Table of Contents

THE PENGUIN PRESS
Published by the Penguin Group
Penguin Group (USA) Inc., 375 Hudson Street, New York, New York 10014, U.S.A.
Penguin Group (Canada), 90 Eglinton Avenue East, Suite 700, Toronto, Ontario, Canada M4P 2Y3
(a division of Pearson Penguin Canada Inc.) • Penguin Books Ltd, 80 Strand, London WC2R 0RL, England •
Penguin Ireland, 25 St. Stephen's Green, Dublin 2, Ireland (a division of Penguin Books Ltd) • Penguin Books
Australia Ltd, 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, Rosedale, North Shore 0632,
New Zealand (a division of Pearson New Zealand Ltd) • Penguin Books (South Africa) (Pty) Ltd,
24 Sturdee Avenue, Rosebank, Johannesburg 2196, South Africa

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

Illustration credits appear on pages xi-xii.

Library of Congress Cataloging-in-Publication Data
al-Khalili, Jim.
The house of wisdom : how Arabic science saved ancient knowledge and gave us the Renaissance / Jim al-Khalili.
p. cm.
Includes bibliographical references and index.
eISBN : 978-1-101-47623-9
1. Science—Arab countries—History. 2. Science—Philosophy—History. 3. Science, Medieval. 4. Science—Methodology—History. 5. Arab countries—Intellectual life—History. 6. Science, Renaissance. I. Title.
Q127.A5A4 2011
509.17'67—dc22 2010053136

To Julie

He who finds a new path is a path finder, 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

List of Plates

18. The Banū Mūsa brothers' self-trimming lamp. (The Art Archive/ National Library Cairo/Gianni Dagli Orti)
19. The Elephant Clock of al-Jazari.
20. The inner workings of the Elephant Clock.
21. 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)
22. 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 electrical engineer, 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-Harīr, a chemical firm in Hindīyya that produced artificial rayon fibres. We lived in Baghdad for a few years before eventually moving to Hindīyya 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 scores 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 a 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 Bjørnøs, 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 Ker*b*alla or Kerbe*llah* rather than the correct *Ker*balla. 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' (ki*tab*) 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 Abbāsid 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 tolerance in which scientific enquiry was encouraged.

Many have argued that the scientific creativity of the Islamic world was short-lived because it came into conflict with religious teaching within Islamic society, culminating in the work of the Muslim theologian al-Ghazāli (the equivalent in terms of importance in Islamic teaching as Thomas Aquinas was to Christianity). However, many of the sciences, such as mathematics, medicine and astronomy, continued to flourish long after al-Ghazāli.

The third reason why I resist the temptation to refer to my subject matter as Islamic science is because of an unfortunate anti-scientific attitude among some Muslims today (although this is of course not restricted to Muslims). It is sad to think that a minority of contemporary Islamic scholars do not seem to be endowed with the enquiring minds of their forefathers. For the early scholars of Baghdad, there would have been no conflict between religion and science. The early thinkers were quite clear about their mission: the Qur'an required them to study *alsamawāt wal'arth* (the skies and the earth) to find proof of their faith. The Prophet himself had besought his disciples to seek knowledge 'from the cradle to the grave', no matter how far that search took them, for 'he who travels in search of knowledge, travels along Allah's path to paradise'. Of course, this knowledge (*'ilm*) referred primarily to theology, but in its early years Islam never made a clear-cut distinction between religious and non-religious scholarly pursuits.

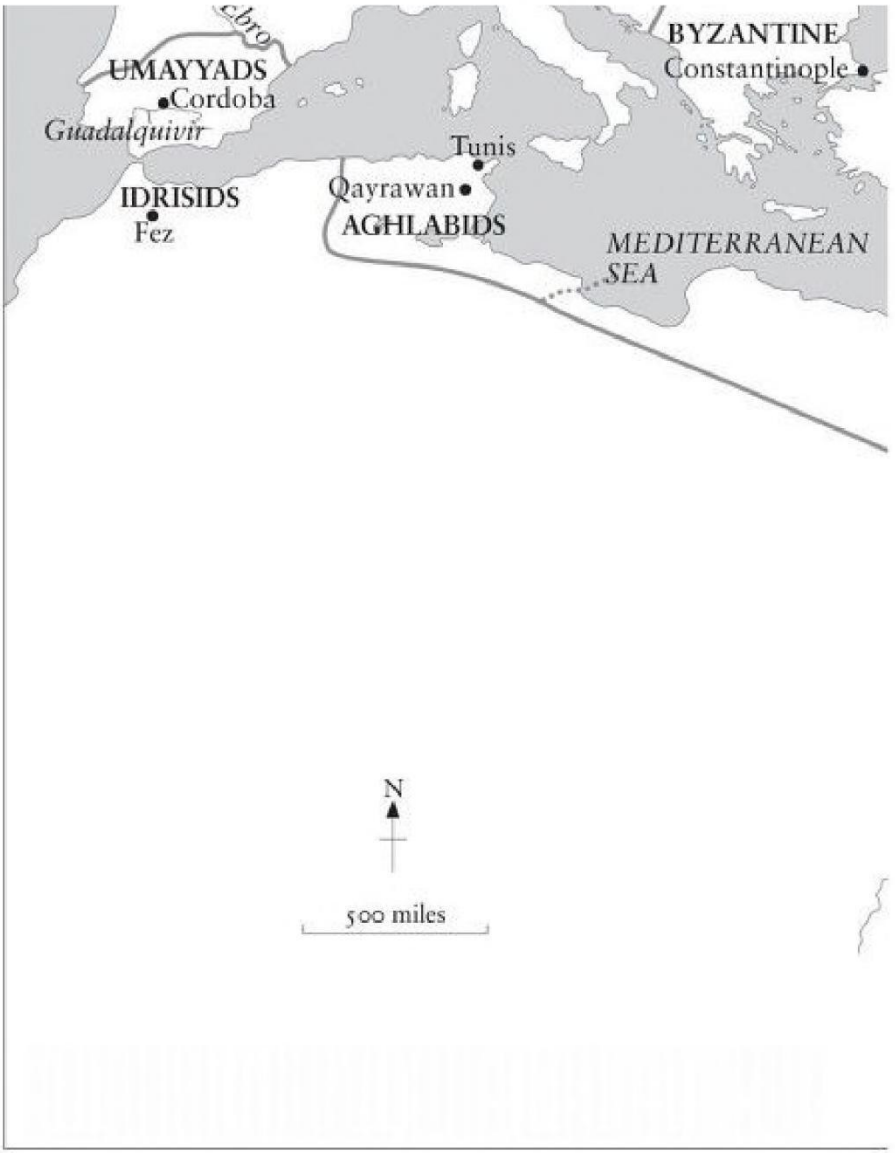
The seemingly comfortable compatibility between science and religion during the Abbāsid Empire contrasts starkly with the tensions between rational science and many different faiths around the world today. None of our modern-day angst existed in early Baghdad. One can of course argue that the science of the time was itself not so far removed from superstition – a mix of metaphysics and folklore. So it could be more easily absorbed into theological ideas. But what we shall also see is that, in contrast to many of the Greek philosophers' abstract notions, the Arabic scientists were grounded in something very close to the modern scientific method in their reliance on hard empirical evidence, experimentation and testability of their theories. Many of them, for instance, dismissed astrology and alchemy as not being part of real science and being quite distinct from astronomy and chemistry.

It is clear that there is a broad continuum of attitudes held by today's Muslim population towards science; all are no doubt sincerely held. Those who see the importance of science and who are able to disentangle it from religion would

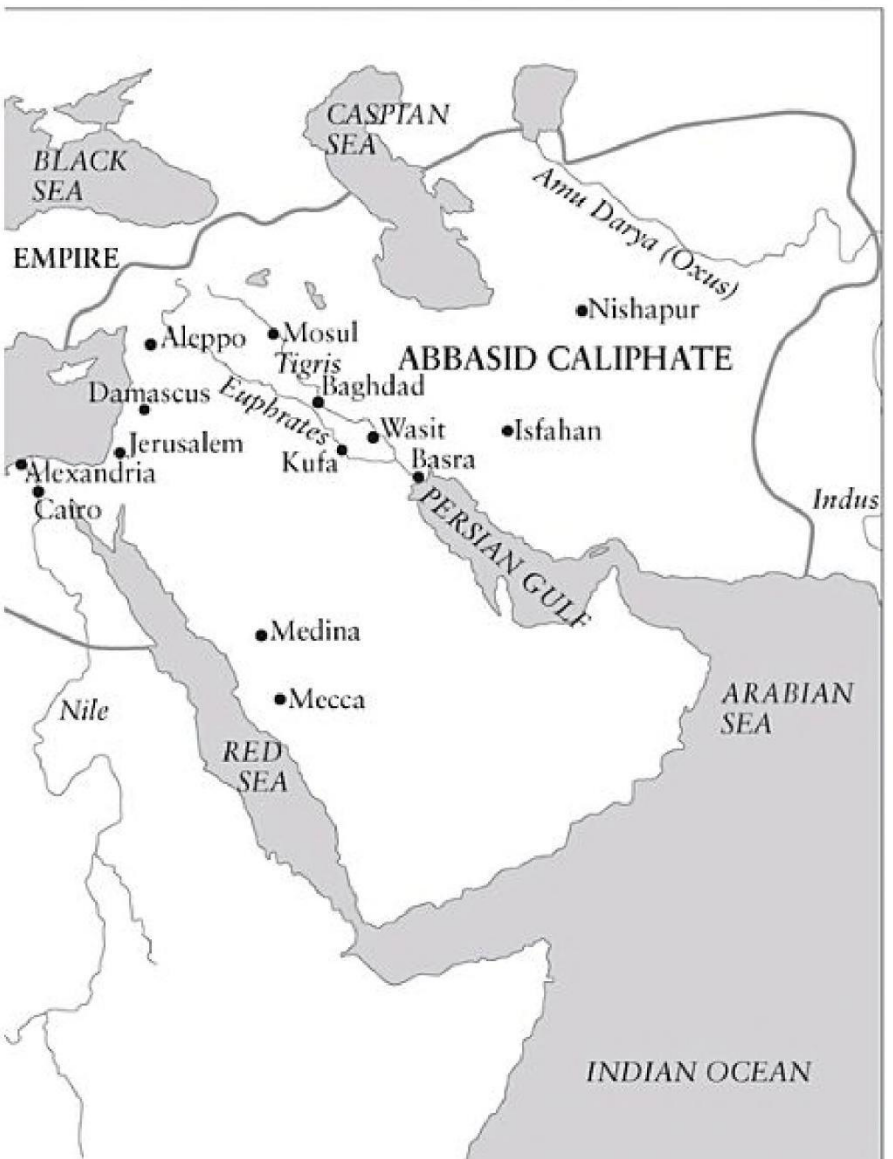
claim that 'the Qur'an tells us how to go to heaven, not how the heavens go'. Many devout Muslim scientists feel it is their religious duty to try to understand the universe from an empirical, rationalist scientific standpoint. Then, armed with this new-found knowledge, they can return to the words of the Qur'an in the hope of gaining a deeper and more profound understanding than they had before their scientific enlightenment. I have no problem here since their faith does not influence how they conduct their science. Only when the process is reversed do alarm bells start to ring: when one hears the argument that it is not necessary to try to understand the world around us from a scientific perspective since all we ever need to know is already written in the Qur'an anyway.

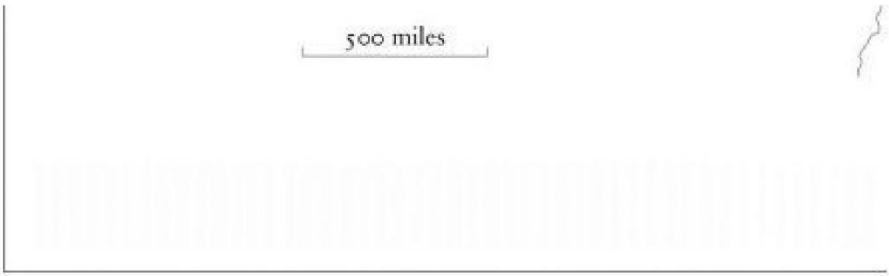
Ultimately, there can be no such thing as *Islamic* science or *Muslim* science. Science cannot be characterized by the religion of those who engage in it, as the Nazis in 1930s Germany attempted to do when disparaging Albert Einstein's great achievements as 'Jewish science'. The term 'Islamic science' may likewise be used by those with similar racist notions who wish to downplay its importance. Just as there is no 'Jewish science', or 'Christian science', there cannot be 'Islamic science'. There is just *science*.

The one misgiving I have about my chosen term of 'Arabic science' (aside from its likely unpopularity among the population of today's Iran, Uzbekistan or Turkmenistan, all proud homes of great scholars of the golden age) is that even choosing to name a scientific age by the language of its communication is problematic. After all, we do not refer to the scientific achievements of the European Renaissance as those of 'Latin science'. Even stranger would be to refer to modern-day science as 'English science'. But I nevertheless feel that 'Arabic' rather than 'Islamic' science is somehow more honest and less problematic. And I really do need to call it something to distinguish it from Greek or Indian or European Renaissance science, the meaning of all of which is quite clear; and to keep referring to it as 'the science practised by the scholars of the golden age of Islam' is, I am sure you agree, a bit of a mouthful.

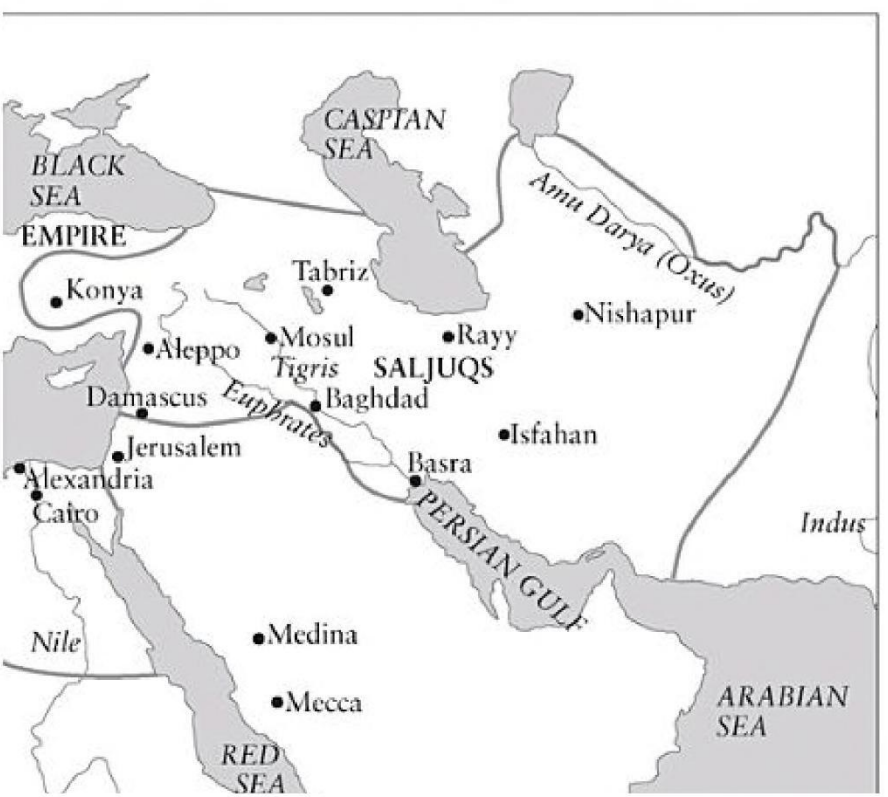


MAP 1: THE ABBASID CALIPHATE AT THE BEGINNING OF THE NINTH





MAP 2: THE MIDDLE EAST AND MAGHRIB, TOWARDS THE END OF THE ELEVENTH CENTURY



1

A Dream of Aristotle

One night the Caliph Harūn al-Rashīd summoned his vizier Ja'far and said to him, 'I wish to go into the city to find out what is happening and to question the people about the conduct of my administrators, so that I may dismiss those of whom they complain and promote those they praise.'

From 'The Tale of the Three Apples',
The Thousand and One Nights

The Bab al-Sharji district in the centre of Baghdad derives its name, which means East Gate, from the medieval fortifications of the city. It was part of the walls probably built around the first half of the tenth century. During the brief British stay at the end of the First World War, its gatehouse was used as a garrison church (and in fact referred to by the British as the South Gate, since the only other surviving gate, called *Bab al-Mu'atham*, was to its north). Nothing of those medieval walls, or the East Gate, remains today; I remember Bab al-Sharji as a hot, smelly, noisy, bustling and congested square, with its food stalls and second-hand record shops scattered around the busy bus depot and taxi ranks, but its name is a reminder of the expansion and transformation of this proud city over the years since its foundation in 762 CE as the new seat of power of the mighty Abbāsid Empire. For Baghdad has grown and shrunk and grown again, with the centre of government shifting over the centuries from one side of the Tigris river to the other as successive rulers chose the most suitable spot to build their elaborate palaces. If we probe into the history of the city we see that whatever suffering its present-day inhabitants have had to endure, they are in very good company. For no other city on earth has had to put up with the levels of death and destruction that Baghdad has endured over the centuries. And yet, as the capital of one of the world's great empires, this had been the richest, biggest, proudest, most supercilious city on the planet for half a millennium.

Exactly twelve hundred years after its foundation, I was born in a Baghdad hospital in Karradat Mariam, a Shi'a district with a large Christian community, just a stone's throw away from today's Green Zone on the opposite bank of the river. That hospital is a few miles south of the spot where one of Baghdad's most famous rulers was born in 786 CE. His name was Abū Ja'far Abdullah al-Ma'mūn. Half Arab, half Persian, this enigmatic and fascinating caliph is central to my story, for he was destined to become the greatest patron of science in the cavalcade of Islamic rulers, and the person responsible for initiating the world's most impressive period of scholarship and learning since ancient Greece.

In order to understand how and why this golden age took place, we shall need to dig deeper into the motives and psyche of early Muslim society and its rulers and carefully examine those factors (both internal and external) that helped shape and influence the period. But before we begin our journey in earnest, allow me to introduce you to this remarkable ruler.

Al-Ma'mūn was not the only caliph to support scholarship and science, but he was certainly the most cultured, passionate and enthusiastic. He created an environment that encouraged original thinking and free debate like no other Islamic ruler before or since. He was in fact the son of an even more famous caliph – in the West at any rate – called Harūn al-Rashīd (763-809), which translates as 'Aaron the Righteous', who pops up frequently as a character in the tales of *The Thousand and One Nights* (see Plate 2). Al-Rashīd oversaw the Abbāsid Empire's expansion as far north as Constantinople and maintained diplomatic ties with China and the European Emperor Charlemagne, with whom he frequently exchanged delegations. They recognized each other as the most powerful men of their respective cultures, and diplomatic ties between the two rulers helped encourage strong trade relations. Charlemagne sent 'Frisian' cloths to Baghdad to correct a 'balance-of-payments' problem caused by Western tastes for Abbāsid silks, rock crystal and other luxury objects. In return, al-Rashīd sent many gifts to Charlemagne, including an elephant and an elaborate brass water clock, both of which must have amazed the European emperor. There are many stories of al-Rashīd's wealth, and his collection of gems was particularly legendary.[1] He is said to have bought a famous pearl called *al-Yatima* ('The Orphan Pearl') for 70,000 gold dinars. Charlemagne is also believed to have given him what is thought to have been the world's largest emerald.

Al-Rashīd took a personal interest in many campaigns against the neighbouring Byzantine Empire, leading military expeditions against them throughout his reign. In 797 the defeated Empress Irene agreed to pay a large sum of money to al-Rashīd as the terms of her surrender. When her successor, Emperor Nicephorus I, withheld the payment, al-Rashīd declared war again, and Arab forces defeated the Byzantine emperor in a battle in Phrygia in Asia Minor (Turkey) in 805. The following year, he invaded Asia Minor again, this time with more than 135,000 men. Nicephorus was humiliated into agreeing to pay a yearly tribute of 30,000 nomismata (Byzantine gold coins).[2]

There is a further account of a sum of 50,000 dirhams[3] sent by Nicephorus as a ransom to al-Rashīd for a female slave captured during the incursion of 806. It seems that the woman was betrothed to Nicephorus' son and that the emperor's offering to Baghdad was part of a larger exchange that involved brocade garments, falcons, hunting dogs and horses.

Back in Baghdad, however, al-Rashīd was a poor administrator, who owed his success to the running of the affairs of state by a powerful Persian family known as the Barmakis (referred to in the West as the Barmakids). The Islamic Empire was at its most powerful under al-Rashīd's reign and many historians and poets have, over the centuries, referred to this period as the pinnacle of Baghdad's golden age. However, this view was to a large extent based on nostalgia towards a bygone era before the cracks in the empire began to appear, which they soon did. It is remarkable that for a city which would remain as the most important in the world for five hundred years, the decline in its glory would begin, as we shall soon see, just fifty years after its foundation. Certainly al-Rashīd has been the beneficiary of almost universal sentimental glorification ever since.

Al-Ma'mūn (786-833) was born the same year that his father became caliph. His mother was a Persian slave concubine named Marajil who had arrived in Baghdad originally as a prisoner of war. She was the daughter of Ustath Sis, a Persian rebel leader defeated by the Abbāsids in Khurasan in what is today western Iran. Marajil worked in the kitchens of al-Rashīd's palace. Historians have unkindly recorded that, as a forfeit for beating him in a game of chess, al-Rashīd's Arab wife Zubayda insisted that he sleep with the ugliest and dirtiest slave in the kitchen. After much pleading he agreed and had sexual intercourse with Marajil, and she bore him his first son, Abdullah, to whom he gave the title al-Ma'mūn ('The Trustworthy').

Marajil died soon after childbirth and al-Ma'mūn was placed in the care of the Barmaki family.

On assuming the caliphate, Harūn al-Rashīd had moved across the river from his father's palace on the east side to the magnificent Qasr al-Khuld ('Palace of Eternity') that had been built by his grandfather and founder of Baghdad, the Caliph al-Mansūr. Within six months of the birth of al-Ma'mūn, Zubayda herself bore the caliph a second son, al-Amīn (787-813). The two boys were destined to grow up in very different worlds. Like al-Rashīd, Zubayda was of pure and noble Arab blood – she was a granddaughter of al-Mansūr and thus al-Rashīd's cousin – and their son, al-Amīn, was the natural successor to the caliphate over his older half-brother, the son of a Persian slave girl. Unsurprisingly, al-Ma'mūn was never close to his stepmother but was certainly loved by his father, for there are many accounts of him as a young boy playing with the caliph in the beautiful gardens of the palace and on the banks of the Tigris.

As a young man, al-Ma'mūn memorized the Qur'an, studied the history of early Islam, recited poetry and mastered the newly maturing discipline of Arabic grammar. He also studied arithmetic and its applications in the calculation of taxes and inheritance. Most importantly, he was a brilliant student of philosophy and theology, or more specifically what is referred to in Arabic as *kalām*, which is a form of dialectic debate and argument. The early Muslim theologians found that the techniques of *kalām* enabled them to hold their own in theological arguments with the Christian and Jewish scholars who lived alongside them, and who had had a head start of several centuries to hone their debating skills by studying the writings of philosophers such as Socrates, Plato and Aristotle – historical figures from ancient Greece whose names would certainly have been known to the young Ma'mūn. It is even quite likely that some of their work had already been translated into Arabic. Al-Ma'mūn's interest in *kalām* was to later play a big part in his lifelong obsession with science.

By the beginning of the ninth century, the teenage prince would have known a Baghdad at the very height of its glory: a vast and beautiful city characterized by the domes and archways of its famously intricate Abbāsid architecture. Although just four decades old, Baghdad was already the largest city in the world, with some estimates putting its population at more than a million. [4] Certainly far larger in area than Rome, Athens or Alexandria had been at their grandest, Baghdad

boasted dozens of sumptuous palaces, occupied by the members of the caliph's family, his generals and viziers.

Given its turbulent history, almost nothing survives of early Abbāsid Baghdad today. It is worth remembering that, unlike for other, far older, cities such as Rome and Athens, there are no stone quarries in Iraq (although significant limestone and marble deposits could once be found in the north and the west of the country). All the buildings in Baghdad, including the palaces, were constructed mainly from sun-dried mud bricks, making them susceptible to the regular destruction of invading armies, fires and floods. But we can get a sense of the scale of these palaces from one of the very few surviving Abbāsid buildings of that early period.[5] Known as the Palace of Ukhaidhir, its ruins stand about 120 miles south of Baghdad (see Plate 3). I vividly remember school trips there, during which my friends and I would race each other, completely unsupervised, around its precarious 65-foot high perimeter walls. It had originally been built as a private retreat by a wealthy member of the caliph's family in the second half of the eighth century.

Most of Baghdad's palaces could be found along either bank of the Tigris, and not all were for residential purposes. The grand vizier (derived from the Arabic word *wazīr*, meaning 'minister'), Ja'far al-Barmaki, another familiar character in *One Thousand and One Nights*, built a pleasure palace known as *al-Ja'fariyya* ('the Palace of Ja'far') in an undeveloped, secluded part of east Baghdad. It would later become the residence of al-Ma'mūn himself and the centre of a district containing a whole complex of palaces and luxury homes known as *Dar al-Khilāfa* ('Home of the Monarchy'). Ja'far had been appointed as the young al-Ma'mūn's personal tutor and he is credited with instilling in the future caliph a love for learning and scholarship.

The palaces, along with many of the important administrative buildings, were tall, multi-storey structures. Many were crowned with elaborate weathervanes depicting warriors on horseback, symbolizing the caliphs' might. One account, for instance, tells how members of a captured rebel group attempting to escape from the caliph's throne room – having realized that they would not be able to defeat his bodyguards – jumped from a window and fell nine floors to their death in the courtyard below.

Within the houses of the wealthy, marble was widely used for pillars, tiled floors

of al-Rashīd's determination to ensure his wishes were carried through is clear. He cut off the influential Persian Barmaki family from power and even went as far as having his loyal vizier Ja'far, who was of course very close to al-Ma'mūn, executed.[8]

But it seems that al-Rashīd's gift of Khurasan to his eldest son was more than a consolation prize. The province was highly symbolic, for this was where the Abbāsid revolution had started in the middle of the eighth century and from where it had spread to seize power from the first Islamic dynasty, the Umayyads. Moreover, al-Ma'mūn seems to have been given absolute power in Khurasan, providing him with an opportunity to rise up against his brother. Did their father predict this would happen? Did al-Rashīd carefully engineer things so that it would look as though he had favoured al-Amīn just to keep his wife and the Abbāsid family happy, while at the same time leaving the door open for al-Ma'mūn to snatch power if he so desired? No one can be sure, and al-Rashīd's motives remain subject to conjecture. It has been speculated that he already harboured serious doubts about al-Amīn during the famous 802 pilgrimage.

In 805 a rebellion broke out in Khurasan. The people of the province had risen up against the governor in protest against the extortionately high taxation. Matters slowly worsened until, in 808, al-Rashīd was obliged to personally ride east with his son al-Ma'mūn at the head of an army to quash the rebellion. Although still only in his early forties, al-Rashīd became ill from the exertions of the long trek across mountains and deserts and died on the way. His death changed the whole complexion of the campaign, for al-Ma'mūn now automatically assumed the governorship of this volatile part of the empire. However, most of his father's army deserted him to return to their families in Baghdad. This setback proved to be a minor one for the 23-year-old al-Ma'mūn, who, after successfully putting down the rebellion, immediately set about establishing his powerbase. He was helped in this by his close adviser and confidant al-Fāthl ibn Sahl, a Persian who had replaced Ja'far the Barmaki as vizier. Slashing the high taxes in the province proved to be a hugely popular early policy. In addition, al-Fāthl advised him in no uncertain terms to improve his public image. Al-Ma'mūn was renowned for his love of good wine and the company of beautiful slave women, but he would need to come across as a far more pious Muslim if he wished to lay claim to the caliphate in Baghdad from the newly installed al-Amīn. All the while, he slowly

and methodically put together his new army, recruited from across Central Asia.

Back in the capital, the new caliph began flexing his muscles and trying to assert his authority in the East. He challenged his brother's role as governor of Khurasan by demanding that tax revenues be sent back to Baghdad, recalling those in the original army who had remained loyal to al-Ma'mūn and even naming his own son as his direct successor, ahead of his brother.

Armed conflict between the two men was quickly becoming inevitable. Al-Ma'mūn was fortunate to be served by the loyal and highly able Persian General Tāhir, who claimed an early victory over al-Amīn's army on the outskirts of present-day Tehran, giving al-Ma'mūn control over much of Persia. Al-Amīn, suddenly growing concerned, appealed in vain first to his brother to see sense and to respect the wishes of their father, and then to his subjects in order to recruit new troops, mainly from among the Arabs of Syria. But al-Ma'mūn's army kept advancing westwards, finally arriving at the outer walls of Baghdad in April 812. And so the great siege of Baghdad began. By this time most of the empire outside the immediate environs of Baghdad itself had already declared its allegiance to al-Ma'mūn.

For more than a year the beleaguered caliph held his ground against the armies of his half-brother and pretender to the throne, who continued to reside in Merv. Al-Amīn initially found an unexpected source of popular support among the city's trapped population, who fought with crude homemade weapons against the well-armed and welltrained Khurasani soldiers. Tāhir seemed initially unable to break down Baghdad's defences and could not understand what was driving this newly emerged resistance from within. Al-Amīn, who had been living in the Qasr al-Khuld by the river, retreated within the fortified walls of the old Round City built by his great-grandfather, al-Mansūr, the founder of Baghdad. While Tāhir's forces used catapults to pound the walls and buildings as they advanced through the vast metropolis, al-Amīn's men set whole neighbourhoods on fire to slow down the enemy advance. By the time Tāhir had reached the Round City walls, much of Baghdad was in ruins.

The ninth-century Baghdadi poet Abū Tammam wrote: 'the death announcer has risen to mourn Baghdad', comparing the city to 'an old woman whose youth has deserted her, and whose beauty has vanished'. [9] Given Baghdad's long and bloody history since that time it sounds strange to hear of it being referred to as

an ‘old woman’ just half a century after it was founded.

After more than a year of siege, the stalemate was finally broken in the autumn of 813 when Tāhir persuaded the merchants of Baghdad to destroy the pontoon bridges across the Tigris that had served as critical communication routes between the resisting forces. The ensuing chaos offered the assembled eastern army the opportunity to attack. Anticipating eventual defeat, al-Amīn listened to the advice of his closest advisers who convinced him that he stood a chance of a future counterstrike against his brother if he escaped from the north and made his way to Syria or Egypt where he could organize a new powerbase. Tāhir, however, apparently having caught wind of the plan, sent a message to the troops loyal to al-Amīn, threatening to retaliate by destroying not only their property inside Baghdad but their estates in the country as well if they did not dissuade al-Amīn from this decision. Al-Amīn was soon ‘convinced’ by his advisers of the benefit of surrender instead – a decision that would prove fatal for him.

Although the civil war had originated with al-Rashīd’s ill-advised decision over the succession – for al-Amīn was never cut out for great leadership – it also revealed the first cracks within the Abbāsid Empire. It was a question not merely of a personal rivalry between the two brothers, but of a conflict between different politico-religious trends that had become apparent during the preceding reign; al-Amīn had emphasized traditionalism and Arab culture, while al-Ma’mūn, who was open to new philosophical movements and outside influences, had courted the support of Persian intellectuals and was a strong supporter of the rationalist movement known as Mu’tazilism, a doctrine of open questioning and enquiry that opposed the literal interpretation of the Qur’an.

The medieval historian al-Mas’ūdi recounts how al-Amīn’s mother, Zubayda, had predicted ill fortune for her son: in each of three separate dreams, a different woman appeared to her and described her son’s future rule as despotic, corrupt, weak, unjust and extravagantly wasteful. On each occasion Zubayda awoke in great horror. On a final visit, all three women appeared together to make their harshest prediction yet by not only graphically describing al-Amīn’s violent death (despite his surrender to Tāhir) but defending it as a fitting and glorious outcome.

But we should not get too carried away with this depiction of al-Ma’mūn as the worthier of the two brothers. A cursory review of the literature of the civil war might at first strike one as overwhelmingly supportive of al-Ma’mūn – not so surprising, given that the sources were written after his victory and needed to be

seen as being on the right side. However, despite his weakness al-Amīn had been a relatively popular caliph during his four years in power. More importantly, while this was not the first case of regicide in Islamic history it was nevertheless the first violent end to befall an Abbāsid caliph. It thus left an indelible mark on the collective consciousness of Islamic society. Al-Mas'ūdi's story of Zubayda's dreams, therefore, seems a harsh reflection on al-Amīn and has more to do with the historian's hagiographic support for al-Ma'mūn.

There does, however, seem to be some doubt over al-Ma'mūn's part in his brother's death. Several historians recount how Tāhir sent a message to al-Ma'mūn from Baghdad asking what he was to do with al-Amīn if and when he was finally captured. Al-Ma'mūn is said to have sent back to the general a shirt with no opening in it for the head. Tāhir interpreted this as al-Ma'mūn's wish to have his half-brother beheaded and as soon as he captured the caliph he carried out his master's wishes.

Some accounts describe how al-Ma'mūn had his brother's head displayed on a pole in the central courtyard of his palace in Merv after it had been carried back by his victorious troops on a two-week, 1,000-mile journey from Baghdad; and that he distributed sums of money among his military commanders, ordering whoever felt he had earned this reward in his service to come to the courtyard to curse the gruesome trophy. However, other Arab historians have argued that the execution of al-Amīn was a decision taken in the field by Tāhir himself and that al-Ma'mūn was horrified and grieved when he discovered what had happened. They claim that he wept openly when al-Amīn's head was presented to him and that he cursed Tāhir for carrying out a deed he had not ordered.

Al-Ma'mūn remained in Merv for a further five years, a period in which he did not endear himself to many of his subjects across the vast empire. This was partly due to his attempts to heal the divisions between the two main sects of Islam: Sunnism and Shi'ism.[10] His sympathies towards the latter were such that he adopted its green flag instead of the black flag of the Abbāsid dynasty. It was also partly due to his sympathies, like his father's, towards Mu'tazilism, a school of thought not shared by all Muslims. He certainly surrounded himself with Mu'tazilite sympathizers, among them his influential adviser, al-Fāthl. He even went so far as to declare that his successor would not be a member of his own family, but Ali al-Ridha, a descendant of the Prophet's cousin and son-in-law, Ali,

the spiritual leader of Shi'ism.

This last decision was extremely unpopular among the Sunnis in Iraq and, in Baghdad, his uncle Ibrahim decided to lay claim to the caliphate. This seems to have been the final straw, and al-Ma'mūn had a change of heart and headed for Baghdad to put down this insurrection personally. Mysteriously, his two closest allies, the Persian vizier al-Fāthl and Ali al-Ridha, both met with their death in suspicious circumstances on the long journey west. Ali al-Ridha is regarded by the Shi'a as the martyred eighth Imam, or saint, and his shrine in the city of Mashhad in north-east Iran is still of great religious importance.

Al-Ma'mūn arrived in Baghdad in 819, with the destructive siege six years earlier now a distant memory and the city mostly rebuilt and back to its former glory. One Baghdadi historian recounted how, as a young child, he was lifted up by his father over the heads of the crowds lining the streets of the capital to watch the caliph as he rode past, and remembered being told never to forget this momentous day.

Upon his arrival in the city, al-Ma'mūn abandoned his policy of reconciliation between Sunnis and Shi'a and quickly reinstated the traditional black Abbāsid flag. But his sympathies towards the Mu'tazilite movement only grew stronger. He subscribed wholeheartedly to their rationalist world-view that borrowed from the works of the Greek philosophers, as well as to their notions of indeterminism and free will, a philosophical standpoint that is, surprisingly, broadly in line with thinking in modern science, based on current theories in theoretical physics.

Under al-Ma'mūn's patronage, and the spirit of openness and inclusiveness towards other religions and cultures that he fostered, many scholars from all over the empire gravitated towards Baghdad, drawn by a vibrant sense of optimism and freedom of expression that epitomized the mood of this golden age. The fusion of Greek rationalism and Islamic Mu'tazilism led to a humanist movement the like of which would not be seen again until fifteenth-century Italy. This attitude is best expressed by one famous Baghdadi scholar, al-Jāhith (*c.* 776-*c.* 869), who wrote in his famous *Book of Animals*:

> Our share of wisdom would have been much reduced, and our means of acquiring knowledge weakened, had the ancients [the Greeks] not preserved for us their wonderful wisdom, and their various ways of life, in writings which have revealed what was hidden from us and opened what

2

The Rise of Islam

The ink of the scholar is more sacred than the blood of the martyr.

The Prophet Muhammad

With the weakening of the Roman Empire at the beginning of the fifth century, Western Europe slipped rapidly into what is now known as the Dark Ages, from which it would not emerge for a thousand years. By the time of the fall of Rome itself, the centre of imperial power in Europe had long since moved eastwards to Constantinople, the capital of the Byzantine Empire. Its rule covered Anatolia, Greece, southern Italy, Sicily, Syria, Egypt and the North African coast, with an eastern border that ran roughly north-south between modern-day Iraq and Syria. The official language of the Byzantines was Greek, but they did not reach anywhere near the great intellectual heights of scholarship and learning achieved by the Greeks of Athens and Alexandria. And although there were Jewish settlements scattered throughout the empire, as well as many pagans, the official and dominant religion of the Byzantines was Christianity.

To its east, four centuries of Persian Sasanid rule produced an empire stretching from Iraq and Iran through to Central Asia. The Sasanids had come to power in the year 224 CE, under the leadership of Ardashīr I, when they defeated the Parthians. Their capital, Ctesiphon, lay on the banks of the Tigris river just a few miles south-east of present-day Baghdad. All that remains of this great city is the ruins of the imperial palace. With its famously huge archway, it is still a favourite tourist destination for Iraqis.

The middle of the sixth century marked the start of nearly a hundred years of long and costly wars between the Sasanians and Byzantines over the lands of Iraq

and Syria, with their mutual border in constant flux as they each advanced and retreated in a continuous and bloody dance. By the early seventh century these two once powerful empires were exhausted and had only themselves to blame for their humiliating defeats at the hands of the powerful and highly organized Muslim armies that rode north out of Arabia after the Prophet Muhammad's death in 63 2. First, the Byzantines were pushed out of Syria and Asia Minor, then the Sasanians were defeated and crushed.

Before the arrival of Islam, the only other sovereign power in the region lay in the far south-western corner of the Arabian peninsula, in Yemen, where several small kingdoms had ruled for more than two millennia before Islam, and whose power and wealth had come from their geographical location and exclusive trade access to both southern Asia and eastern Africa.

The rest of Arabia was inhabited mostly by nomadic Arab tribes. Long before the birth of Muhammad, however, these peoples were already beginning to develop a sense of cultural identity. Despite their wide range of different dialects, a common Arabic language had begun to develop, mainly through the reciting of poetry. The *qasīda*, or ode, was an important feature of the cultural life of Arabia, often telling of lost love or a tribal victory. These poems, which would be recited at festivals, feasts, in market towns or palace courts, came to be known collectively as *diwan al-Arab*, or 'the register of the Arabs', and became a way of preserving a maturing sense of Arab identity and communal history. [1] Most of them were not written down but memorized. However, some were preserved in the ancient Aramaic script. The Arabic script that was to be later used in the Qur'an still had some way to go before it would reach the level of maturity it has today, and its rules and grammatical nuances would take centuries to be established by scholars keen to remove any ambiguities of meaning from the Qur'an.

But not all Arabs belonged to nomadic tribes. Two great cities in western Arabia had been trading centres for hundreds of years before the arrival of Islam. Their names were Macoraba and Yathrib and they were destined to become the two holiest cities in Islam: Mecca and Medina.[2]

The city of Mecca lies in an arid and barren valley surrounded by imposing mountains. Its life force was the well of Zamzam, which provided the city's water.

For a century or so before Islam there had been a massive migration of population from southern to western Arabia (the region known as the Hijaz) and further north to Syria and Palestine. With its prime location along this trade route between Yemen in the south and the Mediterranean in the north, Mecca had grown rich and powerful, not only as a trade centre but as a financial one too.

More importantly, its role as a holy centre for the many pagan religions of the Arabians dating back to antiquity made it a safe haven for those wishing to escape the widespread violence that regularly broke out among the tribes in the region. Mecca housed many shrines and sanctuaries for the worship of several hundred different gods. A century before the birth of Islam one of the most powerful tribes in Arabia, the Quraysh, began to spread its influence in Mecca, both politically and commercially. And it was from one of the less influential clans within this tribe that a 40-year-old illiterate merchant named Muhammad announced in the year 610 that the angel Gabriel had appeared before him to reveal the word of God while he was meditating alone in a cave in Mount Hirā overlooking the city.

According to Islamic history, Muhammad was initially distressed at seeing the vision of an angel. When he came down from the mountain he was consoled by his wife Khadija and taken to speak to her Christian cousin, Waraqah ibn Nawfal, who immediately informed Muhammad that he had been chosen as a new prophet, for God had also sent the angel Gabriel down to Moses two thousand years earlier, and it was Gabriel who had told Mary that she would give birth to Jesus. Muhammad declared his mission, and his very first convert was Khadija herself, followed by members of his family and his close companions. Within a few years, during which he continued to receive revelations, Muhammad began preaching publicly, but he was soon met with open hostility from many of the inhabitants of Mecca. Despite this opposition and the slow start, his teachings marked the beginnings of the new religion of Islam that would soon grow rapidly and spread into one of the world's greatest spiritual, political and cultural forces.

The Arabic word for God, *Allāh*, comes etymologically from a contraction of the word *al-Ilāh*, meaning 'The God' and can be traced back to early Semitic writing. The definite article is included here to make the point that in Islam, in common with the other monotheistic religions of Christianity and Judaism, there is but one divine Creator. The message being spread by the Prophet Muhammad did not therefore go down too well with the pagan Arabs of Arabia, who worshipped a multitude of gods. For instance, of the three most powerful goddesses, al-Lāt,

Manāt and al-'Uzzā, the first of these was supposedly the daughter of another god, al-Lāh, the Lord God of Mecca. All these gods had sanctuaries in or near Mecca, including within the Ka'ba itself, which is of course now the most powerful and holy symbol of Islam and the destination of millions of Muslims for the *Hajj*. Indeed, pre-Islamic pagans would make pious visits to Mecca from all over Arabia, and even walk around the Ka'ba, giving offerings to their gods. Once his mission became clear, Muhammad would order all such shrines and sanctuaries destroyed, but the Ka'ba itself remains to this day, situated within the largest mosque in the world, al-Masjid al-Harām.

Arabic-speaking Christians and Jews also use the same word *Allāh* to mean God in their religions. Islam is of course a much younger religion, but at its heart it has much in common with Judaism and Christianity. This is not surprising given that all three originated in the same part of the world, and among the same race of people, who all claim to be the descendants of Abraham. Muhammad himself had of course interacted with many Christians and Jews while accompanying his uncle on regular trade trips to Syria.

In the early years, as support for Muhammad and his message grew – particularly within his close family, but also among many of the young men of Mecca, as well as traders, craftsmen and slaves – the leaders of the Quraysh turned against him. His call to them to abandon their polytheism and rituals was seen as an intolerable attack on their whole way of life. Circumstances changed when, in 619, Muhammad was devastated by the death of his wife and confidante, Khadija, followed shortly afterwards by the death of his uncle and lifelong guardian, Abū Tālib. Now he no longer had the support of these two powerful figures in his life, the Quraysh leaders stepped up their harassment of Muhammad and even took the decision to have him killed. And so, after twelve years of persecution, he decided to leave Mecca with his followers for the city of Yathrib, 200 miles north, from which he had received an invitation to act as an arbiter in another bitter tribal conflict.

The journey he took in 622 CE is called the *Hijra* ('Migration') and marks the beginning of the Islamic, or *Hijri*, calendar. Yathrib gradually became known as *Medinat al-Nabi* ('The City of the Prophet') or just Medina for short. There had been a number of conflicts between the two Arab tribes in Yathrib, Banū Aus and Banū Khazraj. The large Jewish community in the city was also split in its allegiance to one or other of the two sides. Unlike the Meccans, the exposure to monotheistic

Judaism, with its prophets and holy book, had made the Arabs of Yathrib far more receptive to Muhammad's message and teaching and they welcomed him, with relief, as someone people would listen to and who could bring peace and stability to their city.

Eventually, armed conflict broke out between the two cities of Mecca and Medina. Fighting continued for several years, culminating with the Meccans' failed siege of Medina and the famous battle of the Ditch (*ma'rakat al-Khandaq*). A ten-thousand-strong Arab and Jewish army (the latter an exiled tribe from Medina) had advanced on Medina in 627, but instead of the traditional military tactic of marching out to meet them in open combat, the much smaller Muslim army within Medina chose a different solution. One of the Prophet's closest generals, Salmān the Persian, proposed the digging of a deep trench around the weaker northern side of the city, a feat achieved in just six days. It proved successful and, combined with the strong fortifications around the other sides of Medina, it halted the advance of the Meccan army, who, after a two-week-long ineffective siege, eventually gave up and dispersed.

The Meccans finally realized that they would not be able to break the resolve of the growing Muslim army or halt the continuing spread of the message of the Prophet. In any case, the years of conflict were having a devastating effect on trade. Finally, the peace treaty of Hudaybiyya between the Quraysh of Mecca and the followers of Muhammad was signed in 628. Two years later Mecca itself surrendered to the army of the Prophet, who entered the city unopposed.

Throughout this time, Muhammad had continued to receive revelations, which he passed on to his followers. They, in turn, memorized them or wrote them down. After his death, they were collected in a series of 114 chapters, or *sūras*, in a book known universally as the Qur'an (meaning 'recitation'). Most scholars agree that the final version of the Qur'an was not agreed upon until the time of the third caliph, Uthmān, who ruled between 644 and 656. The word 'caliph' (*khalīfa* in Arabic) literally means 'successor' to the Prophet.

By the time of the Prophet's death in 632, Islam, which translates as 'submission [to the will of God]', had spread throughout the Arabian peninsula. But all was not well in this embryonic nation, for strong divisions surfaced within the Prophet's own family over the issue of succession. Uncertainties were quickly dismissed, however, when Abū Bakr, the Prophet's father-in-law, took on the mantle of the first of four caliphs known as *al-Rashidūn* ('The Rightly Guided Ones'). He quickly

his Umayyad predecessors and is probably best known today for the Dome of the Rock in Jerusalem, the oldest extant Islamic monument, which he built during the first years of his reign. The rock on which this holy shrine sits is still sacred to both Muslims and Jews today.

During the last decade of the seventh century he made the bold decision to establish a common currency for all his dominions. He created the first Islamic royal mint between 693 and 697, modelling the new coinage on those of the Greeks and Persians, but with Arabic Qur'anic inscriptions replacing the traditional images of kings. Abd al-Malik charged Muslim alchemists with experimenting with the best materials to use for the new coins, which were made mainly from gold, silver, copper and alloys of these and other metals.

Other than alchemy, the Umayyads showed little interest in the sciences. Apart from their passion for grand architectural projects, they were also not very interested in culture and learning, in part because of their preoccupation with securing and expanding their borders, and quelling the constant unrest within. And in stark contrast with the later Abbāsids, who relied heavily on the experience and knowledge of the sophisticated Persians to help them rule – a sharing of affairs of state that was to have crucial knock-on effects in initiating the golden age of science – the Umayyads excluded all non-Arabs from positions of power and influence, even if they were Muslim converts.[3]

So it was that, exactly one hundred years after the Arabs marched out of Arabia, they reached the furthest point in their expansion. In the famous battle of Tours in 732, the Muslim armies of the Umayyad dynasty, having conquered half of France, finally ran out of steam and were defeated by the Franks under Charles Martel. By this time the Islamic Empire covered an area larger in expanse than either the Roman Empire at its height or all the lands conquered and ruled by Alexander the Great. In fact, for the first time since Alexander, the lands of Egypt, the Fertile Crescent of the Middle East, Persia and India were reunited, allowing each to grow and prosper through mutual trade and relatively peaceful coexistence in ways that none had quite been able to do for a thousand years beset with wars, divisions and rivalry.

Despite their vast empire and great prosperity, the Umayyads lasted just ninety years and, towards the end of their dynasty, had to face increasingly difficult revolts and uprisings, particularly from the disaffected Shi'a based in the Iraqi city

of Kūfa. But the most serious of these began in the Persian region of Khurasan in the east, where a blend of Arab and Persian culture was catalysing the growth of a substantial religious and political movement claiming its right to power as descendants of the Prophet's uncle al-Abbās. Its army moved westwards and, in a series of bloody battles, finally defeated the Umayyad army in 750. Immediately, a new caliph, Abū al-Abbās, was declared in Kūfa. A descendant of the Prophet's uncle,[4] he became the first of a long line of Abbāsid caliphs that would last for a remarkable five hundred years.

Having defeated the Umayyads in battle, but concerned that they might attempt to seize power again, the ruthless Abū al-Abbās tricked all the members of the Umayyad family into attending a conciliatory dinner party where he instead had them killed. The only survivor, a young prince named Abd al-Rahmān, escaped to Spain, where the Umayyad dynasty would endure for a further three centuries.

After his victory over the Umayyads, Abū al-Abbās's reign was marked by efforts to consolidate and rebuild the caliphate, with a new government made up of Arabs, Persians, Christians and Jews. However, after his early promises, he turned his back on the Shi'a community who had supported him. He died of smallpox in 754, only four years after deposing the Umayyads. His brother al-Mansūr took over as caliph of this vast new empire, and its influence would reach far beyond its own limits.

Two and a half thousand miles to the west, Offa, son of Thingfrith, had been crowned the Christian King of Mercia (Middle England) in 757 and ruled for nearly forty years. Many historians regard him as the most powerful Anglo-Saxon king before Alfred the Great. In the 780s he extended his power over most of southern England. One of the most remarkable extant artefacts from King Offa's reign is a gold coin that is kept in the British Museum. On one side it carries the inscription OFFA REX (Offa the King). But, turn it over and you are in for a surprise, for in badly copied Arabic are the words *La Illaha Illa Allah* ('There is no god but Allah alone'). This coin is a copy of an Abbāsid dinar from the reign of al-Mansūr, dating to 773, and was most probably used by Anglo-Saxon traders. It would have been known even in Anglo-Saxon England that Islamic gold dinars were the most important coinage in the world at that time and Offa's coin looked enough like the original that it would have been readily accepted abroad.

Back in Kūfa, the Caliph al-Mansūr needed a new imperial capital and so set about looking for the best place to build it.

Like the city of Alexandria, founded a thousand years earlier by Alexander the Great, Baghdad grew from nothing to become the world's largest city just fifty years after the first brick was laid. And just like Alexandria, it became a centre for culture, scholarship and enlightenment that attracted the world's greatest minds. Before its foundation, the two largest urban conurbations in Iraq were the garrison cities of Kūfa and Basra, which had both been founded by the early caliphs during the long war with the Sasanians.

Al-Mansūr chose the exact site for his new city carefully. It is told that among the many people offering advice were several Christian monks he met in what is now central Iraq, who claimed that their ancient texts documented how a great king would one day build his new city on the site next to their monastery.[5] This happened to be a farm called *al-Mubāraka* ('the Blessed') and it suited the caliph perfectly, situated as it was on the west bank of the Tigris close to several thriving market villages.

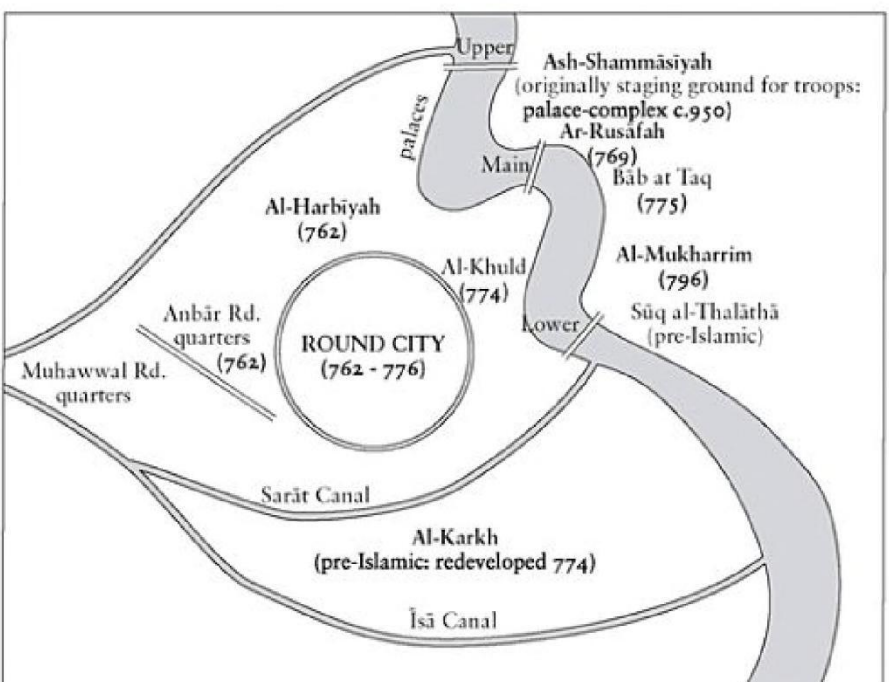
A ninth-century Persian historian by the name of al-Tabari (*c*. 839- 923), who wrote enormous compendiums of early Islamic history, describes in his *Annals of the Prophets and Kings* how al-Mansūr chose the site:

> He came to the area of the bridge and crossed at the present site of Qasr al-Salām. He then prayed the afternoon prayer. It was summer, and at the site of the palace there was then a priest's church. He spent the night there, and awoke the next morning having passed the sweetest and gentlest night on earth. He stayed, and everything he saw pleased him. He then said, 'This is the site on which I shall build. Things can arrive here by way of the Euphrates, Tigris, and a network of canals. Only a place like this will support the army and the general populace.' So he finalised the plans and assigned monies for its construction. [6]

Before laying his new city's foundations, al-Mansūr had asked three of his most respected astrologers to cast a horoscope for him. These wise men were an Arab, al-Fazāri, a Persian, Nawbakht, and a Jew, Mashā'allah, who between them agreed on the most favourable hour on the most favourable day for the first stone to be set in place: 30 July 762.

Four years in the building, the Round City was based on the plans of traditional

Roman military camps and designed with security uppermost in al-Mansūr's mind. It was surrounded by a double set of immense brick walls, the outer one about 6 miles in circumference, and then by a broad moat that was fed by the Tigris. Four gates pierced these fortifications, from which roads radiated to the far corners of the empire. The Khurasan Gate in the north-east was the gateway to Persia, while the Basra Gate in the south-east, the Kūfa Gate in the south-west and the Damascus Gate in the north-west each led to the city after which it was named. Each gate had also been carefully designed so as to secure the inner city against invasion, with a complex series of curved passageways, ramps and chambers. A large chamber was built high into each gate, roofed with a dome that was in turn crested, 100 feet up, by a grand weathervane.



Schematic map of early Abbāsid Baghdad showing the location of al-Mansūr's

original Round City on the west bank of the Tigris.

Within the city, roads ran from each gate to the centre, first through an outer ring of buildings that housed the caliph's family, staff and servants, then through an inner ring of buildings housing the arsenal, the treasury and the government, until they reached a grand, wide esplanade on which stood the headquarters of the palace guard, the mosque and the grand palace itself, known as *Qasr Bāb al-Thahab* (the Golden Door Palace).

Because of its surrounding fortifications and comparable size, one cannot help but compare al-Mansūr's Round City with the US-controlled Green Zone set up in 2003 after the fall of Saddam's regime, just a few miles down the river: a contrast that is both powerful and apt.

The Round City itself was not much more than an enormous palace-complex, which combined the caliph's residence with the administrative buildings of government. While it alone would have been equal in size to most other imperial cities in the world, it was very different from any other city, for the general populace all lived outside its walls. Its construction brought thousands of labourers and troops from far and wide to swell the population of the surrounding districts.

Long before Islam, huge markets had flourished on both banks of the Tigris to serve the villages and farming communities in the areas surrounding the Round City, which would soon be subsumed within the greater metropolis of Baghdad. To its south was the vast market district of al-Karkh (a name that was later used to mean the whole of the city of Baghdad on the west side of the Tigris) and, on the east bank, the bustling *Sūq al-Thalāthā'* ('Tuesday Market'). Soon after al-Mansūr had completed the Round City, al-Karkh in particular quickly became congested, struggling to meet the demands of the new influx of inhabitants, and so underwent extensive development, including the construction of new commercial facilities and the widening of the major roads. Other districts, such as al-Harbiyya north of the Round City, were newly built and quickly grew to rival al-Karkh in size and importance. The name *Harbiyya* derives from the word *Harb*, meaning 'war', for this district was originally the residence of the many thousands of troops who served the caliph.[7] Each one of these boroughs would have been large enough to require its own sprawling markets, wide avenues, mosques and municipal buildings.

what was familiar to the indigenous rural population, and was unlike anything ever seen before. It brought together a multicultural society of Muslim and Christian Arabs, Muslim converts from among other races in the indigenous population, as well as Jews, Sabians, Zoroastrians and pagans. The predominant way of life would not have been too different from that of the Persian Empire which the Muslims had conquered and which had ruled these lands for hundreds of years, but the new mix of mutually tolerant religions and cultures would have made for a fascinatingly colourful society.

Despite the Abbāsids' problems of consolidating power and their need to build coalitions with the Persians who had helped bring about their victory over the Umayyads, the first century of Abbāsid rule was a period of huge prosperity and impressive achievements. It had taken a new Islamic Empire to achieve the necessary unity between different peoples and cultures, but it was this empire's multicultural and multi-faith tolerance that fostered a real sense of expectancy and optimism, and this would usher in a golden age of enlightenment and intellectual progress.

Initially, emphasis among most Abbāsid men of learning was placed on the interpretation of the words in the Qur'an. After all, this was the very first book to be written in the Arabic language. Grammar, syntax, punctuation and calligraphy had all to be agreed and refined. But this in turn encouraged a certain devotion to scholarship that, once started, took on a life of its own. One cannot, therefore, understand Arabic science without considering the extent to which Islam influenced scientific and philosophical thought. Arabic science was, throughout its golden age, inextricably linked to religion. Clearly, the scientific revolution of the Abbāsids would not have taken place if it were not for Islam, in contrast to the spread of Christianity over the preceding centuries, which had nothing like the same effect in stimulating and encouraging original scientific thinking.

But the spread of Islam was not in itself sufficient to light the touch paper of scientific enquiry. There is no evidence of any original scientific activity taking place during the preceding Umayyad dynasty beyond the isolated efforts already being made by Jewish and Christian scholars in the region. It was, instead, a fresh cultural attitude towards scholarship, which the Abbāsids inherited from the Persians, coupled with the newfound wealth and power of the caliphs of the

expanding Islamic Empire that was to help foster an interest in academic enquiry lost since the glory days of Greek Alexandria. The age of Arabic science only began, however, once a quite separate period of almost frantic activity had built up a head of steam. This took place mostly in Baghdad and was known as the translation movement.

3

Translation

The significance of the Greco-Arabic Translation Movement lies in that it demonstrated for the first time in history that scientific and philosophical thought are international, not bound to a specific language or culture.

Dimitri Gutas, Greek Thought, Arab Culture

Why did the golden age of Arabic science that blossomed so suddenly during the reign of the early Abbāsid caliphs begin? And why did it eventually come to an end?

It is always assumed that the answer to the second question is the more difficult to articulate and certainly the more contentious, for there were many different contributing factors to the decline of the Islamic Empire, and the most important turn out not to be the most obvious. But that is for later in our story; for now, we shall explore the answer to the first question. At first glance it seems straightforward. The common view is that the exciting advances made in mathematics, astronomy, physics and engineering, the industrialization of chemistry, the great progress in medicine and the flourishing of philosophy that took place, first in Baghdad and then elsewhere in the Islamic Empire, all began thanks to the success of a spectacularly massive translation movement – a process that lasted for two centuries – during which much of the wisdom of the earlier civilizations of the Greeks, Persians and Indians was translated into Arabic. Then, once a culture of scholarship had taken hold within the Islamic Empire, it quickly became self-sustaining, leading to a grand synthesis of scientific knowledge that grew to far outstrip the sum of what had come before.

But while the Abbāsids did indeed sponsor and encourage a massive translation movement, which brought together essentially all world knowledge under one roof, this only pushes the enigma a stage further back. Why did the translation movement itself take place? Or, more to the point, what was it about the Abbāsid mindset – for the beginning of the translation movement does indeed coincide with the arrival on the scene of the Abbāsids – that differed from earlier civilizations in that part of the world, such as the Persian Sasanians, the Byzantines, and even the Muslim Umayyads of Damascus? Militarily powerful though these great empires were, none had shown any real intention of resuscitating the earlier glories of Alexandria that had flourished in the early centuries after the birth of Christianity.

With the arrival of the Abbāsids, all that suddenly changed. The translation movement began in the mid-eighth century, and before too long all levels of elite Abbāsid society in Baghdad were involved, for this was not simply the pet project of the caliph. A huge amount of money was laid out by a large number of wealthy patrons to subsidize and pay for this movement, and translation quickly became a lucrative business. The patrons supported the movement in part for the practical benefits it brought them in finance, agriculture, engineering projects and medicine, and in part because this patronage quickly turned into a de rigueur cultural activity that defined their standing in society. And everyone was involved. As one historian puts it: 'It was no eccentric whim or fashionable affectation of a few wealthy patrons seeking to invest in a philanthropic or self-aggrandising cause.'[1] The translation movement was not, therefore, a separate process that led on to a subsequent golden age of science. It should be seen instead as an integral early part of the golden age itself. Once it got going, it became part of a wider quest for knowledge. By the mid-ninth century it had evolved into a new tradition of original scientific and philosophical scholarship that further fuelled the demand for more translations, both in quantity and quality.

So why is this incredible Graeco-Arabic movement not a well-known chapter in world cultural history, alongside other similarly seismic events? Baghdad between the eighth and tenth centuries should be spoken of in the same breath as the golden age of Athens during the time of Pericles in the fifth century BCE, or Alexandria of the Ptolemies a few hundred years later, or Renaissance Florence of the Medici family in the fifteenth century. Even if the translation movement were

all we have to thank the Abbāsids for, this would and should still be regarded as a major epoch in history. But it was not all we have to thank them for; it marked just the beginning of the golden age. So before we explore exactly what was translated and by whom we have to look carefully at why it took place at all.

As with the reasons for the eventual decline of the golden age, it turns out that it owes its origins to a variety of factors, not all of them obvious. Many historians are now making compelling arguments for these and are belatedly overturning years of an over-simplistic historiographical view.

Let us first consider the three standard reasons usually held up as having enabled and brought about the translation movement.

The first is that it began on the whim of one or two enlightened caliphs, as might be deduced from al-Ma'mūn's famous dream about Aristotle, which instantly ignited within him a lifelong obsession with Greek scholarship. However, the translation movement began much earlier than the reign of al-Ma'mūn – under his great-grandfather and the founder of Baghdad, al-Mansūr – and was in full swing by the time al-Ma'mūn had his dream. In fact, if the dream story is true, it would have been entirely in keeping with the cultural atmosphere he was an integral part of. So one can more correctly say that the dream was the *result* of the translation movement and the intellectual climate that brought it about, rather than the other way round.

The funding of the movement came from right across Baghdad's society. Along with the caliphate, it included their courtiers, military leaders, officials of state, administrators, even the leading scholars who had become wealthy as they rose through the ranks as translators themselves. During al-Ma'mūn's reign the most famous of these scholars – men such as Hunayn ibn Ishāq – did not work in isolation, but employed teams of students, translators and scribes.

Without the patronage and encouragement of the caliphs themselves, the translation movement that blossomed and flourished in Baghdad simply would not have taken place on anything like the same scale. But the enthusiasm and commitment to scholarship of the early caliphs was just part of this wider intellectual movement.

A second reason for the start of the translation movement that is often heard is the spread of Islam itself; that since it is the religious duty of all Muslims to search

origin; others, such as many medical, mathematical and astronomical works, had been originally translated into Pahlavi from Greek and Indian and were in use in cities such as Gondēshāpūr (called Jundaysābūr in Arabic).[2] So the first and most important factor in bringing about the translation movement was this Abbāsid obsession with Persian culture. This was typified by one translator who, when asked why he searched for Persian books to translate into Arabic, is supposed to have replied: 'we [the Arabs] have all the words, but they [the Persians] have all the ideas.'[3] This need for translation was at the outset almost entirely for practical purposes; it had to be seen as useful and necessary.

This is where the second factor comes in: an obsession with astrology. Sasanian ideology, based on Zoroastrian myth, was very appealing to the Caliph al-Mansūr, who developed a deep personal interest in astrology. He also knew he needed the support of the influential Persian aristocracy, most of whom were still Zoroastrian and had not converted to Islam. His interest in astrology, therefore, while wholehearted and genuine, can also be seen to have a shrewd political motive. Astrology, as distinct from astronomy, was embedded in Persian culture and played a fundamental role in Persian daily life, in stark contrast to the Arabs, who saw it as being against the teachings of Islam with its links to fortune-telling and divination. But such was the influence of Sasanian culture on the Abbāsids that astrology underwent a revival in the second half of the eighth century. Astrologers were employed in the caliph's court to cast horoscopes, offer advice and glorify his achievements. We have already seen how al-Mansūr employed his three top astrologers to advise him on the right day to start building his new capital.

It is not surprising therefore that the first 'scientific' discipline to be systematically translated from Pahlavi into Arabic was astrology. One of the earliest texts was the hugely influential five-part astrological work of the prophet Zoroaster, *The Book of Nativities*, which was first translated into Arabic between 747 and 754.[4] Astrology, the art of plotting the positions of the stars for horoscopes, had become a perfectly acceptable branch of knowledge. Known as *'ilm al-nujūm* (the science of the stars), it was indistinguishable from mathematics and astronomy (*'ilm al-falak*) and those interested in astrological texts were keen to get hold of star charts and mathematical tables. So this early Abbāsid interest in astrology naturally led to the search for astronomical texts already available in

Pahlavi or still in Sanskrit, the language of the Indian mathematicians and astronomers.

Al-Fazāri, one of the astrologers who advised al-Mansūr, and the man credited with building the first astrolabe in the Muslim world, is also associated with translating several astronomical texts from Sanskrit into Arabic. It has even been claimed that he was the first to translate the *Siddhanta*, written by the greatest Indian mathematician and astronomer, Brahmagupta (598-668), into Arabic. This was arguably the very first time that the Abbāsids encountered Hindu astronomy, but the date and authorship of the translation are uncertain owing to confusion surrounding several contemporary scholars, all called al-Fazāri.[5]

The word *Siddhanta* is a Sanskrit term meaning 'The Doctrine' or 'The Tradition'. It was originally written, as was the tradition among Indian mathematicians, completely in verse. But frustratingly, Brahmagupta provided no proofs of the many mathematical theorems it contains. The Arabic translation of this text is known as the *Sindhind* and, along with Ptolemy's *Almagest* and Euclid's *Elements*, it was destined to have a huge influence on the scholars of Baghdad. It appears likely that the *Siddhanta* had originally been translated into Pahlavi, possibly in the Persian city of Gondēshāpūr, which had been a great centre of Sasanid scholarship. The book contained not only tables and star charts, but mathematics and crude trigonometry. However, it was notoriously obscure and difficult to follow.

There is a dubious apocryphal story which, if true, not only dates the translation of the *Sindhind* to the time of al-Mansūr but explains the reason for its lack of clarity. The story describes how Arabs first conquered then settled in the land of Sindh (today one of the provinces of Pakistan) in the early days of Islam. When the Abbāsids came to power these settlers seized the opportunity to declare themselves independent. But al-Mansūr would not tolerate this and sent an army to quell the uprising. After his victory, a delegation from the defeated Sindh came to Baghdad. In the party was an Indian sage named Kankah, who spoke no Arabic or Persian, and his speech, describing the wonders of Indian astronomy and mathematics had to be translated first into Persian by an interpreter, and then into Arabic by a second interpreter, a process which rendered the final form of his instruction very involved and abstruse. What he had been describing was Brahmagupta's *Siddhanta*.

Later Islamic scholars such as the polymath al-Bīrūni in the eleventh century dismiss this story as highly unlikely, claiming that a more likely scenario was that the *Sindhind* was a translation of a Persian version already in use in Gondēshāpūr. The only likely truth in the story is therefore that the *Siddhanta* did indeed pass through two translations on its way to the Arabs.

It is not until well into the ninth century that we see among Islamic scientists and philosophers an emerging confidence in a new rational and scientific world-view that led many to criticize astrology as not having a place alongside true sciences like mathematics and astronomy. Some, however, continued to dabble in it, including the mathematician al-Khwārizmi. Others, even centuries later, would recognize its importance in convincing their less-enlightened rulers to continue funding their astronomical projects. One such scholar was the Persian al-Tūsi, who had to feign an interest in astrology to persuade the Mongol ruler Hūlāgū Khān to fund his new observatory in Marāgha in north-west Persia in the mid-thirteenth century.

But back in the eighth century it was this early widespread obsession with astrology that helped ignite interest in translating the predominantly Greek works in the other sciences.

The third factor that played a role in establishing and accelerating the translation movement was the serendipity of emerging technologies. A knowledge of subjects like geometry was required for engineering projects [6] such as arched stone bridges, waterwheels and canals; accurate astronomical data were needed to predict the phases of the moon for timekeeping; and arithmetic was vital for accountancy. All these played an important role; but all would have been equally important to earlier civilizations and so do not explain the sudden acceleration in the volume of translations. However, it was the arrival of one technology in particular that made all the difference in the world.

The first paper mill in the Abbāsid Empire was built in the city of Samarkand in Central Asia on the silk route between China and the West. The city was already one of the greatest in the Persian Empire many centuries before the Islamic conquest and was to continue as a centre of learning and scholarship well into the Middle Ages. The Muslim army defeated the Chinese in 751 on the banks of the river Talas several hundred miles north-west of Samarkand in modern Kyrgyzstan. This Abbāsid victory marked not only the furthest expansion of the

Chinese Tang dynasty westwards but the furthest east into Asia that the Islamic Empire would venture. Pertinent to our story is that among the Chinese prisoners of war were those who had knowledge of papermaking – an invention of the Chinese in the second century CE – who were taken back to Samarkand. There, their knowledge was crucial in the building of the first paper mill, helped by the abundance of raw materials like flax and hemp crops in the region. The first paper mills in Baghdad began to appear in the last decade of the eighth century.

Parallel with this was a rise in technologies associated with the production of books: the development of dyes, inks, glues, leather and book-binding techniques,[7] all of which exploded on the scene within a very short time. Paper quickly became far cheaper as a writing material than papyrus and parchment, and multiple copies of texts would often be produced by a whole team of scribes working side by side.

Prior to this, the codex (in which sheets are bound together as books between covers, usually wooden) had replaced the scroll much earlier than the invention of paper itself. First used by the Romans and Hellenistic Greeks, codices were originally made of papyrus and parchment. In fact, it is claimed that during the Prophet Muhammad's lifetime, the pages of the Qur'an were kept as a codex between wooden boards.

So the translation movement owes its beginnings to the appeal of Persian culture, and astrology in particular, to the Abbāsids, along with the development of paper-making technology they had learned from the Chinese. But once it began, this obsession with translating ancient texts sparked the beginning of a golden age of scientific progress.

A sharp increase in the number of translations took place during the reign (786-809) of Harūn al-Rashīd. Medical, astronomical and mathematical texts began to be translated from Greek, Syriac, Persian and Indian. But at this relatively early stage, scholars were careful in their choice of manuscripts to translate. The importance of any scholarly scientific work is said to be measured by the extent to which it renders all earlier ones on the same subject superfluous. It was quickly realized that many Persian works on science were themselves translations from the original Greek. Soon those Greek originals were being sought. By this time, Islamic scholars and patrons of the translation movement had moved on from an

interest in purely practical subjects like astrology, medicine and agriculture to mathematics and astronomy. What is missing from this early list of disciplines is philosophy, as exemplified by the work of the two Greek giants: Plato and Aristotle. The later translation movement from Greek and Arabic into Latin *began* with philosophy because of a desire to understand these great works. But interest in this field among Islamic scholars came relatively late in Baghdad's translation movement and finally took off for a quite touching reason: Muslim scholars felt somewhat lacking in their reasoning and debating skills on matters of theology alongside their Christian and Jewish counterparts already familiar with Aristotle and Plato and therefore more experienced in such logical disputations.

It is interesting to note that while a number of significant Jewish philosophers and scientists made invaluable contributions to the intellectual culture of Baghdad, their work was almost entirely in Arabic rather than Hebrew. A good example lies with the work of Sahl Rabbān al-Tabari (*c.* 786-845), who came to Baghdad and is said to have made one of the first translations of Ptolemy's *Almagest* into Arabic. This Jewish astronomer and physician, whose name literally means 'the son of the rabbi of Tabaristan' – by reference to a province in northern Iran – settled in Baghdad during the time of al-Rashīd. His son, Ali (*c.* 838-70), who converted to Islam, wrote the first Arabic encyclopedia of medicine and would tutor a boy named Muhammad ibn Zakariyya al-Rāzi, who was destined to become one of the greatest clinicians who ever lived.

Some historians have claimed that despite the Abbāsids' admiration of all things Persian and, by association, their link to Indian science and culture in the East, the whole of the translation movement was built on what was originally Greek science. [8] To some extent this is true. The expansion of Alexander the Great's empire as far east as India, many centuries before Islam, carried the fruits of Greek science far beyond its home shores – although we should not forget the sea trade routes from Egypt as a separate avenue of transmission. This knowledge, one can argue, eventually made the circuitous journey from its Greek origins, via India, back to the palace courts of Abbāsid Baghdad. Much of Greek knowledge also reached the Arabic world through the great Christian cities of Antioch and Edessa where, to a lesser extent, a translation tradition from Greek to Syriac had flourished in the centuries before Islam's arrival.

Certainly in the fields of medicine and philosophy, where Hippocrates, Galen,

gained from this important text that led to the first observatories being built in the Islamic Empire, in Baghdad and Damascus during al-Ma'mūn's reign. He appointed astronomers, who began a systematic programme of careful observations to check the accuracy of Ptolemy's star charts. This marked the beginning of seven hundred years of Arabic astronomy and provided the bridge from the Greeks to the Copernican revolution in Europe and the birth of modern astronomy.

Many of the most important Greek texts were translated into Arabic several times. A good example is Euclid's *Elements*, which had a huge impact on Islamic mathematics. This was first translated by al-Hajjāj ibn Yūsuf during the reign of al-Rashīd at the beginning of the ninth century. The same man was later to produce a new translation for al-Ma'mūn. But the text was also translated by Hunayn ibn Ishāq, and his version was then revised by Thābit ibn Qurra. Finally, a further revision was made by the astronomer al-Tūsi almost four centuries later. The work probably first became known in Europe through Latin translations of this later version. It has even been claimed that the *Elements* was known to the Caliph al-Mansūr, who had heard of it from Christian priests and had requested a copy from the Byzantine emperor.[10] But the quality of any Arabic translation of the *Elements* made for al-Mansūr is debatable, as is its usefulness to any of the early Abbāsid mathematicians.

The translation movement finally came to an end in the second half of the tenth century, not because of a decline in or a loss of interest in scholarship but because it had naturally reached a stage when it was no longer required. All the great works had been translated, retranslated, studied and commented upon and were by this point being replaced by original Arabic works that took the sciences further. Indeed, some of the very greatest Greek texts, such as Ptolemy's *Almagest*, were no longer seen as 'state of the art' and had been superseded by more sophisticated astronomical works. By this time, the collective scientific enterprise was embedded in Baghdad's cultural atmosphere of scholarly patronage and competition.

The first great scientist of Islam, however, predates this period by a generation. His life and achievements are shrouded in mystery and controversy. He is known in the West as Geber the Alchemist.

4

The Lonely Alchemist

We may ask ourselves what men like Gauss or Faraday would have done if they had been born in the eighth or ninth century instead of being able to take advantage of another millennium of human effort.

George Sarton

Many of the great scientists of the golden age were not Arabs but Persian, even though they wrote all their work in Arabic, the official language of the empire. This is a source of considerable sensitivity to Iranians and other Central Asian Muslims, who understandably dislike their great heroes being mistaken for Arabs (particularly when the Arabic definite article 'al' is attached to their names). To stress to you how difficult it can sometimes be to disentangle the roots and origins of many of these men it might be useful for me to share with you my own somewhat blurred ethnic background.

The al-Khalīlis (Al-Khalilis)[1] are a Shi'a clan from the cities of Najaf and Kūfa in Iraq with strong Persian roots that go back over two hundred years. Around the end of the eighteenth century, my great-great-great-grandfather, Merza Khalil, a prominent physician from Tehran who had originally studied in the city of Qum to become an imam and after whom the Al-Khalili family is named, was on a pilgrimage to Mecca. His trip coincided with that of the Ottoman wali of Baghdad, the administrative ruler of a large chunk of today's Iraq, who fell ill. Khalil was called upon to treat him with the appropriate herbal remedies that he was an authority on. After recovering, the wali invited him back to Iraq to settle, which he did in 1799. Of his six sons, the eldest, Muhammad, remained in Iran to achieve even greater distinction in medicine than his father by becoming the personal

physician to the shah, Nasr al-Dīn Qajar (1831-96), earning him the title of *Fakhr al-Atibbā'* ('The Pride of Physicians'). Naturally, this is a source of great pride to the Al-Khalili clan, even today, for Shah Nasr al-Dīn was one of the greatest rulers in Persian history. A great reformist, he introduced in Iran the postal service, the rail system and newspaper publishing. On a visit to Britain in 1873, accompanied by my great-great-great-uncle Muhammad, the shah was appointed by Queen Victoria a Knight of the Order of the Garter, the highest English order of chivalry.

I am descended from two of Khalil's other sons, Bāqir on my grandfather's side and Merza Hussein on my grandmother's side. The latter, I always find fascinating to recount, was a spiritual leader of millions of Shi'a Muslims in Ottoman Iraq, Persia, Lebanon and India at the end of the nineteenth century. Based in the city of Najaf, he belonged to the group of *mujtahids* (clergy with the authority to interpret the Qur'an) and played an important role in the mobilization of public pressure across the Persian border against the excessive corruption and pro-Russian policies of the last of the Qajar rulers prior to Iran's constitutional revolution of 1905. After the death of the supreme leader Merza Shirazi in Najaf in 1895, Merza Hussein Al-Khalili became the absolute leader of the Shi'a clergy of Najaf. He was responsible for a number of public works, including the building of a canal between Kūfa and Najaf. By the beginning of the twentieth century this great-great-grandfather of mine was given the loftier title of Ayatollah.

I am thus in the fourth generation of Al-Khalilis to have been born in Iraq. Despite this, Saddam Hussein certainly did not regard the Al-Khalilis as true Iraqis, and many of my relatives were executed during the height of hostilities with Iran in the 1980s for having what were perceived to be divided loyalties. When my father came to Britain to study engineering in the 1950s and met my mother he became the first of the Al-Khalilis to marry outside the clan. It could therefore be argued on ethnic grounds that I have no Arab blood in me at all! Does any of this matter? My point is that while Arabs and Persians are technically different races (Semitic and Arian), the inhabitants of Iraq today are of such a racial mix – Arabs living alongside Assyrians, Kurds, Persians, Armenians and Turkomans – that it is rather pointless to try to lay claim to particular figures in history as belonging to any one race.

Baghdad was in fact the second capital of the Abbāsids. For a number of years before its foundation they had taken Kūfa, the city of my father's birth, as their capital. Today, Kūfa is no more than a suburb of the much larger city of Najaf. But