ALIENS

JIM AL-KHALILI OBE is a British physicist, author and broadcaster. He is currently Professor of Theoretical Physics and Chair in the Public Engagement in Science at the University of Surrey. As well as his research and writing, he has hosted many BBC TV and radio productions about science and was the 2016 winner of the inaugural Stephen Hawking medal for science communication.

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Science asks: Is Anyone Out There?

Edited by Jim Al-Khalili

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Introduction: Where is Everybody?

Jim Al-Khalili

Enrico Fermi, the Italian-born American Nobel Prize winning physicist, made some of the most important contributions to twentieth-century science, but in 1950 he posed a very simple question that had nothing to do with his research in nuclear physics. It did, however, have very profound implications for anyone who is interested in the question of extraterrestrial life, as I assume you are since you are reading this book.

The story goes that the question in question came up during a lunchtime chat he was having with colleagues at the Los Alamos National Laboratory in New Mexico, sometime home of the Manhattan Project. They had been discussing the possibility that the Earth had been visited by aliens in flying saucers. The conversation was light-hearted and it doesn't appear that any of the scientists at that particular gathering actually believed in aliens. But Fermi asked a very simple question: 'Where is everybody?'

His point was that since the age of the Universe is so great and its size so vast, with almost half a trillion stars in the Milky Way alone, many of which would have their own planetary systems, then unless the Earth is astonishingly and unjustifiably special the Universe should be seething with life, including intelligent species advanced enough to have the knowledge and technology necessary for space travel. Surely then, he argued, we should have been visited by aliens at some point in our history. Indeed, maybe

those accounts of flying saucer sightings that were being reported at the time were true. For Fermi it was obvious that, assuming our planet was not unique, not only should it be overwhelmingly likely that intelligent life exists elsewhere, but that there has been plenty of time for any alien civilisation with modest expansion ambitions and a sufficiently well-developed space travel technology to have colonised the entire Galaxy by now. So where are they all?

Fermi's conclusion was that the distances required for interstellar travel are so great that, owing to the theory of relativity's restriction that nothing can exceed the speed of light, no aliens would contemplate the ridiculously long journey to visit us. It seems he did not consider the notion that we should nevertheless be able to detect the existence of technologically advanced alien civilisations even if they never leave their home planet. After all, for the past hundred years or so, we have been announcing our presence to any listening aliens advanced enough and close enough to us (which means within 600 trillion miles of Earth, because that corresponds to 100 light years: the distance light will have travelled in 100 years). Ever since we invented radio and television, and more recently with the proliferation of satellite and mobile phone communication, we have been radiating our electromagnetic chatter into space. Any advanced enough aliens that are close enough to us and who happened to point their radio telescopes at our solar system would pick up faint signals betraying our presence.

Given that we have every reason to believe the laws of physics are the same everywhere in the Universe and that one of the easiest and most versatile means of transmitting information is by using electromagnetic waves, we should expect any advanced alien civilisation to use this form of communication at some point during its technological development. And if it has, then some of these waves will inevitably leak out into space, spreading radially outwards through the Universe at the speed of light.

It is not surprising, therefore, that by the second half of the

twentieth century, astronomers began to seriously consider the feasibility of listening out for such signals from space using their newly built radio telescopes. The search for extraterrestrial intelligence (or SETI) began with the pioneering efforts of one man, Frank Drake, who is probably most famous for coming up with a simple equation that bears his name and which includes all the factors he thought were necessary to provide an estimate of the likelihood that alien intelligence exists somewhere else in the Universe.

Today, SETI is the collective name for a number of projects around the world that have been conducted over the years to actively search for extraterrestrial signals. Following Frank Drake's initial projects, the SETI movement really took off, extending its search far beyond the solar system. The SETI Institute in California was set up in 1984 and several years later began Project Phoenix under the direction of astronomer Jill Tarter. Between 1995 and 2004, Project Phoenix used radio telescopes in Australia, the USA and Puerto Rico to look at hundreds of Sun-like stars within a couple of hundred light years of Earth. So far, they have heard nothing. But the project has produced a valuable source of information for research into possible alien life. Today, hunting for extrasolar planets (those orbiting stars other than our Sun) is one of the hottest areas of scientific research, and with bigger and more powerful radio telescopes at their disposal, astronomers are discovering new, potentially habitable star systems on a regular basis. Indeed, it seems that barely a month goes by without news of new Earth-like planets that have the potential to harbour life.

The announcement in 2015 that SETI will invest $100 million in the quest to discover intelligent life elsewhere in the Universe has captured the public's imagination around the world. The physicist Stephen Hawking spoke for many when he commented: 'It's time to commit to finding the answer, to search for life beyond Earth. It is important for us to know if we are alone in the dark.'

Other academic research, however, has in recent years focused

not on searching for radio signals sent by intelligent life forms, but for the planets and moons themselves that might host them. Closest to home, we have extended the search beyond Mars to the moons of Jupiter and Saturn. And then there are the extrasolar planets. Much excitement currently surrounds the James Webb Space Telescope, due to be launched in 2018, that will represent the next generation of space telescopes and will be the first that is truly capable of detecting the biosignatures of alien life.

Of course, an alien planet being suitable for life is one thing, but the really big unknown is this: given the right conditions, how likely is it that life could evolve elsewhere? To answer is that we need to understand how life began on Earth. If we are indeed alone in the vastness of the cosmos, then we need to understand why we are so special. Why would the Universe be apparently so finely tuned for life to exist, yet harbour it in just one isolated corner?

One way of thinking about this is to ask yourself how come *you* exist? What were the chances that your parents would meet and produce you? Indeed, what were the chances of their parents meeting, and so on all the way back? We are each of us the culmination of a long and highly unlikely chain of events leading back to the origin of life itself. Break any one of the links in that chain and you would not be here to ask the question in the first place. Maybe our existence is really no more remarkable than the lottery winner contemplating his or her good fortune: had that sequence of numbers not come up, then someone else would have won and they would also reflect on the improbable odds of their win.

What life on Earth can tell us about alien existence elsewhere in the Galaxy is limited by the fact that we have a statistical sample of just one. Our own example tells us nothing about the likelihood of life elsewhere, or what it would look like if it did exist. Could there be advanced alien civilisations out there or would they only be in the form of simple, single-celled microbes? If we can't begin to address that issue, how will we even know where to look?

Most profound of all of course is what it would mean for us if

we did find them? We've come a long way since the days of flying saucer sightings and scientists these days take the whole search for extraterrestrial life very seriously. In this book I've handpicked a quite remarkable team of scientists and thinkers, world leaders in their fields who will cover all aspects of the subject.

So before you plunge in, dear reader, allow me to introduce my 'Team Aliens'. You will find that each and every one of them offers his or her own unique perspective on the subject.

Leading us gently out on our cosmic journey is the Astronomer Royal, cosmologist Martin Rees, who in Chapter 1 speculates on our place in the Universe, giving a brief history of mankind's ideas on the subject and projecting forward into the distant future to consider whether one day we ourselves will be the 'aliens', exploring space and colonising the Galaxy.

In Chapter 2, astrobiologist Lewis Dartnell asks a question that Enrico Fermi may well have contemplated: if advanced space-faring aliens are out there, what would motivate them to visit us? He explores whether an alien invasion would be the end of mankind as we know it or a meeting of mutually curious peaceful civilisations.

In Chapter 3, science broadcaster Dallas Campbell gives an entertaining historical overview of our obsession with aliens and alien sightings ever since the celebrated Kenneth Arnold flying saucers case of 1947. If you want to get the *real* inside story on the possibility of alien life, it's worth getting the conspiracy theories and wackier mythology out of your system before moving on to the serious science – which you can easily do with Dallas's vivid account of Roswell, Area 51, the 'Men in Black', and alien abductions.

In Chapter 4, cognitive neuroscience and artificial intelligence expert, Anil Seth, explores how alien intelligence might differ from our own by studying the most alien intelligence we can find here on Earth: the octopus. As he says, there is no need to travel to a distant planet to encounter alien intelligence. You can find that

'otherworldliness' here on Earth by examining how the mind of an octopus works.

Chris French is a psychologist and professor of paranormal belief and experiences, and in particular the belief in conspiracy theories and false memories. In Chapter 5, he argues that there are millions of people around the world who believe that speculation on the existence of alien life is a waste of time – because there is already convincing evidence to show that aliens not only exist, but have already made contact with us. According to French, however, there are well-established psychological phenomena which may explain such 'close encounters'.

In Chapters 6, 7 and 8, we begin our quest in earnest. NASA astrobiologist Chris McKay begins, in Chapter 6, by asking what the ingredients for life elsewhere might be. In some ways, you might think the answer is obvious: surely all life needs energy – that's a given. But what about water? And what of the various elements, such as carbon and oxygen, and the molecular building blocks they would have to form? How vital are they and are we being imaginative when we think about the limits of life?

McKay hands over to space scientist Monica Grady and planetary geologist Louisa Preston as we head off into the solar system. Our first port of call is, naturally, our nearest neighbour, Mars. In Chapter 7, Grady rightly begins, 'In any book about aliens, there has to be a chapter about Mars'; she goes on to explore how Mars differs from Earth and whether there was a time, billions of years ago, when it might have been teeming with life – instead of the barren wasteland it appears to be today. In Chapter 8, Louisa Preston takes us to the outer planets of the solar system – the gas giants of Jupiter and Saturn in particular – and asks whether their giant moons – Europa, Enceladus and Titan – while possessing far more hostile environments than Earth, might in fact be home to *some* form of hardy microbial life.

Having explored what aliens might look like in reality, mathematician Ian Stewart introduces us to some of the more

imaginative manifestations of alien life. I have known Ian for many years and was aware of his great love of science fiction – he has a remarkable collection of over 8000 SF books – and so I invited him to explore aliens in science fiction writing in Chapter 9. From H. G. Wells and A. E. van Vogt to Arthur C. Clarke, Larry Niven, Stephen Baxter and, my personal favourite, Robert Heinlein, if you thought all fictional aliens were little green men with bug eyes and ray guns, then have a look at what these writers have dreamt up. Stewart also brings a sceptical eye to the scientific principles involved in inventing plausible aliens, and the extent to which SF writers have toed the line.

We are now well into our stride and come to one of the thorniest issues in the book. You see, in order to assess the likelihood of alien life somewhere else in the Universe, we really need to understand how special life is, and how and why it emerged on Earth. Chapters 10, 11 and 12 explore the science of life itself. First, chemist Andrea Sella takes us back to basics. Ultimately, all biology must boil down to chemistry, so are there chemical reactions that can drive a system towards complexity – from inanimate matter to something that is able to maintain a highly organised state? He then hands over to biochemist Nick Lane, who examines the origins of life on Earth in Chapter 11. If you thought it was simply a matter of mixing all the chemical ingredients together under the right conditions in some warm pond nearly 4 billion years ago, then you're way behind the times. Science may not have solved the mystery of the origin of life, but it has made great strides in recent years. Lane first defines what it means for something to be 'alive' and then explores some possible ways that chemistry might have become biology.

In Chapter 12, my long-time colleague and collaborator, molecular geneticist Johnjoe McFadden, adds a novel ingredient to the mix. He argues that the sheer improbability of life emerging spontaneously on Earth almost as soon as the conditions were right for it cannot be explained away so easily. He postulates that

quantum mechanics, that strangely counter-intuitive theory of the subatomic world, may have played a crucial role in speeding things up.

Theoretical physicist Paul Davies has written extensively on the question of whether life exists elsewhere in the Universe. Among his many activities he has the intriguing role of acting chairman of SETI's 'Post-Detection Science and Technology Task Group', whose job it is 'to be available to be called on at any time to advise and consult on questions stemming from the discovery of a putative signal of extraterrestrial intelligent origin'. I think this means he is the person who announces the news to the world if and when we discover aliens. In Chapter 13, he examines the likelihood of alien life from a broader cosmological perspective and ponders why so many distinguished scientists are convinced that life must exist beyond our planet.

This book is nothing if not balanced, and in Chapter 14, zoologist Matthew Cobb provides a sobering counter-argument to the optimism of the previous few chapters. He claims that the emergence of life on Earth, and complex multicellular (and intelligent) life in particular, was so incredibly unlikely that his answer to the Fermi question I posed at the beginning could be summed up as another question: Why should we even expect there to be anyone else?

In Chapter 15, geneticist and broadcaster Adam Rutherford explores the way film-makers have portrayed aliens in the movies. He takes us on an entertaining and rich digression through a century of cinema, from the brilliantly plausible to the just plain awful, the common thread being that almost all of them have given us a vision of aliens that are remarkably like us – which is almost certainly wrong.

Finally, we are ready to explore the vast expanse of space. The common theme of the next four chapters is that their authors, all world-class scientists, search for extraterrestrial life for a living. Astrobiologist Nathalie Cabrol is director of the Carl Sagan

Center and has been a leading SETI researcher for almost two decades. In Chapter 16, she gives us an insider's perspective on the search for extraterrestrials (past, present and future). Then, in Chapter 17, MIT astronomer Sara Seager reviews what will be possible with the new James Webb Space Telescope, and updates Drake's famous equation to give us a way of calculating the likelihood of alien life using some of the most recent advances in our understanding.

Chapter 18, by astrophysicist Giovanna Tinetti, describes how we are now able to use a technique known as spectroscopy, which can do more than just detect distant Earth-like exoplanets. In early 2016, she was one of the authors of a paper that reported the first direct identification and measurement of gases in the atmosphere of an exoplanet – one twice the size of Earth, orbiting a yellow dwarf star called Copernicus, 41 light years away in the constellation of Cancer. Discovering what the atmosphere of a distant planet is made up of is a fantastic way of looking for the telltale signs of life there. For example, if we find oxygen, water vapour, or complex organic compounds, then I for one would be very excited.

Last but most definitely not least, Chapter 19 is the contribution of the current director of SETI, the astronomer Seth Shostak, who stresses just how ingenious, creative and resourceful we will need to be in our search for life elsewhere.

All these essays, and the work of the pioneering scientists and writers that they are based on, reflect the fact that today, in the second decade of the twenty-first century, we are only just beginning our adventure, seeking answers to the most fundamental questions of existence: What is life? Are we unique? And what is our place in the Universe?

The search for aliens is a subject that has a reputation for being light-hearted, and even silly at times – beset with conspiracy theories and little green men – but, actually, thinking about extraterrestrials has led us to ask, and even begin to answer, some of the most profound questions about our own existence. What has

changed in recent years is that deep questions such as these are no longer just the preserve of theologians and philosophers – serious scientists have joined in too. What's more, we are actively doing something about it. This collection of essays will help you make up your own mind. I'm sure you'll enjoy them.

Stop press:
Oh, and before we begin our journey, I have to mention a recent exciting discovery. In a way, I guess it emphasises just how thrilling and fast-moving the field of astronomical research is at the moment.

At a distance of 4.25 light years from our solar system, Proxima Centauri is our closest stellar neighbour. It is a small, moderately active red dwarf star and, with a surface temperature of under 3,000 degrees Celsius, it is considerably cooler than our sun. On 24 August 2016, the European Southern Observatory announced the discovery of an Earth-sized planet, dubbed Proxima b, in a tight orbit around it – with an orbital radius just 5 per cent that of the earth's around the sun, making its year just eleven earth days long. What is exciting is that this rocky planet, with an estimated mass at least 1.3 times that of the Earth, would have a temperature estimated to be within the range where liquid water could exist on its surface, meaning that it sits in the habitable zone of its star.

Moreover, at just over four light years away, there is even hope that we might one day be able to visit Proxima b to check it out for ourselves. In fact, at the time of writing, a planned unmanned mission to Proxima, named Project Starshot, and which would involve a fleet of micro-spacecraft, powered by laser beams, is on the cards. Travelling at a fifth of the speed of light, these craft could reach Proxima b in twenty years and beam back information on whether there is life there. Who knows what we might find.

Jim Al-Khalili, *26 August, 2016*