage of those struggling to lead a semblance of normal life in today's Iraq stretches back over seven

thousand years, to the birth of some of the very first civilizations on earth. Archaeologists have dated the remains of the Ubaid culture in southern Iraq to the middle of the sixth millennium BCE; and the succeeding Uruk civilization, which saw the invention of the wheel, as well as such vital technical advances as the fusion of metals, the potter's wheel, the seal, the brick mould and the temple plan, to around 4100 BCE. And it was in Uruk that an invention – possibly even more important than the wheel – was made. For it was here that writing first appeared.

The rest, as they say, is history.

The first powerful ancestor of today's indigenous Arab people of Iraq was Sargon, Semite king of the Akkadians, who conquered the Sumerians in the twenty-fourth century BCE. Very little is known about Sargon, but it is believed that he founded a new capital, Akkad, not far from today's Baghdad. Within a short time his empire extended from the Mediterranean in the west to Persia in the east and he would take the title 'King of the Four Parts of the World'.

The Akkadians were followed by the dynasty of Ur. It is estimated that the city of Ur in southern Iraq had grown (by around 2000 BCE) to become the largest in the world, with a population of more than sixty thousand. It is from this city that Abraham, patriarch of the three great monotheistic religions of Judaism, Christianity and Islam, is supposed to have originated.

The first Babylonian dynasty began not long after this, during which we encounter the greatest of all the ancient kings of Iraq, Hammurabi, who reigned for more than forty years (1792–1750 BCE). It is during his rule that we find the world's first schools as well as the earliest written legal code. Of all the great rulers who followed Hammurabi, and there were many, none would come close to his achievements for a thousand years, until the Assyrian king, Ashurbanipal, founder of the great library of Nineveh near the modern city of Mosul in the north of the country.

The decline of Iraq's self-rule began several hundred years before the birth of Christ and marked the beginning of more than two millennia of almost uninterrupted outside occupation; by the Persians, Greeks, Mongols, Turks and, briefly – between 1917 and 1921 – the British, after which the modern state of Iraq was born. The great Abbāsid Empire, which lasted from 750 to 1258 CE, should certainly not be regarded as an occupying power. For long periods, however, its caliphs were mere puppets of foreign dynasties, notably the Persian

Buyids and the Turkish Seljuks in the tenth and eleventh centuries.

---

The earliest Persian rule over the land known as Mesopotamia (from the Greek 'Land Between Two Rivers' – the Tigris and Euphrates – which largely corresponds to what is modern Iraq) ended with defeat at the hands of Alexander the Great in 333 BCE. The death of Alexander signalled the division of his great empire among his generals: Egypt for Ptolemy, who ruled from Alexandria, and Asia for Seleucus, who built his new capital, Antioch, in north-west Syria, a city that would later play a vital role in the transfer of scientific knowledge from the Greeks to the Arabs.

By the time of the arrival of Islam in the early seventh century CE, what we now call the Middle East was divided between the Persian and Byzantine empires. But with the spread of this new religion from Arabia, a powerful empire emerged, and with it a flourishing civilization and a glorious golden age.

Given how far back it stretches in time, the history of the region – and even of Iraq itself – is too big a canvas for me to paint. Instead, what I hope to do in this book is take on the nonetheless ambitious task of sharing with you a remarkable story; one of an age in which great geniuses pushed the frontiers of knowledge forward to such an extent that their work shaped civilizations to this day.

I have for some time had the strong desire to bring this story to a wider audience. That I do so now lies in my belief that it has never been more timely, nor more resonant, to explore the extent to which Western cultural and scientific thought is indebted to the work, a thousand years ago, of Arab and Persian, Muslim, Christian and Jewish thinkers and scientists. Popular accounts of the history of science typically show a timeline in which no major scientific advances seem to have taken place during the period between the ancient Greeks and the European Renaissance. In between, so we are told, Western Europe and, by extrapolation, the rest of the world, languished in the Dark Ages for a thousand years.

In fact, for a period stretching over seven hundred years, the international language of science was Arabic. For this was the language of the Qur'an, the holy book of Islam, and thus the official language of the vast Islamic Empire that, by the early eighth century CE, stretched from India to Spain.

I must also stress at the outset that my task is not to cover the whole of the history of science around the globe. I am well aware of the richness and variety of scientific achievements in other parts of the world, particularly in China and India, and there have



been many books written – and no doubt many more yet to be written – about these two glorious civilizations. But that is not my story.

I have been helped tremendously in my task of exploring the subject through the making of a recent BBC television series, *Science and Islam*. But unlike in the series, I have had the luxury in this book of exploring in more depth both the science and its associated social, political and historical influences and implications. Of course, the extensive travelling I undertook around the Islamic world in the making of the series was useful in two ways. First and probably most importantly, it brought the subject alive for me in a way that the many books and scholarly articles I have buried myself in could not do. Secondly, it provided me with an opportunity to meet and discuss ideas with many scholars and historians from a wide range of backgrounds. I hope this book does them justice too.

Naturally, there will be those who might suspect that, having grown up in Iraq, I see the Muslim world through rose-tinted glasses, a biased partisan on a mission to demonstrate what a wonderful and enlightened religion Islam is. However, as an atheist my interest in Islam is cultural rather than spiritual. So if Islam as a belief system, unencumbered by the misconceptions and misinterpretations of many of today's Muslims and non-Muslims alike, comes out of my account in a positive light, then so be it.

There is no doubt that, to the ear of many non-Muslims around the world today, the term 'Islam' too comfortably evokes a negative stereotype that contrasts with our Western secular, rational, tolerant and enlightened society. This lazy view can make it difficult to acknowledge that a thousand years ago the roles were reversed. Think of the Crusades: which side back then was the more enlightened, the civilized, the 'good guys'? Even those in the West who have a vague awareness of the contribution of the Muslim world to science tend to think of it as no more than a reheating of Greek science and philosophy with the odd bit of originality subtly added, like Eastern spice, to enhance the flavour. A grateful Europe then eagerly reclaimed its heritage once it awoke from its slumber during the Renaissance of the fourteenth and fifteenth centuries.

I shall address many questions that have long intrigued scholars of the history of science. How much science, for instance, did the Arabs actually know? How important were the contributions of Persian culture, Greek philosophy and Indian mathematics? How and why did scientific scholarship flourish under the patronage of certain rulers? And, possibly most interestingly, why and when did this golden era come to an end?

As a practising scientist and a humanist, I believe that what is referred to as the ‘scientific method’, and the knowledge that humanity has gained from rational science, gives us far more than just ‘one way of viewing the world’. Progress, through reason and rationality, is by definition a good thing; knowledge and enlightenment are always better than ignorance. Growing up in Iraq, I learnt at school about such great thinkers as Ibn Sīna (Avicenna), al-Kindi and Ibn al-Haytham (Alhazen), not as remote figures in history but as my intellectual ancestors. Many in the West will have heard, for instance, of the Persian scholar Ibn Sīna. But there are very many other great names that have been largely forgotten. Even in Iraq, I encountered these characters not in science classes but in history lessons. For the teaching of science in the Muslim world today follows the Western narrative. While it is not surprising that European children are taught that Copernicus, Galileo and Kepler were the fathers of astronomy, that nothing of note came before them, it is rather more disappointing that children in the Muslim world are taught the same thing. Might they not sit up and take notice if they were told that most of the stars we see in the night sky have Arabic names? For instance, the names of five of the seven main stars that make up the constellation Ursa Major (or ‘Great Bear’) – also known as the Big Dipper or the Plough – are Arabic in origin: Dubhe, Megrez, Alioth, Mizar and Alkaid.

The scientists who feature in this book truly were pathfinders, both literally and metaphorically. The title of the book is taken from a quotation about the fourteenth-century scholar Ibn khaldūn, but is in fact applicable to all those whose stories and achievements I touch upon. For they all broke new ground in advancing mankind’s knowledge, yet most have been forgotten.

The transmission of science, especially that of mathematics and astronomy (referred to by historians as the ‘exact’ sciences), is one of the most powerful tools for establishing relationships between different civilizations. Other areas of human thought – such as religion and philosophy – are transferred more slowly and will only gradually diffuse into, and influence, a particular culture. But the exact sciences require the direct use of treatises and other written work and so can tell us a great deal about the circumstances of the time. And while my motives for trying to piece together a complete picture of Arabic science are no different from those of a historian, I should stress that my primary interest is in the origin and development of the science itself. For this reason, it does not really concern me whether the science in question was developed by Greeks, Christians, Muslims or Jews. And while I

devote a chapter to examining how the Islamic Empire inherited the science of the Greeks and other civilizations, I nevertheless wish in this book to explore the ideas themselves, in the fields of natural science, medicine, philosophy and mathematics, which emerged and matured during medieval Islam.

For a theoretical physicist more familiar with the inner workings of the atomic nucleus, this has been an exhilarating and refreshing journey. I am particularly pleased therefore to have turned over many stones that others before have either ignored or had not seen fit to describe to a wider audience.

This book has been three years in the writing, throughout which time I have been on a relentlessly steep, yet hugely enjoyable, learning curve. I have been helped enormously in my research and education by many people; some are experts on the subject of Arabic science, others have provided insightful comments and helpful advice. Each one of them has added to this book and helped me turn it into something I am immensely proud of. First and foremost I thank my wife Julie for her constant encouragement and companionship. I also owe a huge debt of gratitude to my agent Patrick Walsh, and commissioning editor at Penguin Press, Will Goodlad, both of whom have shared my enthusiasm for the subject and helped me mould my initial clunky, diffident and tentative draft into a more assured final product that I hope is both accurate and readable. I would also like to thank Afifi al-Akiti, Ali al-Azzawi, Nader al-Bizri, Salim al-Hassani, Faris Al-Khalili, Salima Amer, Amund Bjørnø, Derek Bolton, Paul Braterman, Anna Croft, Misbah Deen, Okasha El Daly, Kathryn Harkup, Ehsan Masood, Peter Pormann, George Saliba, Mohammed Sanduk, Simon Schaffer, Andrea Sella, Paul Sen, Karim Shah, Adel Sharif, Ian Stewart, Rim Turkmani, Tim Usborne and Bernardo Wolf. I am hugely grateful to them all.

---

## *A Note on Names, Pronunciations, Spellings and Dates*

It is common for English speakers to mispronounce Arabic names – not because some of the guttural-sounding letters have no English counterpart, but because the wrong syllables are often stressed. For instance, the Iraqi city of Kerballa was often mispronounced by news reporters during the Iraq invasion in 2003 as *Kerballa* or *Kerbella* rather than the correct *Kerballa*. To transcribe Arabic words in English correctly, diacritical symbols should be added above or below letters to give them the correct pronunciation. However, I have not been overly pedantic or rigorous on this front, and have instead aimed at a ‘halfway house’ convention that closely approximates to the correct vowel sounds without worrying too much about the more awkward consonants. Therefore, you will find many names with a macron over a vowel to extend its sound. For instance, the Persian scholar *Ibn Sīna* is phonetically pronounced *ibin seena*. Without the macron over the ‘i’, *Sina* would more likely be pronounced by a native English speaker as *sinner*, which would be wrong. For Arabic words familiar in English I dispense with all diacritical marks. Thus, I do not bother to write *Baghdād*, *Islām*, *Qur’ān* or *Irāq* (provided the ‘a’ in Iraq is understood to sound like it does in ‘car’ rather than ‘cat’). Even for less familiar words, if I can get away without a diacritic then I will. Thus, the Arabic for ‘book’, *kitab*, should be written as *kitāb*, but since it is natural for a native English speaker to pronounce it correctly anyway, with a short ‘i’ and longer ‘a’ (*kitab*), then the bar is deemed unnecessary.

In scholarly works, historians often insist on a comprehensive transcription of Arabic words into English with additional diacritics, such as dots underneath consonants. But I feel no obligation to follow this convention closely. Let me give you an example of what I mean: a famous text by the eleventh-century scholar Ibn al-Haytham, translated as ‘The Book of Optics’, is traditionally transcribed as *Kitab al-Manazir*. But the ‘z’ should really be written with a dot underneath it, *ẓ*, denoting the Arabic letter **ظ**. The correct way to pronounce this letter is like the hard ‘th’ in ‘the’ (and not soft as in ‘think’), but with the tongue protruding further outside the mouth, which is more rounded. So, for me, a more faithful and closer

pronunciation would be to spell the word as ‘al-Manathir’. The only reason to use a ‘z’ is if the word were pronounced in the colloquial style of certain Arab countries today, such as Egypt. So, my decision not to use any diacritical marks with consonants means I sometimes stray from the conventional scholarly transliteration and focus on a more natural transcription that is closer to the correct classical Arabic.

In some cases, I have deferred to tradition. Thus, the word ‘ibn’ (‘son of’) is really pronounced *ibin* but it is usual not to include the second ‘i’ in the spelling; in any case it is difficult not to include a vowel sound between the ‘b’ and the ‘n’. Likewise, the name *al-Khwārizmi* – a mathematician we shall meet later – is always spelt this way, but the more accurate Arabic, and Persian, pronunciation is to include a vowel (an ‘a’ or an ‘o’) after the ‘Kh’.

In a break with popular Western tradition on this subject, I believe there is no excuse not to refer to people by their correct Arabic or Persian names rather than the Latin derivation that has been passed on to us. Thus, I refer to Ibn Sīna and Ibn Rushd rather than the better known, in the West, Avicenna and Averroës. Finally, most Persian scholars have Arabized names with the definite article ‘al’ placed in front of the name. Thus al-Bīrūni and al-Tūsi would simply be Bīrūni and Tūsi in Persian. I have, however, stuck with the more familiar (usually Arabic) version of their names and hope that Iranian readers are not too offended. Thus, while I keep the more familiar Persian name of the mathematician Omar Khayyām, another Persian, Khwarizmi, is better known by the Arabized al-Khwārizmi.

Many of the characters we shall encounter have impressively long names that involve not only their forenames and family names but, sandwiched in between, the names of their fathers and grandfathers. They may also pick up a *laqab* (nickname) or *nisba*, based on an attribute of their personality, profession or origin, such as describing someone from Baghdad as ‘al-Baghdadi’. They can even be known by the name of their eldest son. Thus the word *Abū* (pronounced *aboo*) means ‘father of’. If a man does not have children then his first name is often associated with a prominent character in Arabic or Islamic history who would have had a son. Among many Shi’ite Muslims, the name *Ali* is always associated with that of Imam Ali and his son, Hussein. Thus, when a man is referred to as Abū Hussein, he may either have an eldest son named Hussein or may simply be an Ali with no sons.

For example, the mathematician al-Khwārizmi has the full name Abū Abdullah Muhammad ibn Mūsa al-Khwārizmi, which means his first name is Muhammad but his son is Abdullah and

his father's name is Mūsa (Moses). Sometimes he is referred to as Muhammad ibn Mūsa, but is far better known as al-Khwārizmi, named after his birthplace Khwārizm (modern Khiva in Central Asia).

The common language used universally across the Arab world is referred to as classical Arabic. This is the Arabic of the Qur'an, and the Arabic of the educated classes. However, Arabic dialects differ widely from one country to the next and certain letters are pronounced differently. Thus a 'j' in Iraq is pronounced the same as in English, whereas in Syria it would be pronounced as in the French *bonjour* and in Egypt as a 'g' sound. But more than just accents differentiate Arabic dialects. Often words are completely different. For instance, in Iraq, the word for 'yes' is *ee*; in Egypt, it is *aywa*, but in classical Arabic, it is *na'am*. I mention this because classical Arabic, being the language of the Qur'an, has not changed at all in fourteen centuries, making the writings of the early Islamic scholars as accessible today as they were then.

On the issue of dates, there are several standard conventions, and I have chosen the one most commonly used by contemporary historians. Apart from the early chapters, when I cover the sciences of antiquity and have to use the 'BCE' notation (Before the Common Era, or Before the Christian Era), years not so identified should be taken to denote the Common Era (or Christian Era), CE. For brevity, I have chosen not to include Muslim *Hijri* dates – the calendar that began in 622 CE.

---

## *A Note on the Term ‘Arabic Science’*

Throughout the book, I use the term ‘Arabic science’ in its broadest sense. I do not mean by this only the science practised by people of Arab blood, and therefore carefully refrain from referring to it as ‘Arab science’. That would necessarily constrain the discussion to the inhabitants of Arabia (modern Saudi Arabia and southern Syria and Mesopotamia) many of whom, outside the cities, were in any case simple Bedouin desert tribes. What I mean by ‘Arabic science’ is that carried out by those who were politically under the rule of the Abbāsids, whose official language was Arabic, or who felt obliged to write their scientific texts in Arabic, the lingua franca of science in the medieval world. A large part of the scientific body of work was initially (in the ninth and tenth centuries) carried out in today’s Iraq, in the cities of Basra, Kūfa and, most importantly, Baghdad.

Many of the scientific figures we shall encounter along our journey, such as al-Bīrūni and Ibn Sīna, were Persians, and were often even anti-Arab in their sentiments. But what matters in this context is that most of their scientific work was written in Arabic, not Persian. Nor indeed do we find that all the scientific work was carried out by Muslims, despite the undeniable fact that this explosion in scientific creativity would not have been possible without the spread of Islam, as I shall explain later on. Many important contributions were made by Christians and Jews, particularly in the early days of the Abbāsid era when the main body of translation from Greek texts was being carried out. But even they shared with their Muslim rulers a common culture that encompassed their customs, thinking, education and language.

Thus, when I speak of ‘Arabic’ scientists I do not mean the word in the sense that they had to have been born and educated in today’s Arab and Arabic-speaking countries and would have regarded themselves as Arabs, rather that it was the Arabic language that united them. I therefore include the great Persian scientists as part of this broad definition.

A nice example to emphasize this point is that of the Alexandrian astronomer Ptolemy, author of the *Almagest* (c. 150 CE), one of the most important astronomical texts ever written

Those who would question whether the work of Persians such as al-Bīrūni and Ibn Sīna is rightly part of Arabic science cannot then class the work of an Egyptian such as Ptolemy as part of Greek science. However, it is acknowledged universally that Ptolemy's work was no less a part of the science of the Greeks than that of Euclid, Archimedes or Aristotle.

Naturally, you might ask whether it is not more appropriate to define this as Islamic, rather than Arabic, science. There are three reasons why I have not done so. The first is one that I have alluded to already: not all the important scientific advances were carried out by Muslims. Before the spread of Islam in the seventh century, much of the Middle East was Christian. Its two main sects were the Nestorians (chiefly in the cities of Hīra in southern Iraq and Edessa and Antioch in northern Syria) and the Monophysites (who were spread throughout Syria, Anatolia and Egypt). In addition, large parts of the region before Islam also practised the ancient Mazdean and Zoroastrian religions, even Buddhism. Consequently, during the golden age of Arabic science many of the leading figures were not Muslims. The greatest of all the translators of Baghdad, Hunayn ibn Ishāq, was a Nestorian who never converted to Islam. Other Christian scientists of ninth-century Baghdad include the astronomer Yahya ibn abi Mansūr and the physicians Jibrīl ibn Bakhtyashū and Ibn Massāwayh. Likewise, many Jewish philosophers and scientists, such as the translator [Sahl al-Tabari](#), the medic Ishāq ibn Amrān and the astronomer Mashā'allah, all made valuable contributions to the intellectual culture of Baghdad. Nor can we ignore the many contributions of the Andalusian Jewish scholars between the eighth and eleventh centuries, or even later, such as the great medieval Jewish philosopher and physician Maimonides, who was born in Córdoba but spent much of his life in Egypt.

The second reason is that Islam is today practised by more than a billion people across the world. The subject of this book does not extend to include the scientific heritage of those Muslim countries such as Pakistan or Malaysia, which would have also been influenced by Indian and Chinese science. I am defining my subject matter more narrowly.

Of course we cannot hope to understand the context of Arabic science if we do not explore the extent to which the religion of Islam influenced scientific and philosophical thinking. Arabic science throughout its golden age was inextricably linked to religion; indeed it was driven by the need of the early scholars to interpret the Qur'an. Furthermore, politics in Baghdad during the early Abbāsīd rule was dominated by a movement of Islamic rationalists known as the Mu'tazilites, who sought to combine faith and reason. This led to a spirit of



- [click Anarchism and Art: Democracy in the Cracks and on the Margins \(SUNY series in New Political Science\)](#)
- [download online The Kennedy Chronicles: The Golden Age of MTV Through Rose-Colored Glasses.pdf](#)
- [Before Nature: A Christian Spirituality here](#)
- [download The House I Loved](#)
- [read online All the Rage \(Repairman Jack, Book 4\) pdf, azw \(kindle\), epub](#)
  
- <http://fortune-touko.com/library/SQL-Injection-Attacks-and-Defense.pdf>
- <http://aseasonedman.com/ebooks/Holier-Than-Thou--Tome-of-Bill--Book-4-.pdf>
- <http://betsy.wesleychapelcomputerrepair.com/library/PhoneGap-Beginner-s-Guide.pdf>
- <http://pittiger.com/lib/The-Passing-of-the-Armies--An-Account-of-the-Final-Campaign-of-the-Army-of-the-Potomac--Based-upon-Personal-Reminis>
- <http://paulczajak.com/?library/Hard-Times.pdf>