Science and the Truthfulness of Beauty

How the Personal Perspective Discovers Creation

Robert Gilbert

Routledge Science and Religion Series

Science and the Truthfulness of Beauty

When scientists describe their results or insights as 'beautiful', are they using the term differently from when they use it of a landscape, music or another person?

Science and the Truthfulness of Beauty re-examines the way in which seeing beauty in the world plays the key role in scientific advances, and argues that the reliance on such a personal point of view is ultimately justified by belief that we are made in the 'image of God', as Christian and Jewish believers assert. It brings a fresh voice to the ongoing debate about faith and science, and suggests that scientists have as much explaining to do as believers when it comes to the ways they reach their conclusions.

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2018
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

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British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book has been requested

ISBN: 978-1-4724-7217-5 (hbk)
ISBN: 978-1-315-60777-1 (ebk)

Typeset in Bembo Std
by Swales & Willis Ltd, Exeter, UK

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Preface and acknowledgements

This book is based on my own experience as a research scientist, as a tutor and lecturer with significant administrative and pastoral responsibilities over the last ten and more years, and as a lifelong member of the Church of England and now Anglican priest. It is grounded in my working life, practically engaged as a professional scientist in a university setting, and also in my experience of parish life in different contexts: as a child, in Leicester from 1995 to 1998, and, since 1999, in three parishes in Oxford. I hope it is an honest account of how I have come to understand things, based on a rich variety of experience for which I am very grateful.

The thinking that has led to this book began while I was at school, and particularly during my sixth-form years. I am immensely lucky to have attended the King's School in Worcester, which has provided the most significant influence on my intellectual and professional development. The atmosphere of open and honest enquiry, in which we were taught by great personalities who were unafraid to express themselves in ways they found natural, has been of lasting and profound benefit. I wish in particular to acknowledge the influence of Bob Allum, Keith Bridges, Peter and Rosemary Diamond and Stephan le Marchand.

This book has also been influenced by some peak experiences that have turned my head and made me see things in new ways. Significant among them was a series of lectures on sacramental spirituality held in Durham while I was an undergraduate there and organised to celebrate the 900th anniversary of Durham Cathedral. I will never forget hearing George Steiner lecture on a comparison of the Gospel of John and Plato's *Symposium* (who could? The topic is too striking to be forgotten); or John Tavener give a kind of lecture-recital with the help of the cathedral choir. Sacramental spirituality lies at the heart of what I am trying to say, and I continue to benefit from some of the things I learnt from this initiative of David Brown and Ann Loades, and from things they themselves have said and written.

It will be clear that I am greatly indebted to a host of contemporary writers who have, for years, provided inspiration and opened my mind. It will also be clear who is the most significant of those writers. Alongside the encouragement I have received in this way, I have been greatly enabled by the kindness of

people who have helped me to 'realise' myself, among them Michael Piret, Andrew Davison and Peter Groves, who each invited me to give talks that happened to help me give shape to my thoughts, James Alison and Philip Kennedy, Helen de Cruz and Johan de Smedt, Paul Fiddes and Richard Parrish. The influence of friends made at Magdalen College in Oxford is obvious, especially Ralph Walker and Robin Dunbar, and most especially Angus Ritchie. This book is part of a conversation we have been having for many years now, and Angus has been very generous always in his particular encouragement. He also very kindly read the book prior to publication. I am, of course, grateful to all Magdalen's staff and students for the ways in which I have been able to make better sense of life by being part of their context since 2002.

A number of other friends have always been good at bringing me down to earth, and I would especially like to thank Robert Kealey, Howard Cattermole, Allen Young, Ed Horn and Diarmaid MacCulloch for their loyal friendship over many years. Diarmaid's particular influence is woven throughout this book, as a kind of leitmotif. Robert Kealey also was good enough to read the book and provide feedback. The thoughtfulness and friendship of Lucy Dunlop and Jennifer Lau are also greatly appreciated. But, while still keeping my feet on the ground, others have helped me better understand the things of heaven, and, among them, Timothy Radcliffe has been most important – profound thanks to him as well for his great and loving friendship.

But, above all, it is to my parents, my brother Toby and his wife Helen Keron with their children Noah and Sanna, my sister Holly and her husband (and my school friend) Roger Bowles, my sister Poppy and her late companion Adrian Sudbury that I am most grateful. Their love and support has been the most important thing in my life, whatever else has helped it take its shape. Getting ordained might be the best single thing I ever did, but, without them, I wouldn't exist. Without them, and most simply and obviously without my parents, none of the above would have been possible, and none of the experiences that provide the basis for the argument that follows could have taken place. So, it is with profound gratitude that this book is dedicated to my parents, Barry and Patricia Gilbert, and in loving memory of Adrian Sudbury.

Robert Gilbert
Sunday before Lent, 2017

1 Introduction

In the eye of the beholder

This book is grounded in personal experience and reflects an engagement with an ancient tradition of thought that Peter Brown, in his biography of Augustine of Hippo, summarises thus:

> 'Delight' is the only possible source of action, nothing else can move the will.[1]

My aim is to explore the different ways in which the human sense of the aesthetic empowers, guides, inspires, shapes and brings understanding to natural science. What do I mean by the aesthetic? What do I include in the arc of 'beauty'?

I think that, at its most basic, I would say that the beautiful is what pleases, or gladdens, human beings. The beautiful is whatever draws me in, fascinated; whatever engages my mind's attention and my body's ability. When we see something beautiful, there is a transfer of feeling and/or meaning between it and us.[2] You can see my definition is not a narrow one: it is as broad as you care to allow. Beauty is whatever causes delight in me – and it is delight that causes me to act.[3] I would like us to explore how delight in the world drives scientists.

The contemporary writer A.L. Kennedy provides an appealing starting point. Her BBC Radio 4 essay 'The power of art' (broadcast as part of the series *A Point of View*, on 25 January 2015) was a remarkable reflection on beauty and meaning.[4] Part of what makes it so appealing is the very beautiful way in which it was written (and spoken).

A.L. Kennedy begins and ends with a single rose petal, placed by her mother next to a bowl of rose petals, a petal that A.L. Kennedy tidied away into the bowl with the rest of the petals, before realising her error.

> I moved the petal, just to be neat, but then I heard my mother say – very quietly and as if she might be wrong – that she'd meant it to be where it was. And then I realised, of course I did, that at a time when my mother needed to be sustained, she had made something beautiful which pleased her and which she saw every day when she came in from work.[5]

The out-of-place, the deliberately left rose petal, can for someone be as much a thing of beauty as anything made through human skill or found in the world

around us, as much a thing of beauty as a rose window or the magnified image of a snowflake. This rose petal led A.L. Kennedy to reflect on the power of art to make sense of the world. Why should one rose petal matter when much in the world is tragic and wicked and where beautiful things are destroyed just because they can be? By contrast, why should one rose petal matter in a world in which many people live quite beautiful lives or perpetrate acts of outrageous generosity and kindness? The petal seems so little. And her answer is, that the rose petal matters because it is an example of *unnecessary* beauty, and that unnecessary beauties are statements of hope and of a belief in the meaningfulness of human life. She says: 'Even if all you can do for now is put a petal where you want it – that's a promise to your future and a light.'

A.L. Kennedy is not alone in making this point. In a recent book, *The Edge of Words*, the former Archbishop of Canterbury, Rowan Williams says something similar. We will focus on Dr Williams's detailed arguments later on, in Chapter 7, but, in his discussion of the power of silent communication between people, and made by people, he notes the meaningfulness of something like a single bowl or flower being *deliberately* (which is the point) placed in an empty room.[6] However dismissible by someone who wants to dismiss it, the *deliberate* placing of an object of beauty – or what, by the way, or with the intention, it is placed, *becomes* an object of beauty – communicates *meaning*.

Beauty, they say, is in the eye of the beholder; the perception of beauty is personal. So, how can it be reasonable to argue, as I want to here, that the sense that scientists have of the world as a place that is beautiful and that can be understood by acting in beautiful ways (for example, by doing experiments) is equivalent to other experiences of beauty we have in other parts of our lives? Especially as I then want to argue that this begs profound questions of the way in which science and scientists are often presented by themselves or others, because it reminds us that science is a far more subjective affair than many like to pretend. Ultimately, I will want to suggest that the role that the human estimation of beauty plays in objective scientific discoveries supports the claim that humanity is made in the image of God. But, if my argument relies on the idea that beauty is generalisable (like science is supposed to be generalisable, in its case seeking universal truth), when actually what you think beautiful is very personal, how can my argument be coherent?

In a sense, the fact that the experience of beauty is fundamentally subjective, is personal, is precisely my point. The personal nature of aesthetic sensibility implies that there will be a lot of different versions (to understate) of what is beautiful, of what is personally pleasing, of what seems gorgeous, harmonious, balanced, coherent, elegant or awesome. But, at the same time, there is a wonderful agreement, among some quite large groups of people, that certain things *are* beautiful. We collectively apply the idea of beauty to some very different phenomena – to the sublimities of a sunset and a mountainscape; to Bach's B minor Mass and the singing of Cilla Black; to a portrait by Rembrandt, 40,000-year-old cave paintings, tapestries by John Piper or the pattern on animal skin; to a mother and child by Henry Moore or a teapot with a crack in

it; to a poem by U.A. Fanthorpe and a novel by George Eliot; to a mathematical equation and a molecular structure; to another person and to a dog. You can argue that this makes the term far too broad for use in the way in which I am applying it. But, for myself, I think we know what we mean when we say something is beautiful, because it's something *we* say. Of course, we also qualify the term – it's a beautiful horse or a beautiful child, or a beautiful symphony or a beautiful proof – but it is (or they are), ultimately, beautiful. They all please us. They don't have to please everyone, but they please some of us, some of us agree – and the pleasure we have relates to something common to all human beings. The principle is, that we *can* be pleased, gladdened, thrilled, excited, overwhelmed, turned on, by beauty. What matters is that we can and do respond, and in common ways that characterise our response as *human*. The common ground on which we universally recognise beauty in our world and in each other is our humanity. We will return to this in Chapter 5.

It is easy also to point out that my use of terms such as 'beauty' here is rather slipshod. Aesthetics – a branch of philosophy that relates to the human appreciation of beauty – is a very large area of thought. I am not intending to try and address the whole field of aesthetics here – I couldn't, I don't have the space or the time or the ability. What I can do though is to address this one issue, why scientists can't stop talking about beauty and what that implies for them and for all of us, from my own particular position as a researcher, a teacher and a priest.

It has been asserted 'that beauty is an innate, hardwired response'[7] – although our wiring is not really *hard* at all, of course, but rather soft and wet and dynamic, and subject to constant modification. But, the idea that we are 'hardwired' in this way is supported by some common themes or ingredients in what is rated as beautiful by people around the world. The recognition of beauty might relate particularly to motion, to movement and dynamics,[8] as in dance (but this is only a very special example of the general point). The reason we find something beautiful can often also derive from the origin of an object or experience we find beautiful, what its principal characteristics are, and how it relates to its audience.

Aesthetics has traditionally – at least, since the eighteenth century – been concerned with two kinds of experience, the *beautiful* and the *sublime*.[9] Whereas the beautiful is something we marvel at, the sublime is something that awes us; whereas the beautiful is exquisite, the sublime is impressive; whereas the beautiful is elegant, the sublime is gargantuan. As explored by the philosopher and social historian Charles Taylor, the emergence of 'the sublime' as a philosophical category derives from an experience of the world become 'disenchanted' as humanity got an improved grip on what makes the world tick.[10] We lost a sense of 'intra-cosmic mystery' while gaining a sense of the universe as vast, ancient and minutely structured – and, in some sense, tragic. For one key writer, Thomas Burnet (who prefigured a Darwinian sense of the evolution of species), mountains were 'the ruins of a broken world'.[11] We marvel at the beauty of something but, presented with the sublime, we experience 'excess' – our senses are overwhelmed by 'the boundlessness of the heavens, or by high

mountains, vast oceans, trackless deserts'.[12] This induces fear: for Kepler, a '"secret and hidden horror". . .[at] infinite space, where 'we feel ourselves lost'; for Pascal a terror of 'the eternal silence of the infinite spaces'[13]. Derek Parfitt asserts that 'No question is more sublime than why there is a Universe: why there is anything rather than nothing'[14]: indeed, no question is more simultaneously perplexing, fascinating and to some extent terrifying, and in Chapter 6 we shall explore that question in more detail.

In his massive book *A Secular Age*, Taylor argues that a major shift in understanding has taken place over the last 500 years, from the experience of human nature as 'porous' – the self as porous to and continuous with the world around, and to/with other people – to an experience of what he calls the 'buffered' self, in which individual personalities are stuck inside their skulls: we are all psychologically atomic now. This shift has accompanied the loss of a sense of the world as enchanted, as containing spiritual powers and as being open to the powers of heaven, where humans existed in a kind of soup of meaningfulness. That sounds rude, but actually, losing a sense of personal porosity is, it seems to me, a *real* loss, because it has led us towards a sense of the individual as cut off from others, isolated, atomic. And, ironically, the loss of personal porosity and the appearance of the buffered self have been accompanied by a developing sense that the *world* is porous – open, possibly unlimited, indeterminate, random, continuous. Later, we will look at criticisms the gerontologist and philosopher Raymond Tallis makes of what he calls 'neuromania' and 'Darwinitis' in our understanding of human nature.[15] Tallis argues that we should instead see human nature as something we share, not something individuals possess; he is, I think, calling for a recovery of a sense of ourselves as porous beings, though from an atheistic standpoint, unlike Charles Taylor's. In the final chapter, we will note how the role of beauty in science draws us out of ourselves and frees us from the imprisonment our skulls impose on self-consciousness.

To some it will seem that, although the role played by the human appreciation of beauty in scientific discovery can be accepted – because it draws scientists to make the efforts we do, because we experience reward in the discoveries we make, and everything in between – the place of the *sublime* in this is hard to grasp. However, the sublime is no less a part of the human aesthetic response bound up with science than what you could call 'beauty (simple)'. Apart from anything else, science *finds* the beauty in the sublime – examples that spring to mind being the theory of general relativity, the discovery of quasars, and apparently intractable technical problems or challenges that many scientists face each day: What on earth do these data mean? How on earth am I supposed to solve that multidimensional problem?

What can terrify or give a sense of awe is revealed to be intricate and beautiful by the analyses of science. When you've solved the problem or made sense of the data, you can't see what was worrying you any more. General relativity is a response to our experience of the sublime in the immensity of the universe; quasars are something beautiful we have found because we were (or rather, Jocelyn Bell Burnell was) willing to stare into the abyss of the cosmos;

Frank Wilczek's exposition of quantum chromodynamics and of a possible single symmetry property space that could provide a theory of everything is an exercise in identifying the exquisite in the immense contrasts of time and space we find in the universe.[16]

Second, the reason why we are overwhelmed by our experience of the sublime is that we are very small, very fragile and very temporary human beings. God is obviously not overwhelmed by the scale of existence in the way that we are; God presumably finds the immensity and antiquity of the universe a thing of beauty and not (like Pascal) a source of fear.[17] Indeed, seeing the beauty of the world – including the beauty of what is sublime delineated by scientific analysis – is to see the world somewhat as God sees it. We might be overawed, but we can find beauty (simple) in scientific understanding.

Finally, science demythologises, de-terrorises the universe. Myth-making by our ancestors – and, where it occurs today, by us – is a way of responding to the terror we feel at the world because of its independence from *us*, our *dependence* on it and the complexity the world displays. Actually providing a proper scientific analysis defuses such myths – whether it's about why the river floods or why people suffer disablement – and de-terrorises the sublime to enable us to find the beauty within.

These points are made, too, by Charles Taylor, who argues that horror at the sublime is 'neutralized, by the disenchantment of the world and the development of a buffered self . . . Mountains and plains were harmonized, brought together in the single ordered space of maps, and scientific theory.'[18]

Like someone making sense of the human propensity to enjoy scary stories or horror movies – though in this case with respect to the writing of Edmund Burke and Immanuel Kant on the sublime – Taylor also here points out that it is our personal safety, frankly, that draws us to want to experience the sublime and be a little bit scared by it. And this experience also enables us to advance in other ways, developing our moral sense and giving the sublime a moral value, because it enables us to see ourselves in a different way, to see ourselves as fundamentally different from the world around us because we can experience it as beautiful and as sublime, because we can *think* about it, because we can be scared by what, in fact, does not and could not actually threaten us. Other animals, as far as we know, are not terrified by the eternal silence of infinite vacuum-filled space. Self-absorption is broken up by our experience of what is excessive, what we can't get our heads around, what is sublime. Our experience of the sublime has enabled us to imagine the infinity of God, and to discover an objective morality; it can make us less selfish, less anthropocentric, better people – but it also gives us the 'capacity for heroic affirmation of meaning', even when existence seems meaningless and futile.[19]

In some ways, the issue of the beautiful *and* the sublime lies at the heart of what I want to say. Ultimately, we do have a choice, there are alternative points of view, and I want to argue that a theistic view is far more strongly supported by the way in which scientific advances have grown from the human

capacity to find the world both beautiful and sublime than is an atheistic view. Thus, although '[a] vast and unfathomable universe, from which we have made a dark genesis, is obviously compatible with materialism', it simultaneously opens up a moral sense in us. It gives us:

> the sense of our deep nature, of a current running through all things, which also resonates in us; the experience of being opened up to something deeper and fuller by the contact with Nature; the sense of intra-cosmic mystery . . . Some people may even want to claim that we cannot make sense of [such moral meanings] within a totally materialist outlook; and some materialists agree, arguing that this is so much the worse for these moral meanings.[20]

In Chapter 7, we will explore the implications of moral facts and moral knowledge for our argument and our understanding of the point or goal of existence, in some detail. And, of course, art has, for tens of thousands of years, enabled people to explore the meaning *for them* of the sublimity of the world we experience[21] – a meaning that is individual and that ranges from stark and nihilistic materialism to a rich faith and the knowledge of God.

One thing that this implies is that humanity's aesthetic sense might be fundamental to the rise of modern science at all – that, as a matter of historical fact, we understand *now* because we were enchanted by the beauty of the world *then*. Our sense now of 'art' is quite a new kind of concept – when our ancestors fashioned sculptures or painted pictures or composed motets, they didn't think they were making objects of beauty per se, though of course they *were*. Instead, they were engaged in making sense of the world and of their place in it, in the way that they could, through devotion and ritual, through a sense of their origins and the meaning of existence. It's just that, incidentally, what they made is what we would categorise as 'art' and stick in a museum, often robbing it of its original context or purpose. In a sense, today we do something similar, but in reverse – we use art to express our feelings about the world, and to make sense of our lives, urgently, without resorting to religious belief. Our experience of what is beautiful, said Friedrich Schiller, gives us something we need: 'a spontaneous unity, a harmony of all our faculties . . . [as] form and content, will and desire, come of themselves together . . . [in] an integral fulfilment . . . in which we achieve full freedom'. Schiller introduces the term 'play', as a way of designating the ways in which we respond to beauty, and the freedom we find in that response. This free response is play, and for Schiller it sets the limits to our humanity.[22] To Johan Huizinga, too, play was central:[23] human beings are playful animals, as we will explore in Chapter 4. In our playfulness, using our freedom, we made sense of our world and our existence within it in ways we would now denote as art – but realised, maybe with a shock, that this gave us a way to understand the world, not just *for ourselves*, but *in itself*. In the fifteenth century, Nicholas of Cusa was making this argument:

> Since man has observed the order of the heavens, when they move, whither they proceed and with what measures, and what they produce, who could deny that man possesses as it were almost the same genius as the Author of the heavens? And who could deny that man could somehow make the heavens, could he only obtain the instruments and the heavenly material, since even now he makes them, though of a different material, but with a very similar order.

Not just for Nicholas of Cusa, but for Leonardo da Vinci, too, we have to make sense of things by two kinds of 'second creation': 'one in reason, which is science, and the second in imagination, which is art'.[24]

Science and art are humanity's twin agents of understanding. But the art came first and grounds the science.

Nicholas of Cusa is talking about modelling the world, about building analogies of things that (if we could just find the right material) would be the things themselves. Today, that is the hope of the field of research known as 'synthetic biology'. In our experience of the beautiful and of the sublime, they are things we seek to make sense of, to interpret, and in doing this we make use of metaphor and analogy. As one of my favourite aphorisms of Wittgenstein has it, in order to express why we find a piece of music meaningful (which is to say, in some sense or other, aesthetically pleasing) we can only compare 'it with something else which has the same rhythm (I mean the same pattern)'.[25]

Irving Massey speaks of two types of visual metaphor, which map on to the meanings of the *beautiful* and the *sublime*. Massey points out how, in one kind of metaphor – say when we comment that a branch of a tree looks like a bent arm – the arm 'presses through' the branch, the arm is the 'tenor' and the branch the 'vehicle' of the metaphor. 'In a sense we "see" not the branch but an arm'.[26] However, if we encounter a majestic waterfall, 'where the play of light on the masses of water at the foot of the fall suggests piles of glass plates', the waterfall is dominant and has sent us in search of a metaphor to express what we see – the waterfall is the tenor, the pile of plates is the vehicle.[27] It seems to me that metaphor 1 (the branch that is seen as a bent arm) is an example of seeing beauty in the world, whereas metaphor 2 (the experience of a waterfall expressed using 'a pile of glass plates') is an example of trying to make sense of a sublime experience. In metaphor 1, a beautiful idea emerges from the thing we see, the arm 'presses through' the branch; in metaphor 2, the experience of seeing the waterfall sends us scurrying for another image to make sense of it.[28] In terms of art, metaphor 1 might be the experience of an abstract sculpture, and of the aleatory – the accidental – in art (a de Kooning painting); metaphor 2 might be that of the internal cast of a house, or a bridge wrapped in cloth (as in the work of Christo). Metaphor 2 is the use of allegory to make sense of the immensity before us with a story that makes it digestible.[29]

But, talk of beauty in the context of art is, for experts, a deeply questionable activity. In his book *Playing to the Gallery*, the transvestite potter Grayson Perry points out that, although someone might exclaim of a large David Hockney

picture of trees[30] that it is 'beautiful', one needs to be very careful in what one says like this – if an expert[31] were to hear such language, 'there will be a sucking of teeth and a mournful shaking of heads . . . To judge a work on its aesthetic merit is to buy into some discredited, fusty hierarchy . . . It's loaded, this idea of beauty, because where does our idea of beauty come from?'.[32] Because, of course, what we find beautiful *is* conditioned by our backgrounds, our upbringing, our religion, our politics, is conditioned by everything we experience, as we have already admitted.[33] But then, in a sense, I repeat, that is my point – scientific training enables you to see the beauty of data, or a theory, or a model, or an experiment. You see the beauty and that helps you get at the truth: your beauty and mine are different, yet we share the same truth.

The idea of what is beautiful and what is sublime applies well to the work of David Hockney: a picture of his parents is beautiful; the large canvases of trees or abstract Californian landscapes are sublime. And, in front of a large painting – whether it's the Royal Academy's 1512 copy of *The Last Supper* by Leonardo da Vinci[34] or Hockney's very large paintings of trees from East Yorkshire – in front of something sublime or on the edge of the sublime, we can exclaim, 'It's so beautiful!', as a way of dealing with the sensory overload of what's before us. People do this with music too – when it gets too much, they gasp and, at the end of the performance, they shout out. 'We can make something a touch more beautiful just by the very act of exclaiming to a friend, "Wow, that is beautiful!"'.[35] But, we can exclaim at what is exquisite too, not just what overwhelms us. The exquisite can wound us, stabbing us with its beauty, because our experience of art is highly relational. Grayson Perry says, 'art can be lots of different things. It can (between you and me) be beautiful'.[36]

Perry also wants to point out how artists do not come from nowhere – they have to be *formed* – as of course is true of scientists also. There is a serious aspect of play in art – for some artists (maybe for all, I don't know), throughout their work. Apparently Picasso thought every child an artist. Perry takes from this the idea that:

> a child has an unselfconscious joy in creativity that is often lost as we get older. We're playing and painting and making things without a thought in the world and then as we get older we become aware of art history and that what we're doing might not be very good and so making things becomes harder and harder and harder . . . But when you're growing up, art is certainly serious play.[37]

He quotes a child's definition of a contemporary artist: 'They notice things'.[38] To quote Paul Klee, 'Art does not give us the visible again: it *makes* visible'.[39]

Science, too, is child's play as, again, we will discuss in Chapter 4 – and there is a close alignment to be found in the ways in which play relates to the life and work of artists and of scientists. Scientists and artists similarly do serious work with 'the carefree joy of a child'. In both cases, it is the job of the practitioner, of art or of science, to notice things that other people don't.[40] In both

cases, the case of the artist and that of the scientist, we are *making meaning*[41] out of what is before us. Yes, we are *finding* meaning, but we are certainly *making* it also, because to express ourselves (whether artistically or scientifically) is to *make meaning out of our data*, out of what is given to us. Scientists and artists are pilgrims on 'the road to meaning'.[42] As an artist, it is, for Grayson Perry, his duty 'to seek out and look for beauty'.[43] Jennifer Yane is quoted as saying that, 'Art is spirituality in drag'.[44] I wonder, if art is spirituality in drag, is science spirituality in overalls?

Making meaning is an exercise in world-making, and this is something we begin as children and continue throughout our lives. We classify what we find around us – and classification, as a start at world-making, at the making of meaning, at the construction of a conceptual understanding of who we are and how our world works, is a procedure common to artistic and scientific endeavours. But, the construction of meaning is profoundly analogical, about saying that *this* is like *that*; in Wittgenstein's terms, we say that *this* has that same pattern as *that*. In Nicholas of Cusa's terms, we discover an ability to *remake* the world. Children classify objects by similarity and relatedness from a young age using principles of analogy,[45] and so make a start at the building of the analogical universe that sees them through their days.

Analogy is actually fundamental to science, in some rather obvious ways. Mathematics is a symbolic form of analogy; any science involving visualisation includes analogy – representation of one thing in another form – as its most basic form of discovery and communication. Forging into new realms of understanding, new kinds of science, requires analogy as a way of navigating from systems of meaning we understand to systems we do not understand – for example (and we shall return to such things in Chapters 2 and 3), the use of tools by crows – something we understand by analogy to our own way of life.

The anthropologist Nelson Goodman, in his book *Ways of Worldmaking*, seeks to explore the ways in which subjective meaning/sense and objective perspective are woven together in the getting and application of all kinds of human knowledge and understanding, 'scientific' or otherwise: 'the line between artistic and scientific judgement does not coincide with the line between subjective and objective'.[46] Thus, to imagine that science is in some sense only bothered with objective statements about facts that have to their credit adequate experimental support and a lack of refutation is to ignore:

> the analog instruments often used, the metaphor involved in measurement when a numerical scheme is applied in a new realm, and the talk in current physics and astronomy of charm and strangeness and black holes. Even if the ultimate product of science, unlike that of art, is a literal, verbal or mathematical denotational theory, science and art proceed on much the same way with their searching and their building.[47]

A fruitful analogy, in science, can prove extraordinarily powerful: yes, the black hole, but also the selfish gene, the red queen, the viral self, the flavour

of a cell surface receptor protein, and the wiring of the brain.[48] In science, we also choose our perspective, our level of description, and, to publish in the top journals (in biology, at least), you must come up with a neat model, expressible in cartoon form, that encapsulates (except, presumably, it doesn't exactly capture) the impact of your finding:

> where truth is too finicky, too uneven, or does not fit comfortably with other principles, we may choose the nearest amenable and illuminating lie. Most scientific laws are of this sort: not assiduous reports of detailed data but sweeping Procrustean simplifications.[49]

I'm not sure what other grounds scientists have for such judgement than aesthetic ones – and the alternatives (e.g. wilful ignoring of facts) should be less attractive. Goodman argues that we do not need to understand why this works – for it does – and that the obvious fact that there are messy truths and neat falsehoods just shows our tests are corroborative rather than conclusive – a splendidly acceptable scientific view: 'truths' are just what our tests test, just what the experiments we design are capable of showing us.[50] I guess many of my colleagues would agree that we do not need to ask why analogy built on our sense of beauty and our experience of the sublime works as a way of understanding the way the world really is in itself, but I want to argue that we are missing a trick if we do not try and ask exactly this question, as I hope to show in the rest of this book. Indeed, the role of aesthetics in science raises the question more sharply, as it relates to the ways in which scientists stop operating on the basis that 'truths' are just what our tests test and start thinking that truths are what they are finding, ready-made as it were. In other words, scientists will claim what others might call a 'coherence theory of truth' (truths are what we test), but work, because of the beauty they recognise in their data, with a correspondence theory of truth (we see and describe what is really there; we will discuss this point further in Chapters 6 and 7).

I think there is something irreducible, something singular, about the human experience of beauty; it is packed with meaning and significance, however personal it might be. I think we see this played out very clearly in the successes of modern science. I don't need to be told that what we find beautiful is somehow a product of our background and culture and experience; nor do I find this fact somehow unpalatable. Of course, the things that I find particularly attractive are bound up with my personal history, my sexuality, my gender, my education, my class, my opportunities, my experience, my self. But that doesn't stop what I find beautiful not only attracting me but also helping me to understand things that are true and things that are good. A neuroscientist can explain that certain neurons are tickled by certain features in a painting, or that certain neurons resonate with certain intervals between musical tones, but that doesn't detract from the meaning of a painting or the beauty of a melody. You can provide a neurological explanation of what Macbeth is doing when he holds a dagger before his eyes, but this is, frankly, silly if it is intended to

somehow deconstruct the significance, the meaning and – in a terrible kind of way – the beauty of Shakespeare's play.[51] You really don't need to be a neuroscientist to understand that certain bits of the brain will be involved in holding a dagger up and speaking about it, and you don't need to use a scene from a Shakespeare play to make the point: 'using a Shakespeare play to illustrate this process does nothing for either Shakespeare or neurology'.[52] Indeed, the fact that the same words could presumably have been spoken by a historical Macbeth and also are spoken by actors on stage (different actors, in different ways) helps to make this point.

Music is one especially communicable form of beauty: humans need to know nothing about a piece of music – whether the instruments on which it is played, the composer who wrote it, or the era it came from – in order to find a melody beautiful. Of course, as with everything, from sex to science, our tastes can be and are trained, both deliberately and accidentally, via our experiences; but still, a novel melody can be heard and distract us with its beauty, and that's all that needs to be said, in a sense. In Chapter 3, we will look at the thinking of Frank Wilczek, a Nobel Prize winner in Physics, on the relationship of beauty and truth in science and life. Wilczek's recent book, *A Beautiful Question*, aims to explore the mathematical beauty of fundamental physics (quantum (chromo)dynamics and general and special relativity). He uses the example of music to explore his beautiful questions for, I think, two reasons: because he thinks music is beautiful, and because the mathematics that underlie pleasing harmony also underlie the atomic physics he has spent his adult life defining. This highlights the mathematical edge to our appreciation of beauty. Our appreciation of mathematical beauty is also exemplified in the 'golden ratio' of rectangle edges of 1.618:1, beloved of the Greeks, which is also the ratio between adjacent numbers in a Fibonacci progression – the Fibonacci progression that also determines the shape of the spiral shell of a nautilus (an equiangular spiral) and the patterns of growth of some plants.[53] Whether this is surprising or not, it is the case. It just highlights that it's not just mathematicians who find mathematical relationships beautiful; subconsciously, so do we all.

In a radio interview with Michael Berkeley, Frank Wilczek was asked to what extent the writing of his book had made him 'think about the presence or lack of presence of a grand design, of indeed a God'.[54] Wilczek replied:

> Well, I let the world speak for itself, that's my goal in the book, but its subtitle is *Finding Nature's Deep Design* because when the world speaks for itself you find an extraordinarily tight, conceptual, beautiful structure underneath. And it's not inconsistent [he laughs] with ideas about transcendence or spirituality but it certainly doesn't force them either, doesn't agree in detail with any received body of dogma that I've encountered. But for me this has been a real voyage of discovery to get in touch with those questions again and which I hadn't really thought about since my teenage years . . .

> I say in the book, *Blessed are those who believe what they see*, and that's my attitude. Just believing what you find, engaging with the natural world, is an engagement with deep beauty and surprises and strangeness that has some of the elements of religious experience. I engage with the world as it is and I find what I find and it's beautiful and it's wonderful but does not match any existing dogma but to me gives some of the experience which was very meaningful to me as a child in religion.

Wilczek's subtitle underlines the point of his book, which is to explore the *deep* harmony and coherence that physics reveals in the world and the ways in which it echoes more everyday experiences of beauty. His aim is to identify links between the two and to use them to help us see how very beautiful atomic and cosmic physics is, and how it has validated and continues to validate the physical scientist's and the mathematician's conviction that beauty is a guide to truth. He wants us to note, again and again, how the Ideal turns out to be Real, and how reality embodies idealised relationships.

Closer to my own scientific specialism, the developmental biologist Bassem Hassan has written in terms of absolute clarity (and in the world's leading biological scientific journal) of the ways in which his own evolution as a scientist and the work he has chosen to be engaged in have been driven by his appreciation of beauty. Scientists, he admits, have the 'interminable child-like' curiosity we will explore in Chapter 4, and, in genetics, there is an aesthetic elegance, which reveals how his earlier love for poetry can continue to be celebrated in his exploration of scientific understanding. He says: 'the hatred of war and the pursuit of beauty remain with me as major sources of inspiration . . . I find it extremely difficult to take on a project if I am not esthetically moved by it.' And later, 'There is poetry in biology in both its form and content, and the pursuit of that beauty is both rigorously rational and emotionally uplifting.'[55]

The subtitle for this book is *How the personal perspective discovers creation*. I want to end this introductory chapter by unpacking that slightly. My idea is to explore the ways in which scientists must operate as people – as persons – in order to make discoveries and tell us about the world. My idea is to look at the fundamentally subjective basis for much of scientific activity – and possibly for any scientific activity that is at all interesting. We look for what we reckon would be ideal and, too often for comfort, find the real. When I use the word 'discovers' I use it in the sense that scientists are exploratory discoverers, seeking new understanding, but also in the sense that scientists unveil aspects of what is true about the world in their work (they uncover reality), and necessarily therefore also unveil truth by the way in which they express their work, whether in words, mathematical notation or diagrams. And when I use the word 'creation', I am not just using it as a poetic reference to the world around us, but to mean that, in their work, scientists actually reveal the world to be created, by a creator, if they did but know it.

But, the approach I am taking is *not* one in which I am going to try and argue that *facts* that science offers us about the world imply that it is created,

and that there is a creator. That is an approach that others have taken, but it is not the principal angle I wish to adopt. Instead, what I want to argue is that the success of the ways in which scientists actually work remains unjustified without an understanding of ourselves as created in the image of God. That probably sounds very far-fetched at this stage, but I hope to have justified the argument (though I accept I can't prove it) by the end.

So, to close this first chapter, a quote from Irving Massey:

> To the best of my understanding, the body of fact available to, or produced by, the scientist is not in itself like an art object, which invites contemplation, identification, or appreciation for its own sake and in its own right. The same body of information may yield different theories to different scientists, or to the same scientist at different times, but one does not initially immerse oneself in it for its own sake.[56]

I take a different position, however, because I think that the scientist *does* immerse herself or himself in what is studied, and does contemplate it, and does identify with it, and does appreciate it for its own sake and in its own right. This is what we will explore in Chapter 3.

But first, in Chapter 2, I wish to take a tour of the different ways in which scientists actually work.

Notes

1 Peter Brown, *Augustine of Hippo* (University of California Press, 2000 edn), p. 148, 'therefore, a man can act only if he can mobilize his feelings, only if he is "affected" by an object of delight'.
2 'There is an automatic transfer of feeling from object to subject – we feel what we see. In a sense, we are never entirely ourselves – we are our percepts.' Irving Massey, *The Neural Imagination* (University of Texas Press, 2009), p. 36.
3 Of course, such delight, like any desire, can be perverted.
4 www.bbc.co.uk/news/magazine-30939668, audio version available at www.bbc.co.uk/programmes/b04yk3w3
5 A.L. Kennedy, *The Power of Art*, www.bbc.co.uk/news/magazine-30939668
6 Rowan Williams, *The Edge of Words* (Bloomsbury, 2014), p. 168.
7 Irving Massey, *The Neural Imagination*, p. 3, quoting Jamie Ward.
8 '. . . following the now widespread assumption in psychology that consciousness is largely concerned with phenomena involving motion', Massey, *The Neural Imagination*, p. 15. On this and the next point, see pp. 14–15.
9 As framed by Immanuel Kant. See the online Stanford Encyclopedia of Philosophy for an extensive discussion: https://plato.stanford.edu/entries/kant-aesthetics/
10 Charles Taylor, *A Secular Age* (Belknap Press of Harvard University Press, 2007), pp. 327, 331.
11 Taylor, *A Secular Age*, p. 333.
12 Taylor, *A Secular Age*, pp. 334-335.
13 Taylor *A Secular Age*, p. 337.
14 Derek Parfitt, *London Review of Books*, 22 January 1998. He cautions: 'Nor should we assume that answers to this question must be causal.'

15 Raymond Tallis, *Aping Mankind* (Acumen, 2011). See, for example, pp. 11–12.
16 Frank Wilczek, *A Beautiful Question* (Allen Lane, 2015).
17 I realise that assigning sensations such as 'fear' to God is ludicrous, but it helps me to make my point.
18 Taylor, *A Secular Age*, p. 337
19 Taylor, *A Secular Age*, pp. 338–43 and p. 359.
20 Taylor, *A Secular Age*, p. 350
21 Taylor, *A Secular Age*, p. 351
22 On the points made here see Taylor, *A Secular Age*, pp. 354–9. Indeed, via Schiller and with Friedrich Nietzsche, the aesthetic (beauty *and* the sublime) becomes 'an ethical category . . . a source of answers to the question, how should we live? what is our greatest goal or fulfilment? . . . Beauty is what will save us, complete us. This can be found outside us, in nature, or in the grandeur of the cosmos' (pp. 358–9). For such an analysis, the idea that science rests on aesthetic response is a matter of historical fact.
23 Johan Huizinga, *Homo Ludens* (Beacon Press, 1955).
24 Taylor, *A Secular Age*, p. 99, including the quotation above from Nicholas of Cusa.
25 Ludwig Wittgenstein, *Philosophical Investigations* (Blackwell, 1967 edn), § 527.
26 Irving Massey, 'Two types of visual metaphor', in *Criticism 19*, 285–95 (1977), p. 286.
27 Massey, 'Two types of visual metaphor', p. 287.
28 However, if a heroic man is said to be lion-like, the man is the tenor, which might argue that metaphor 2 is not limited to the sublime – unless men are sublime, which maybe they are; Massey, 'Two types of visual metaphor', pp. 288–9.
29 Massey, 'Two types of visual metaphor', pp. 289–91.
30 I have the postcard in front of me as I write: *Three Trees near Thixendale, Winter 2007*, which covers eight canvases and a whole wall, as shown at the Royal Academy exhibition, 'David Hockey RA: A Bigger Picture', in 2012.
31 A 'pope of art' – Grayson Perry, *Playing to the Gallery* (Particular Books, 2014), p. 29.
32 Grayson Perry, *Playing to the Gallery*, p. 14, the argument continuing to p. 15.
33 'Perhaps art is ultimately all about the personal experience, the action you have to it, the reaction I have to it' – p. 73.
34 Which, from 1993 to 2017, hung in the Antechapel of Magdalen College, Oxford.
35 Grayson Perry, *Playing to the Gallery*, p. 14.
36 Grayson Perry, *Playing to the Gallery*, pp. 94–5.
37 Grayson Perry, *Playing to the Gallery*, pp. 109–10. Perry has this glorious analogy: 'The sound a box of Lego makes is the noise of a child's mind working, looking for the right piece. Shake it, and it's almost creativity in aural form' (p. 116). Building with Lego can make you an artist, an architect, an engineer or (in my case) a biochemist.
38 Grayson Perry, *Playing to the Gallery*, p. 116.
39 Irving Massey, *The Neural Imagination*, p. 34.
40 Grayson Perry, *Playing to the Gallery*, p. 127.
41 'Because of course art's primary role . . . is to make meaning', Grayson Perry, *Playing to the Gallery*, p. 111.
42 Grayson Perry, *Playing to the Gallery*, p. 125.
43 Grayson Perry, *Playing to the Gallery*, p. 133.
44 Grayson Perry, *Playing to the Gallery*, p. 129.
45 Robin Dunbar, *The Trouble with Science* (Faber & Faber, 1995), pp. 68–9.
46 Nelson Goodman, *Ways of Worldmaking* (Hackett, 1978), p. 140. Of course, just because we are engaged in ways of world-making does not mean that the worlds we make do not relate clearly and directly to the way the world really is. Being 'square'

is not just a feature we all agree on, it is a real aspect of reality, some things are (what we would call) 'square'. We do not have complete freedom in how we choose to make sense of the world – of course, because we must allow for the data. See Ralph Walker, *The Coherence Theory of Truth* (Routledge, 1989), pp. 118–20 and 147–66.

47 Nelson Goodman, *Ways of Worldmaking*, p. 107.

48 And we need to be careful in our use of analogies that we don't forget that that is what they are and start to imagine they are the thing we are studying itself. This is arguably the problem with the idea of a 'selfish gene' and of the brain's 'wiring'.

49 Nelson Goodman, *Ways of Worldmaking*, p. 121.

50 Nelson Goodman, *Ways of Worldmaking*, p. 122.

51 Irving Massey, *The Neural Imagination*, p. 16.

52 Irving Massey, *The Neural Imagination*, pp. 84–5.

53 D'Arcy Thompson, *On Growth and Form*, abridged edition edited by John Tyler Bonner (Cambridge University Press, 1961; Canto edn, 1992), pp. 172–201.

54 *Private Passions*, presented by Michael Berkeley. Broadcast on 27 September 2015, www.bbc.co.uk/programmes/b06db6tx

55 Bassem A. Hassan, 'The I in scientist', in *Cell 166*, 790–3 (2016).

56 Irving Massey, *The Neural Imagination*, p. 28.

2 Two different ways of knowing?

Scientific understanding is often thought of as purely objective, the result of hard facts. In one way, it is. Yet, you will often hear scientists speak about the 'beauty' in their data, or the 'beauty' of a result, and appreciating beauty is, as we acknowledged in Chapter 1, in the eye of the beholder. Given their commitment to the truth, if a scientist talks about beauty in their data, then we should listen to them. But, this might suggest that scientists operate in two completely different ways – in an objective mode that governs the actual discoveries they make and in a subjective mode by which they appreciate them. Alternatively, it might mean that there is something objective in a subjective viewpoint looking for the beautiful. This book will argue that, indeed, searching for what is beautiful puts us more closely in touch with reality.

How scientists see their work

Practising scientists tend to think of themselves as searching out objective truth. Science seeks to cut through confusion and wishful thinking to a dispassionate understanding of what's what, and the *detail* of the scientist's knowledge of the world seems to give the insights they have into the way it works a special status. In my experience, practising scientists also have a strong sense of the *rightness* of what they do, the *morality* of their activity. Maybe that seems perfectly reasonable. After all, science gives us experimentally validated, or empirical, facts that we can apply in new technologies and medicines, which make a practical difference to the world. On the other hand, individual scientists can take themselves and their work too seriously, and it can seem to be more about career success than the search for truth.

Science is a culture, and within that culture there are certain ways of doing things – certain rules that should be followed. For example, if you form a hypothesis, you must test it honestly by experiment, and, if the experiment proves your hypothesis to be wrong, then you must rework the hypothesis or reject it. When you conduct experiments, you must include a control, and preferably at least two: one sample that is guaranteed to give a positive result and another guaranteed to give a negative result. If you collect data, then you must collect enough to perform a standard statistical analysis so that you can detect

whether any trends you observe are significant or not against the 'background', the 'noise' in the data. You must be totally committed to the search for truths about reality; you must be willing to let the world be itself and not impose your theories on it. Rather, you must allow the world to *correct* and *shape* your theories. You must allow the data to speak for themselves.

The scientific ideal is that, if these rules *are* followed, then you are being a good scientist. What I have provided is, however, a technical and practical description of what scientists *do*, a description that could be equally well applied to any scientist, as well to an engineer as to a biochemist. And the fact is that all scientists do follow rules in this kind of way, and that science does very well out of it. But there are three very odd things about a view of science at this level alone. First, obeying the same rules again and again is not going to produce the paradigm shifts and sudden clarifications of understanding that push science forward – the ones that get recognised as the great breakthroughs, the discoveries that get you a Nobel Prize. You have to step outside the iteration of a technique over and again to get at a new perspective. To quote the mathematician Henri Poincaré:

> Pure logic could never lead us to anything but tautologies; it could create nothing new; not from it alone can any science issue. In one sense these philosophers are right; to make arithmetic, as to make geometry, or to make any science, something else than pure logic is necessary. To designate this something else we have no word other than *intuition*.[1]

Second, this viewpoint is oddly unconcerned with the correlation between our thinking and the way the world works. *Why* should our thinking and the world's reality correlate? There is no obvious reason why they should gear together in the way they do. We will consider this matter further in Chapters 6 and 7, but the fittingness of language is a particularly helpful focus here because it links together what I have just said about how science works in terms of hypothesis and experiment and what I shall shortly say about the way in which we picture the world using science, or build models of it. Our modelling of the world will be considered in detail in the next chapter, but makes perfectly clear that a point made by Rowan Williams about scientific language is certainly correct. The language I used above was 'dyadic' – it suggested that, when we describe things in science, we describe what is in fact there. Actually, what we do is generate a representation of what we sense – we model it, one way or another – and so there is a three-way relationship: the scientist, what she is studying, and the way in which she represents it. In science, we think in mechanical terms, and this is a very useful shorthand, but our mechanical analogies are always mediated through the 'softness' of our models, which inevitably leave something out. Indeed, pretending that we describe what is really 'there' when we describe things in science undercuts our capacity to advance knowledge at all – as Dr Williams also points out. Because, if you have no model or representation of what you are studying

to reject (or at least modify), then you have no basis for going on with your study.[2] So, the metaphors and analogies we use in science, which we discussed briefly in Chapter 1, aren't just a helpful addition to data, but at the cutting edge of our search for understanding.

Third, and relevant to both how the great advances are made and why our thinking matches our world, this description leaves unexplained why scientists enjoy their work, what attracts them to it in the first place, and what keeps them at it hour after hour after hour, and when experiments fail, and when the treasured theory turns out to be rubbish. In this book, I wish primarily to address this last issue – what is so attractive about science – but, in doing that, I will have something to say about the first two issues I raised as well. I will argue that the great advances in understanding are made because of the peak experiences scientists find in their everyday work, as they are bowled over by the beauty of the world. And I will argue that the appreciation of the world's beauty brings us literally face to face with an answer to the issue of the human capacity to 'track the truth' at all, to know about the world accurately.

An account of modern science

Science is hugely varied and, in all its current forms, hugely successful. It is very good indeed at its aims, which are to seek more accurate and more detailed understanding of the way the world works, and to manipulate the world for human benefit. The scientists who work alongside me in Oxford are studying the basic genetic patterns in human populations, to understand susceptibility to many kinds of disease, and they are using studies of the molecular biology of viruses and malaria to plan new vaccines. Other colleagues are working on new optical techniques for microscopic imaging, or new ways of transplanting organs, or new ways of delivering drugs, or new techniques for measuring how proteins interact in the living cell. Still others are using our knowledge of biological molecules to engage in synthetic biology or to come up with 'biosensors' – biological molecules repurposed for the detection of trace chemicals, for example – of extraordinary sensitivity. My theoretician colleagues can predict with accuracy the behaviour of an ion channel involved in nerve impulses and the dynamics of a lipid membrane. The details of natural selection itself are being probed using model systems that can be run again and again from beginning to end, even while others study the development and functioning of the human nervous system and the ways in which we might understand how humanity, in all its complexity, came to exist, a complexity that enables the wonders of science at all. There is an outstanding diversity in just my corner of the scientific world – a world of thousands of universities and research institutes, a world of wholly astonishing scientific reach and expertise.

The twentieth century saw two massive shifts in scientific understanding. The first concerned the nature of reality at all, the stuff of the universe, the tiniest building blocks of reality and the curvature of space–time: quantum mechanics and general relativity. The second was triggered by two men, one

of whom is more popularly associated with the first leap forward: the idea of *molecular* biology, which underpins so much modern science – including innovations in chemistry and physics and engineering – was the compound effect of Erwin Schrödinger and Francis Crick. In 1948, Schrödinger published a book entitled *What is Life?* As he developed his thesis that life could be understood in simple molecular terms, he made an important assertion: that the 'gene' might be a:

> more and more complicated organic molecule in which every atom, and every group of atoms, plays a role not entirely equivalent to that of many others (as is the case in a periodic structure). We might quite properly call that an aperiodic crystal or solid and express our hypothesis by saying: We believe a gene – or perhaps the whole chromosome fibre – to be an aperiodic solid.[3]

Crick set out to determine the structure of this aperiodic solid and made the major discoveries that established molecular biology as a discipline: the structure of DNA, the nature of the genetic code, and how the genetic code is translated into proteins such as enzymes and hormone receptors in living cells, which then carry out the mechanical work of life.[4]

I am a kind of molecular biologist, a *structural* biologist, someone who studies the molecular structures of the proteins and other macromolecules that make up living cells and by which living cells communicate and cooperate within a multicellular organism such as a human being. As a structural biologist, I am most powerfully aware of two particular fundamental approaches to finding out the scientific facts about a natural system. First, there is the hypothesis-driven approach, in which I propose a model for how things might be (for example, I hypothesise, on the basis of some initial observations, that two proteins interact with one another) and then I carry out an experiment to test that hypothesis. I do the experiment repeatedly in order to establish a measure of the statistical significance of my data, or I rely on a technique that has been tried and tested itself and that we know will give accurate information if it is carried out in the right way and with the right statistical treatment of the data. If the data indicate, for example, that my two proteins do not interact, then I have to drop or modify my hypothesis – perhaps by positing that they need the presence of a third protein or a fragment of DNA in order to bind to one another. This provides me with a new hypothesis to test.[5]

Second, there is an approach based on the development of a new molecular imaging technique, and its rigorous, statistically validated application to biological questions. Clearly, imaging techniques play their role in testing hypotheses, but some techniques have proved so powerful and so successful in *picturing* the world in molecular detail that they seem sometimes to remove the need for a hypothesis to test. If you can, in effect, make a movie showing how atomic-resolution structures behave, then you may not need to 'test' them in any other way. In fact, experiments to test hypotheses are still required, but

they may well not be done by the scientist who solves the atomic structure – he or she may be too busy working towards that longed-for trip to Stockholm one December.[6]

Modern structural biology is based on the development of techniques into 'pipelines' of analysis that lead from data to an accurate description of how a molecule or set of molecules operates via statistical validation of the way data are interpreted. Molecular imaging techniques within these pipelines are based on the development of instrumentation whose reliability as a way of probing reality has been validated. Such instruments used in biology include electron microscopes, which allow the imaging of individual molecules and how they assemble together to produce the molecular machinery of life, magnetic resonance techniques (related to MRI imaging), to study protein structure and dynamics, and very bright 'synchrotron' sources of X-rays, which enable the determination of atomic structures of proteins that have been crystallised. Each of these technical developments has been recognised by Nobel Prizes,[7] and we will discuss the use of such 'toys' in the games scientists play in Chapter 4.

The possibility that X-ray diffraction of crystallised molecules might be used to determine their structures was opened up by the work of William and Lawrence Bragg (an amazing, father-and-son team).[8] Max Perutz was not believed when, in 1936, he claimed that he would be able to use this approach to solve the structure of proteins, but the technical developments he made alongside John Kendrew and Dorothy Hodgkin allowed them to solve the structures of haemoglobin, myoglobin (its cousin, involved in muscular oxygen storage), vitamin B_{12} and insulin.[9] Since 1964, Nobel Prizes have been awarded to twelve other individuals who built on the technical advances of the Braggs, Perutz, Kendrew and Hodgkin. Among the many biological processes thus modelled in atomic detail are how light is harvested by plants during photosynthesis, how ATP (the 'currency' of biological energy) is mostly generated inside all living cells, how proteins are synthesised and, most recently, the basis on which we respond to hormones such as adrenaline. In the field of structural biology, technical developments have led to astonishing leaps in understanding, which have, of course, now fuelled new hypotheses.

X-ray crystallography and electron microscopy are examples of technical approaches that image the world, that enable the actual reconstruction of nature – but this approach is not limited to molecular biology. As mentioned above, the same principles of magnetic resonance mapping that can be used to study molecular structure lie behind the medical use of MRI scanners.[10] Nor, of course, is it limited to biology at all – radio telescopes are responsible for many discoveries, such as of pulsars[11] and the background cosmic radiation that tells us about the age and size of the universe.[12] Nor is this even a modern approach – throughout the history of science, the development of technical know-how has empowered fundamental discoveries. For example, William Herschel's design and construction of progressively larger telescopes, with greater powers of magnification and resolution, enabled a wonderful expansion in our understanding of the mechanics and antiquity of the universe and

the development of many concepts in the late eighteenth and early nineteenth centuries that are current to this day,[13] such as *nebulae* (the birthplaces of stars) and the *light year* as a measure of distance. Nor is this approach at an end: striking and fundamental physical discoveries are expected to emerge from the Large Hadron Collider – indeed, the Higgs boson is confirmed already, and the Nobel Prize recognising that fact was swiftly awarded, to Peter Higgs and François Englert. There will continue to be larger and more detailed discoveries concerning biology too, through the continuing technical triumphs of structural studies. In other aspects of biology, the vast new computational abilities at our disposal will enable ever more detailed studies of the genetic signals that make us who we are and determine our liability to suffer from infections or cancer (Oxford has a new Big Data Institute), and the use of robotic technology will continue to allow larger and larger datasets, of all kinds relevant to science, to be collected in the first place.

An end to hypotheses?

The development of powerful molecular imaging techniques has allowed the growth of approaches in science that can seem more like mountain climbing and flower picking than the testing of hypotheses. Like climbing a mountain 'because it's there', we can sometimes seem to be solving molecular structures or looking for the fundamental particles of matter 'because we can'. However, the structures themselves become a rich source of question-begging and the framing of new hypotheses that drive experimentation forward. The larger the 'mountain' whose structure we capture, the more magnificent the questions we can ask and the hypotheses we can frame. Imaging more and more aspects of the world, getting a snapshot of greater and newer aspects of it, in all its intricate beauty, enables us to ask questions we did not even know existed before and design scientific approaches to get them answered. So, now, our capacity to image the world does not end our need to hypothesise: instead, it enables us to think in bigger and bigger terms.

Scientific methods are concerned with the ability to perform experiments, repeatedly. They are concerned with the physical response of the universe when it is prodded – we set up certain boundaries, certain horizons, by the way we carry out experiments, and within those boundaries we can discover and then define how things regularly behave. We dignify those regularities with the names of 'laws', the Laws of Nature, and we can codify them in mathematical expressions. Mathematics, though, offers a way of reaching far beyond even what is technically achievable, even what our instruments can detect, beyond the horizon of our current *ability to see* imposed by our know-how, or even by our being physical creatures of a certain time and place with certain technical abilities. Here, the beauty that scientists find in their discoveries gains a new significance, because, at the boundaries of our ability to test our ideas, we are faced with hypotheses that may or may not be provable at all. Maybe they could be proved if we could widen our boundaries enough, stretch our

horizons enough, but if, as a matter of fact, we cannot, then we are stuck this side of an unanswerable question. One such question is: What existed before the beginning of the universe? One answer is that there is no 'before' where time does not yet exist; another is that a quantum fluctuation in a vacuum gave rise to what there is now.[14] Either way, our own time-boundaried, physical position here in this universe prevents us in principal from getting outside it or before it. We cannot, in principal, know a measured answer, and this is the point where physical science breaks through into cosmology, mathematics and philosophy. Another example, within the universe and not trying to reach outside it, is string theory, which might provide a grand basis for understanding the nature of matter, enabling the unification of quantum mechanics and general relativity, but is unprovable, because the experiments required cannot be performed. However, the coherence of the mathematics describing this unprovable physics has convinced some that it is true. We will return to some of these questions in Chapters 6 and 7.

Mathematics can allow us to step outside this universe, in our minds, because we have found that what is most mathematically beautiful is often actually mathematically – and physically – true. One of the best known examples of this point is perhaps Paul Dirac, who is famous for his championing of the value of mathematical beauty as a guide to truth: 'it is more important to have beauty in one's equations than to have them fit experiment . . . if one is working from the point of view of getting beauty in one's equations, and if one has really a sound insight, one is on a sure line of progress'.[15]

The relationship of beauty to truth, in mathematics and other sciences, is the central theme of this book, but it begs the question that I used as the title for this chapter: Are we not talking about two *different* ways of knowing? Doesn't the scientist know scientific facts scientifically, while privately enjoying the subjective pleasures of seeing the world's beauty? There is no doubt that seeking the experimental falsification of a hypothesis is an essential aspect of scientific method and culture, and that reliable protocols are needed to maintain scientific integrity. There is no doubt that the development of new technical approaches underpins the leaps forward in understanding. Why do I need to bring beauty centre stage?

Because I do not believe that our scientific discoveries are solely underpinned by technical expertise and honest experiment. We need to make the leaps in understanding and interpretation that require our imaginations, we need to see the beauty in the world that attracts us in the first place and takes us to the bench early in the morning and keeps us there long into the night. But, more than that, the pursuit of what is beautiful *because it is beautiful* is what seems to get scientists into new modes of understanding, and, in mathematics, what is beautiful is, it turns out, just more likely to be true (see Chapter 3).

I will argue in this book that science as exercised by scientists is an exercise as much in aesthetic judgement as in empirical judgement. I will argue that science is driven by subjective experiences codified and trained by objective rules, but that the subjectivity is essential and is the stimulus that leads to the

truthful hypothesis. I will argue that our subjectivity is, actually, a window on objectivity, and that this tells us something about the *subjectivity* of reality, and the significance of *personality* within it.

The realism of scientific insight

Does this mean that I am not a realist about scientific insights? Does this mean that I value as highly a subjective viewpoint (what seems good to me) and an objective one (what is, as a matter of fact, true)? Absolutely not, and a brief return to the theme of structural biology will show why not. I just think that subjectivity is the route we take to objectivity.

Structural biologists have won more than what some would consider their fair share of Nobel Prizes because of the great impact of their findings following from the robustness of their conclusions and the sheer amount of information provided by the atomic structure of a biological molecule. Our structures are very beautiful, but they also tell us a great deal that is true, and that is never going to change in fact, but just become better understood. The best justification for that claim I can think of is the development of new pharmaceuticals and vaccines based on atomic structures of proteins. However much personal insight and subjectivity were involved in the work towards a structure, however much it relied on matters of opinion and points of view, when a new drug is developed and it stops people dying, an undeniable leap has been made from what is subjective and depends on the eye of the beholder, to what is objectively a fact. Imatinib (also known as Gleevec/Glivec) is my favourite example, an enzyme inhibitor that first became well known because of its capacity to target a chimeric enzyme (called Bcr-Abl), which humans do not normally have but which is a hallmark of the vast majority of cases of chronic myeloid leukaemia (CML). Imatinib was originally designed using atomic structures of the class of enzymes to which Bcr-Abl belongs, kinases,[16] and has proved an astonishingly successful therapy – 86 per cent of patients with chronic-phase CML survive after 7 years,[17] and 10 years after starting treatment nearly 90 per cent of the original cohort of treated CML patients showed no sign of disease progression; the patient benefit of this drug was so stark that the original clinical trial was not even completed.[18] Like every other replicating entity in the universe, cancer cells evolve and, in the presence of Imatinib, they have now been found to evolve resistance to it. But this in no way reduces the significance of the fact that computational modelling of Bcr-Abl led to a drug with obvious therapeutic impact.[19]

Another example is the anti-influenza drug, Relenza. Fear of a global 'flu virus pandemic is regularly a highlight of media reporting on science and medicine, and one of the frontline drugs on which it is said we might need to rely, in addition to an aggressive vaccination policy, is Relenza, which inhibits – like another well-known drug, Tamiflu – the neuraminidase enzyme on the virus surface. Relenza, like Imatinib, is the result of rational drug design based on the atomic structure of the enzyme that it targets.[20] Like Imatinib,

Relenza is a demonstration of the factual, objective truthfulness of the insights molecular science provides into how things work, despite the fact that the underlying research was done by humans motivated to a large extent by their simple, childlike excitement at seeing into the details of molecular biology and finding it beautiful.

Vaccine design can also benefit from studies of molecular structures. Some recent results focused on targeting the foot-and-mouth disease virus provide a good set of examples.[21] Based on an understanding of the virus structure, its protein coat has been redesigned to make it more stable and enable a new vaccine to be produced that has been shown to work; the same strategy can be applied to other human and animal pathogens, such as poliovirus.[22] Watson and Crick were the first to propose, on entirely theoretical grounds, that viruses have structures based on principles of geometry popularly associated with Ancient Greece and referred to as Platonic solids,[23] and they were right. The principles of spherical viral assembly have been shown experimentally to be just as Crick and Watson thought they might be, and it is the designed stabilisation of this symmetrical arrangement that has enabled the development of a new vaccine against foot-and-mouth disease, just as assuming the symmetry allowed the atomic structure to be solved in the first place. It seemed to Crick and Watson that the most elegant, the most economical – the most beautiful – way in which a virus could form a coat to enclose its genome would be according to the Platonic icosahedron; their perception of the most beautiful solution turned out to be the way things really are, and now we can use those icosahedral structures to design new vaccines. Not just new vaccines, either: similar structural studies have revealed a 'pocket factor' (a small lipid molecule, in fact) that stabilises the coat of a virus called HEV71, which causes hand, foot and mouth disease in adults; theoretical modelling has now allowed the development of new classes of virus inhibitors based on the mimicking of this pocket factor, which may again be relevant to related viruses such as polio.[24]

I have just used viral examples of how the microscopic truthfulness of our scientific insights can be observed in real time, in the macroscopic world. Viruses also provide an important example of the confirmation of an elegant theory, the one about evolution by natural selection. There are a variety of examples one can use of ways in which natural selection – a *theory* proposed by Darwin and Wallace, as everyone knows – can be objectively observed playing itself out now, as we watch, in *our* world, such as the occurrence of antibiotic-resistant strains of bacteria and the evolution of drug resistance in cancer. I have chosen the example of HIV, however, because it just is one of the best examples of real-time evolution.

The evolution that produced us was slow, because animals like us reproduce slowly and quite accurately. By contrast, the evolution of HIV is very rapid, because it reproduces fast and very inaccurately. You might think this is a problem, but, in the economy of natural selection, and in the biological niche occupied by HIV, it is an advantage. The advantage comes in particular when the environment occupied by the virus changes – such as when someone takes

an antiviral drug. Because HIV is inaccurate in its replication, a large number of mutant viruses exist in any one host after they have been infected for a while, and one or more of those viruses will have a better tolerance of, or immunity towards, the applied drug than the original viral form with which the person was infected. So, the taking of a drug just allows that mutant virus to be selected for out of the large pool of random viral mutants generated by accident during its replication cycles, and to become amplified – to become the dominant viral form. This is why HIV patients are now treated with combination therapies – several different drugs at once – so that no one mutant virus becomes dominant, and all are kept to a greater or lesser extent in check. Evolution in these terms can be seen in our own immune systems too – and, indeed, some of my colleagues are interested in understanding how the human immune system and the pathogens that affect us interplay as two evolved and adaptable systems entwined with one another.

The really interesting detail, though, is what happens when the form of HIV adapted to the presence of a particular drug in its environment moves to a new host. Suddenly, the selective pressure is off, because the new host is not taking any anti-HIV drugs, and, as the virus varies randomly, by chance new versions of its genome will arise – only they aren't new, it turns out, but a re-invention of the old. Although the virus that actually infected the new host had one specific genomic type, containing a mutation that confers resistance to an anti-HIV drug, when the virus no longer has to rely on that mutation – for example, in the enzyme reverse transcriptase – to maintain resistance, because the new host is not taking the drug, then it will revert to its original form.[25] In colloquial terms, it will reinvent the wheel. Darwin's theory of evolution by natural selection was 'just' a theory, but we now can watch it occurring live.

Viruses provide extraordinary examples of evolutionary stasis as well as evolutionary variability. The taxonomic grouping of viruses used to be based on their hosts and the kinds of genome they had, but, more recently, it has become clear that viruses that currently infect hosts occupying totally different environments (e.g. human beings and bacteria in the ocean) are in fact related through a common ancestor. This discovery was made by solving the atomic structures of the viruses and finding that, although immensely separated in time and space, the *fold* – the elegant knotting and twisting – of the protein structure was conserved.[26] The prior art of an original evolutionary solution has remained unaltered in form over billions of years. This amazing economy of form is not limited to viruses, however: some of my own work is on proteins that attack the membranes enclosing and protecting living cells to form holes, or pores, within them. I started that work focusing on bacteria infecting humans, but it is now known that the same fold, the same solution to a protein structure, is found in the human immune system, where it is used to protect against bacteria and other pathogens and against cancer, and also in the organism causing malaria, *Plasmodium*, and in fact in most different types of cellular life. Thus, the deep rooting, the prior art, of a single molecular solution to a single biophysical problem – how you open up a lesion in a targeted membrane

in this case – is found in the mechanisms by which bacteria and *Plasmodium* attack us and in the mechanisms by which we defend ourselves against them.[27] Other members of the same protein family are also involved in a process as different from those already mentioned as the migration of neurons within the developing and adult human brain and the self-defence mechanisms of plants.

Scientific method versus religious method?

In this chapter, I have so far done three things: I have talked in a preliminary way about how scientists find the beauty of what they study a stimulus for their work and a validation of their insights; I have discussed some of the advances in modern science and how they relate to this fact; and I have emphasised the objectivity of the insights scientists gain – that, however much they are grounded in a subjective experience, they can result in objective truth. In the rest of this chapter, before we embark on a more in-depth study of the different ways in which a sense of the aesthetic empowers scientific discovery and insight, I want to make a comparison of scientific and religious methods, especially as religious practice too is inspired by beauty. One way of summarising what I have argued so far would be to say that the pursuit of science involves a religious attitude in the scientist – an attitude of attentiveness and commitment, an attitude open to being awe-inspired by what we study. The title of this chapter concerns two different ways of knowing: objective scientific knowledge and subjective affective knowledge, personal knowledge. I now want to compare an equivalent pair of methodological approaches: scientific method and religious devotion.

The methods that people of faith use in their worship and in the different ways they seek to have their lives shaped around religious commitment look from the outside very different indeed from what scientists do in their research. The religious pray – as a Christian, I pray to God the Father through our Lord Jesus Christ in the Holy Spirit. I do not pray to experiment with God's covenant with humanity or God's faithfulness to his creation. I do not pray because I want to get something out of God, because he is much more powerful than I am and can do anything he likes. Instead, I pray because I love my family, I love my friends, because I want to love my neighbour and I want that neighbour to be as much my brother or sister in Somalia, Sudan, Syria or Afghanistan as my neighbour in Oxford. I pray because I want to love the world God has made and I want it to be a world more fitting his own desire. I pray, radically, fundamentally, for different reasons to those for which I experiment. Or do I? But, generally, the methods of religious practice and scientific research *are* seen as being vastly different, and one respected approach has been to see this as meaning that science and being faithful are two very different parts of human life and do not overlap, but can be combined by choice within the envelope of one personality. One can be a scientist and religious, but the two aspects of the one life don't speak to each other. Stephen Jay Gould (himself Jewish) held this view,[28] but I do not hold this view; in fact, I think that what we do, methodically, in enacting our faith

is a purer form, a more objectively realised form, of what our science is enabled by, what science subsists on. I think science presupposes a kind of faith.[29]

Clearly, there are some simple articles of faith or trust that a scientist needs to be able to operate at all. Scientists need to believe that the perceptions that they have are accurate, and that humanity in general is capable of accurate perceptions of the world. We must believe that we see into reality in a genuine way when we study it, and that, just as when we see down the street, when we look into the living cell and at the atomic nucleus we 'see' what is really there. A more fundamental belief underpins this one, and that is that the world has a logical and ordered structure that we can make sense of because it is always the same kind of place (see Chapters 6 and 7). In other words, the scientist must believe that the world is independent and free, and that it is not in the control of water sprites or the gods and demons. And this article of faith means that scientists are committed to a belief in free will and to a belief that reality is not deterministic – that the way things will turn out is not set from the start, that there is a genuine openness of outcome in the events of reality and, most strikingly, in the mental experiences of the human being. In fact, scientific discoveries are one of the clearest signs that the freedom of our wills is a reality, as, if you do not have free will, then you cannot make genuinely new discoveries. It would be possible to argue that someone, somewhere, was always going to make a particular discovery, and that this permits a kind of determinism. But, the fact is, discoveries are *not* made by anyone, anywhere, but by specific people who stay in the lab all night,[30] by people who are provoked to get things right because they are angry,[31] and by people who destroy their own health by accident in the experiments they perform.[32] Discoveries are born from passions distinctive of human beings, and our personality provides us with a radical freedom as we respond deliberately and determinedly to those passions. Out of this freedom comes our capacity to discover independent truths about reality – natural selection, atomic structures, the Higgs boson, you name it. The only deterministic element in scientific discovery is the objective reality of the world, the truth we are trying to discover. And, we know the discoveries we make in science are new and are freely made because we can see them changing the world around us – the drugs we design and manufacture, the zippy new computers we develop, and so on.

It could be responded: Yes, but this very fact makes scientific beliefs different from religious ones, because scientists can see that their beliefs are true by looking around and seeing them working out, and by doing experiments again and again. Therefore, the kind of belief and trust involved in scientific research is different from the kind involved in prayer. Of course, scientists *do* find that doing similar things repeatedly gives them the same answer again and again and allows them to make more useful sense of the world, but, in fact, just the same could be said of prayer. In a discussion group I was conducting someone asked, 'What good is it going to do praying for peace in Israel?'. And someone else replied, 'Well it can't do any harm'. This seems quite right to me – and it might do a great deal of good! Because prayer is a way of engaging with my own deepest desires and needs, it is a way of trying to understand what is truest

about myself and the world, and it is a way of trying to hear God's word for me, today. I am not convinced, in the end, that my prayer is all that different from my science, and I do believe that my prayer makes me a better scientist.[33]

Like scientific research, prayer grows out of a tradition of thought and practice, out of patterns of activity that have been tried and tested and shown to work out over years, hundreds of years. Like scientists standing on the shoulders of giants (as Newton put it), people of faith take very seriously what their religious predecessors have said and done – their predecessors in their own faith and all people of seriousness and commitment with regard to worship of God. They treat with reverence things that have been written in the past – by the prophets, by the evangelists. They seek to learn truthful things from people whose understanding of the nature of the world was very different from their own, but whose understanding in faith is possibly normative. They are, fundamentally, open-minded people whose basic attitude commits them to a search for what is truthful, and the practice of prayer is an essential aspect of keeping our minds focused on a search for what is true. However, all these features of prayer and religious devotion can also be said to apply to scientific research.

Thus, scientists take very seriously what their predecessors in research have said and done – those in their own science but all people of seriousness and commitment with regard to investigation of the physical and natural world. Scientists treat with reverence things that have been written in the past – by the innovators and by the communicators (by Charles Darwin, by Richard Dawkins). Scientists seek to learn truthful things from people whose understanding of the nature of the world was very different from their own, but whose understanding of the basics of reality is possibly normative (Archimedes, Hooke, Newton, Schrödinger, Einstein). Scientists are, fundamentally, open-minded people whose basic attitude commits them to a search for what is truthful, and the practice of scientific research is an essential aspect of keeping our minds focused on a search for what is true.

I do not believe that we are faced with two completely different ways of knowing when we talk, on the one hand, about scientific knowledge and, on the other, about what we find beautiful. I do not believe that we are even faced with two completely different ways of knowing when we talk about experimentation and prayer. I believe that the way in which what we find beautiful guides us to what is demonstrably true tells us that *in* our appreciation of beauty and its experimental validation is a demonstration that we have one way of knowing, and it is human. We have the ability to *know* things – whether they relate to God or to the world around us – *because* we are *people*. In the following chapters, I will explore in greater depth our human way of knowing and what it tells us about the divine way of being: ours, and God's.

Notes

1 Henri Poincaré, *The Value of Science* (trans. C.B. Halstead; The Science Press, 1908), p. 19. Robin Dunbar (*The Trouble with Science*, pp. 86–7) makes a similar point, saying that, to claim that our scientific advances 'are produced by trial-and-error learning is

simply to display ignorance of how modern technology . . . is designed' while citing the Apollo 13 spacecraft as a magnificent proof of the truthfulness of science.

2 'The scientist moves forward by identifying what is difficult [in data], what does not fit in an existing framework, but what account of such difficulty can be given in a purely dyadic, causal picture of language?', Rowan Williams, *The Edge of Words*, p. 57. 'Going on' is a significant term to use here, as Williams's book emphasises. Robin Dunbar agrees: 'Theories are essentially constructs or models of how the world works . . . Science . . . is a feedback process, it learns from its own mistakes' (*The Trouble with Science*, p. 25).

3 Erwin Schrödinger, *What is Life? The Physical Aspect of the Living Cell* (Cambridge University Press, Canto edn, 1992), pp. 60–1.

4 Francis Crick and James Watson, 'Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid', *Nature*, *171*, 737–8 (1953); Francis Crick et al., 'General nature of the genetic code for proteins', *Nature*, *192*, 1227–32 (1961); Francis Crick, 'Codon–anticodon pairing: The wobble hypothesis', *Journal of Molecular Biology*, *19*, 548–55 (1966).

5 See Robin Dunbar, *The Trouble with Science*, pp. 19–32, for discussion of hypothesis formation and falsification as a strategy in science, and its limitations, in the context of various theories about the nature of scientific method and knowledge.

6 When the Nobel Prizes are handed out.

7 Electron microscopy: Aaron Klug, Chemistry, 1982, and Ernst Ruska, Physics, 1986; magnetic resonance for molecular studies: Richard Ernst, Chemistry, 1991, and Kurt Wüthrich, Chemistry, 2002; X-ray studies: discussed further below.

8 Nobel Prize in Physics, 1915.

9 Perutz and Kendrew shared the 1962 Nobel Prize in Chemistry, the same year Watson and Crick won the Medicine prize. Hodgkin, alone, received the Nobel Prize in Chemistry in 1964, for her vitamin B_{12} work.

10 Paul Lauterbur and Peter Mansfield, Nobel Prize in Medicine, 2003.

11 Martin Ryle and Peter Hewish, Nobel Prize in Physics, 1974, Ryle for the telescope, Hewish for the application to pulsars, though they were in fact first noted by his student, Jocelyn Bell Burnell.

12 Jean-Pierre Luminet et al., 'Dodecahedral space topology as an explanation for the weak wide-angle temperature correlations in the cosmic microwave background', *Nature*, *425*, 593–5 (2003).

13 See Richard Holmes, *The Age of Wonder* (HarperPress, 2009).

14 Ilya Prigogine et al., 'Thermodynamics of cosmological matter creation', *Proceedings of the National Academy of Sciences of the United States of America*, *85*, 7428–32 (1988).

15 Paul Dirac, 'The evolution of the physicist's picture of nature', *Scientific American*, May 1963, reprinted June 2010.

16 Brian Druker et al., 'Effects of a selective inhibitor of the Abl tyrosine kinase on the growth of Bcr-Abl positive cells', *Nature Medicine*, *2*, 561–6 (1996); Yen-Lin Lin et al., 'Explaining why Gleevec is a specific and potent inhibitor of Abl kinase', *Proceedings of the National Academy of Sciences of the United States of America*, 110, 1664–9 (2013).

17 Steven Horne et al., 'Why Imatinib remains an exception of cancer research', *Journal of Cellular Physiology*, 228, 665–70 (2013).

18 Craig Thompson, 'Attacking cancer at its root', *Cell*, 138, 1051–4 (2009).

19 For a while, but not long enough, it helped to keep alive Adrian Sudbury, to whose memory this book is dedicated.

20 Graeme Laver and Eslpeth Garman, 'The origin and control of pandemic influenza', *Science*, 293, 1776–7 (2001).

21 Ravi Acharya et al., 'The three-dimensional structure of Foot-and-mouth disease virus at 2.9 Å resolution', *Nature*, 337, 709–16 (1989).

22 Claudine Porta et al., 'Rational engineering of recombinant picornavirus capsids to produce safe, protective vaccine antigen', *PLoS Pathogens*, *9*, e1003255 (2013).
23 Francis Crick and James Watson, 'Structure of small viruses', *Nature*, *177*, 473–5 (1956).
24 Luigi De Colibus et al., 'More-powerful virus inhibitors from structure-based analysis of HEV71 capsid-binding molecules', *Nature Structural & Molecular Biology*, *21*, 282–8 (2014).
25 Michele Tang and Robert Shafer, 'HIV-1 antiretroviral resistance', *Drugs*, *72*, e1–e25 (2012).
26 Dennis Bamford et al., 'What does structure tell us about viral evolution?', *Current Opinion in Structural Biology*, *15*, 655–63 (2005); Nicola Abrescia et al., 'Structure unifies the viral universe', *Annual Review of Biochemistry*, *81*, 795–822 (2012).
27 Robert Gilbert et al., 'Effects of MACPF/CDC proteins on lipid membranes', *Cellular & Molecular Life Sciences*, *70*, 2083–98 (2013). See also Gregor Anderluh and Robert Gilbert (eds), *MACPF/CDC Proteins: Agents of Defence, Attack and Invasion* (Springer, 2014).
28 *Rock of Ages: Science and Religion in the Fullness of Life* (Ballantine Books, 1999).
29 'The light of faith . . . illumines the material world, trusts its inherent order, and knows that it calls us to an ever widening path of harmony and understanding. The gaze of science thus benefits from faith: faith encourages the scientist to remain constantly open to reality in all its inexhaustible richness. Faith awakens the critical sense by preventing research from being satisfied with its own formulae and helps it to realize that nature is always greater. By stimulating wonder before the profound mystery of creation, faith broadens the horizons of reason to shed greater light on the world which discloses itself to scientific investigation', Pope Francis Encyclical *Lumen Fidei*, 34 (2013).
30 Such as Linda Buck, who, at Columbia University in New York, used the lab bench by night that my colleague Quentin Sattentau used by day to carry out research that led to her receiving the Nobel Prize in Medicine in 2004, on how we sense smell. Quentin remembers how, when they met for one of their regular breakfasts at handover time, she showed him the critical result that was to lead to her great discovery.
31 Such as Max Perutz. See his *I Wish I'd Made You Angry Earlier* (Oxford University Press, 2002).
32 Such as Marie Curie and Rosalind Franklin.
33 A recent BBC Radio 4 play (www.bbc.co.uk/programmes/b07q2r50) *There is No-one in the Lab but Mice*, by Tania Hershman, explored the abandoning of their labs by the world's scientists, to embrace more 'human' activities, before their return (to universal relief), though with a self-conscious attitude changed by their time out in 'the world'. It contained a poem introduced with the words, 'I am a post-doc, a molecular biologist, this is from all of us', entitled *This Too Is Prayer* and beginning: 'No, not some lovers' glance, / A newborn's grin, sunset, Autumn leaves, / But this, green fluorescent protein: / A molecule borrowed from the jellyfish . . . '. Roger Tsien, Osamu Shimomura and Martin Chalfie shared the 2008 Nobel Prize in Chemistry for their discovery and development of green fluorescent protein as a molecular biological tool. In my lab, we use it all the time.

3 Beauty everywhere

It can be argued that there are as many perspectives on beauty as there are people. I think all people find some things or some experiences beautiful, but *what* those are is a matter of personal judgement. 'Family, friends, education, nationality, race, religion and politics – all these things help shape our idea of beauty.'[1] What's more, we can make something more beautiful to ourselves just by pointing out that it's lovely to someone else, as we noted in Chapter 1 – and maybe we can help them see it as beautiful in that way, too. Indeed, those of us given to talking to ourselves (most of us, surely?) will perhaps comment on the beauty of a landscape or a piece of music as a route to its actual appreciation, as a way of dealing with the sensory excess it confronts us with. I know I do.

One recent project that seeks to explore the interface between the arts/art and the sciences is the *Interplay* series produced by the Swedish Radio Symphony Orchestra. Their conductor, Daniel Harding, has had this to say:

> Richard Feynman . . . used to have arguments with a friend who was an artist. And he said to the artist: 'You artists are lost, you have no subject. You've lost your religion and you don't understand science and you've nothing to write about, nothing to make art about'.
>
> And they would argue endlessly, as people have for hundreds of years about whether scientific knowledge of a flower or of the rainbow or of the heavens, of what we see in the night sky, of whether scientific knowledge enhances or reduces the sense of beauty you get when you look at it. And the artist said to him, 'You don't appreciate the beauty I see because it's all confused with these scientific thoughts'. And Feynman said, 'No, I see so much more beauty, because there is beauty', they were talking about a flower, 'There is beauty in the understanding of how a flower is constructed to attract pollinating insects, there is beauty in the cellular structure of a flower, there's enormous beauty in what we see in the night sky.'
>
> 'This is an age-old debate . . . Artists deal with the great questions that mankind has always posed. Art and ideas have always been on the same – page.[2]

Yet, despite this subjectivity, science is one example of an area of human intellectual activity in which there is some agreement as to what is beautiful and what is not. I know there is agreement in other areas too, but in science in particular there must be, otherwise what one scientist thinks is beautiful would not resonate appropriately with others, and the enthusiastic conversations that underpin science, as scientists pore together over a satisfying pattern or insight in their data, would not work.

In fact, with respect to painting and music themselves, and other traditional arts, there is probably no more agreement, and very likely less, as to what is beautiful and what is not than there is in science. Many would consider the music of Mozart, for example *The Marriage of Figaro*, supremely beautiful, supremely aesthetically pleasing as an example of music and as among the finest products of Western civilisation. Yet, I have a very accomplished friend, a historian, who dislikes the music of Mozart intensely – it very definitely does not please him. Marcus du Sautoy comments, of the role of mathematics in music, and of the transition away from a harmonic approach to music: 'If you throw away structure you need new structure in order to frame your composition'.[3] The world gives us the structure that frames our aesthetic experience of it. So maybe, in science, our appreciation of what is beautiful is more rooted and so more consistent than it is when applied to works of art, music, poetry. My appreciation for the paintings of Rembrandt is tied up with my emotional response to the expressions on the faces of his subjects and the stories they seem to tell. I can hope to share that emotional response with someone else and, the better I know them, maybe the more I hope we will understand each other, he or she will understand what I mean. But, in science, we can be more confident of being on common ground: in science, we also share an emotional response to a beautiful demonstration or a very pleasing molecular structure, but there is less of ourselves bound up with the judgement being made. Less of our particular story, less of our personal experiences, is in the mix, and more of our common life in which publicly demonstrated discoveries are commonly recognised for their beauty. Indeed, to the extent that we involve our personal experiences, our subjective make-up, in our scientific judgements about what is fitting, pleasing or beautiful – *to that extent* we are liable to miss something important. Scientists can be very self-regarding, but the more self-regarding they are, the less they are useful as scientists. If you're particularly brilliant, maybe you can get away with both being massively egocentric and being a great scientist. But, in fact, *you* would be an *even better scientist* if you forgot about yourself and focused more on trying to discover the truth. By looking to their own interests, scientists very definitely run the risk of missing a trick – it's just sheer ability that saves some of our most able scientists from self-defeat. Recently, for example, I heard a Nobel Prize winner give a talk in which he presented data revealing a new understanding of the biological system for which he received his prize, which provides a new and fascinating framework within which to understand its operation. The system in question is the basis for energy generation in every nucleated cell on Earth. The problem is, the

insights he was reporting had been known from the work of others for about 5 years. But, the Nobel Prize winner totally ignored this fact in his talk. This is a very common mistake for scientists to make, and it is tragic.

In this chapter, I want to look at a series of perspectives on beauty in science, moving, roughly speaking, from more theoretical points of view where we seek simplicity, towards more applied insights where we seek to understand complexity. In all cases, the more we give ourselves over to an appreciation of the beauty (the less we think about ourselves), the more we come to understand the system we are studying, and the better we are as scientists.

Classification and statistical analysis

Putting things together in groups of similar objects or patterns is my starting point as we look to the all-pervading role of aesthetics in science. I place this at the start of my sequence because it is an activity directly based on our ordinary experience of the world, and it is without *necessarily* particular sophistication of analysis. That being said, of course such analyses *can be* very sophisticated, and all the more powerful for that – such as the use of Bayesian statistics, which makes use of probabilistic, or 'maximum likelihood', methods to analyse data to a reliable conclusion.[4] Such methods have revolutionised data analysis within my own speciality, structural biology, in recent years. Another recent example of the power of this area of statistics to provide a scientific understanding of patterns in data is the People of the British Isles project. In this, statistical geneticist colleagues of mine have analysed the different patterns of mutations found in the genomes of residents of rural areas of Britain with strong ties to their locality. This has enabled the identification of clusters of relatedness and interrelatedness within and between British geographical regions. It surprisingly shows, for example, a limited genetic input by Danish Viking invaders, and that the Celtic regions of the British Isles are more genetically different from each other than had been thought.[5] It is a clear example of using classification, the inference of relatedness, to uncover hidden patterns of genetic inheritance that can be correlated with historical, linguistic and archaeological evidence. It is also an in-principle demonstration of the power (or usefulness) of statistically based, fine-scale genetic mapping of human populations.

This is a sophisticated example of classification, but classification itself is a very basic human capacity and one, I would argue, that has roots in our appreciation of beauty: of what is fitting, or what pleases us. It's a matter of what fits together, what things belong together. For example, Robin Dunbar points out (following Paul Harris) that children seem to classify objects based on similarity and relatedness from a young age, using principles of analogy, and draws parallels between children being analogical and scientists who are analogical in their thinking.[6] The use of analogy is a universal feature of science, and an essential one. It allows us to model the world and thereby to come to an understanding of it, as we have already noted in Chapter 1.

The relevance of this to the issue of classification can be appreciated by taking a step back from the scientific process and thinking of the ways in which we detect and infer similarities between things. The philosopher Mary Douglas writes:

> Analogy creates similarities, it doesn't find them ready made. An analogy has to be a cultural construct. If a likeness seems to hit you in the eye, such as the likeness between the majesty of a lion and the majesty of a king, or if you don't see the majesty but see an obvious likeness between lions and other less noble-looking carnivorous predators, your cultural training has selected the points of comparison for you. There is nothing in nature that produces similarities. Similarity is constructed.[7]

This may seem a distant example, but the fact is that the human capacity to assign similarity to things is something cultural that we do; it is something in which we sample points of comparison in order to infer relationship. Indeed, going back to the example of the People of the British Isles project, the points of comparison are the single-nucleotide polymorphisms – differences of one nucleotide base in DNA – which are used as markers for the definition of groups of relatedness and groups of difference. The use of this approach in science is validated explicitly by the way it works out in practice.[8] 'Classes came to be defined through involvement in practical situations' such as working together, playing, making music, because we needed or wanted to denote classes of events and things.[9]

This was a process of world-making,[10] of constructing a framework of concepts and models to make sense of the world, but in the same process making that world happen. Acknowledging this as the basis for scientific classification is not at all to denigrate the accuracy of a scientific world-view, but it is to clearly say that that view is constructed, by us. In a sense, that is one of the key points of my argument – that the sense we make of the world, aesthetically and otherwise, is the sense *we* make of the world – and yet it is, broadly speaking, a kind of truth.

I say *a kind of truth* not to be provocative – it should be clear from Chapter 2 that I rate the 'truths' of science highly – but just, I think, to be honest. After all, our scientific point of view now is rather different from Newton's, and his was different from that of Democritus, who is the first person we know of to have thought about atoms as a way of understanding the relatedness of things that appear very different (such as earth, air, fire and water).[11] So, Nelson Goodman speaks of the 'fabrication of facts'.[12] We do not find facts lying around waiting to be picked up: we make them up and show them to be reliable ways to understand the world. So, we make versions of the world we live in – we make *different worlds* – using numbers, pictures and other symbols in science, for example.[13] We can focus on versions of our description of the world that are literal and numerical in science, but that is definitely not the only way in which we do science – we use diagrams and pictures and,

with the advent of computer graphics, more and more sophisticated and, well, beautiful representations of 'reality'. Goodman wants to argue that the world-making we engage in using metaphor, exemplification, pictures, sounds and gestures shows that, 'the arts must be taken no less seriously than the sciences as modes of discovery, creation, and enlargement of knowledge in the broad sense of advancement of the understanding'.[14] And, artistic and scientific modes of discovery share the characteristic that they are *fitting*. Goodman sees correct descriptions and representations of the world – whether the products of 'art' or 'science' – alongside the very idea of the truth, as belonging together 'under the general notion of rightness of fit'.[15] Art, science and perception are continuous and unified as branches of world-making – which is *not* to say that truthful things are beautiful, or vice versa, because, in fact, to equate beauty or aesthetic rightness with truth *and* to say that they are incomparable with truth are equally misleading statements.[16] Nevertheless, pursuit of the beautiful is *a* way of making truth known, in the arts and in the sciences, and the classification of objects with one another, their fit to one another, is one way in which that works out. Practical testing then interrogates the extent to which the 'world' that got 'made' actually tallies with the physical world and other manufactured versions of it.

> Briefly, then, truth of statements and rightness of descriptions, representations, exemplifications, expressions – of design, drawing, diction, rhythm – is primarily a matter of fit: fit to what is referred to in one way or another, or to other renderings, or to modes and manners of organization. The differences between fitting a version to a world, a world to a version, and a version together or to other versions fade when the role of versions in making the world they fit is recognized. And knowing or understanding is seen as ranging beyond the acquiring of true beliefs to the discovering and devising of fit of all sorts.[17]

In other words, classification. Fitting a version together is an example of classification. Historically, the construction of evolutionary trees of relatedness and the definition of members of genera and species have greatly benefitted from classification at this simple level – grouping together different individuals of apparently identical or similar form. The finches of the Galapagos Islands, visited by Darwin, provide us with an excellent case in point, in which their beak form helps to define their difference, selected for by the different foods they encountered on the different islands of the Galapagos Archipelago. You might think that that is a rather nineteenth-century example (not even last century), but the Galapagos finches continue to provide excellent examples of the mechanisms of evolution, such as mechanisms of *modularity*, the way in which different evolutionary traits can be inherited together[18] – something we can understand using the same kinds of approach, such as polymorphism analysis, that were used in the People of the British Isles project. Examples of classification applied to speciation can be multiplied almost indefinitely;

another modern example is when a new kind of hominid is identified on the basis of half a jawbone – that is, when the individual from whom a fossilised jawbone derives is classified with us as a member of the hominid set of species. In molecular studies, the similarity of structure found for proteins making up the protective coats of viruses infecting very different kinds of host shows an evolutionary relationship and indicates a common ancestor (see discussion in Chapter 2). It classifies them together.

One classic meta-analysis of the physical nature of living things, seeking a mathematical and physical description of biological phenomena, is D'Arcy Thompson's 1917 book *On Growth and Form*. A number of examples could be given of ways in which Thompson performs classification using his visual judgement of similarity – spirals in leaf patterns and seashells, the arches of vertebrate backbones, and so on – but the one I wish to highlight concerns a form of symmetry found in a great range of different scales in the biosphere, that based on hexagonal arrays of building blocks. Such an array will extend without curvature, but, if you introduce a set of pentagons (as in a football), then the hexagonal sheet closes up into a spherical or quasi-spherical closed shell. This gives you one of the Platonic solids we encountered in Chapter 2, the icosahedron. You find these structures in the form of pollen grains, the outer shells of Radiolarians (kinds of single-celled marine animal, or zooplankton),[19] also the coats of vesicular bodies transporting material around our cells, the structure of the enzyme in mitochondria that makes the transition from anaerobic to aerobic respiration, and, as we noted before, in virus coats ('capsids'). D'Arcy Thompson classified a single biological 'idea', one whose definition tells us something interesting about the fundamentally geometric basis of biological function. In much science, then, we build on what Martin Kemp calls 'the human proclivity to visualize geometrical order in the apparent chaos of complex systems in nature' – exploiting our 'structural intuitions of wholes and parts', whether we are an 'artist' or a 'scientist'.[20]

Symmetry

Clearly, the use of arrays of hexagons closed into shells by the use of inserted pentagons (or pentagon-shaped defects in the arrays) is an example of symmetry in biology – of a point group or 3D symmetrical arrangement. One famous commentary on the presence of symmetry in nature and in the structure of the Universe more generally is that by Herman Weyl. Concerning, for example, the icosahedral and other point group symmetries displayed by many biological objects, Weyl comments:

> The fact that there is for every number $n = 3, 4, 5 \ldots$ a regular polygon of n sides is closely related to the existence for every n of a rotational group of order n in plane geometry. Both facts are far from trivial. Indeed, the situation in three dimensions is altogether different: there do not exist infinitely many regular polyhedra in 3-space, but not more than five, often called the Platonic solids because they play an eminent role in Plato's natural philosophy.[21]

The existence of the Platonic solids is an outstanding example of something that Plato and others intuited and that has turned out to be a fundamental aspect of the way in which the world is constructed. The identification of the group of objects known as the Platonic solids is an example of the power of our aesthetic appreciation of symmetry to inform our objective understanding of the structure of reality.

Symmetry is one of the more obvious examples of how aesthetics can inform scientific understanding, and in fact the one that seems to spring most often, most immediately to mind when the involvement of aesthetic thinking in science is discussed. At least part of the reason for this is the fact that symmetry plainly is so frequent a feature of the world we live in, the world of 'medium-sized objects', if you like, which is the everyday ecology of human beings.[22] Many things in the world we inhabit show rotational symmetry – when you look at them, you can rotate them and then can (more or less) superimpose them on themselves. Flowers in our gardens frequently show rotational symmetry, as does a section through an orange and a starfish. Many things in our world also show bilateral or line symmetry – an apparent mirror plane – such as the patterns on a butterfly's wings, the feather of a peacock's tail, the human face and the outside of a human body. We also frequently encounter helical or spiral symmetry – in snail and sea shells and the organisation of leaves on a tree and of seeds in a sunflower. Many such objects follow a particular form of spiral symmetry, the Fibonacci sequence that governs, not only how objects are organised within themselves, but also, apparently, the possible ways in which organisation can occur. For example, the numbers of petals in flowers are frequently Fibonacci numbers.[23]

Of course, symmetry is an aspect of the way in which aesthetic judgement plays a role in the way people do science, but, for my purposes, it is only a relatively minor aspect of it. Reduced to just appreciations of symmetry, our aesthetic judgement of the world can become what Philip Ball calls 'mathematics-worship'.[24] And this is not my point at all. The symmetrical has something pleasing about it, but human aesthetic sense can be as (or more) drawn to broken symmetry – in another person, to the things that make us unique, our unevenness and lop-sidedness;[25] in a landscape, to the single tree that stands out on a horizon; in a piece of music, to the unidirectional pattern that develops as it repeats and does not just stay the same; in a painting, to the patterns of light and shade. In science, too, it is often broken symmetry, the unique instance, the gradient in a chemical's concentration, that attracts our notice, that piques our interest. Philip Ball cites the seventeenth-century philosopher Francis Bacon: 'There is no excellent beauty that hath not some strangeness in the proportion'. I noted in Chapter 2 the example of the structure of DNA (something outside the realm of medium-sized objects) as having been defined using aesthetic principles – and, in its case, yes, principles of symmetry: it is a *double helix* (doubly symmetrical indeed). But, of course, at the chemical level, DNA is *not* symmetrical: its chemical bases are variable – that's why it can encode genetic information – and this break in the symmetry is itself aesthetically pleasing. The replication of DNA is also a break in its symmetry – it is

a unidirectional flow in a pattern of nature. Somewhere even further from the world of medium-sized objects (about as far as you can get, I guess) is the Big Bang – the symmetrical explosion of material that began the Universe. But, what is critical above all in that explosion is the presence of asymmetry – asymmetry between matter and anti-matter – which enables anything at all to exist.

Philip Ball wants to defend the aesthetic judgements we make from what he sees as the scientist's tendency to reduce 'beauty' to symmetry and simplicity. I could not agree more that the way in which our appreciation empowers science is far more than in the symmetrical and the simple:

> If, on the other hand, we want beauty in science to make contact with aesthetics in art, I believe we should seek it precisely in the human aspect: in ingenious experimental design, elegance of theoretical logic, gentle clarity of exposition, imaginative leaps of reasoning. These things are not vital for a theory that works, an experiment that succeeds, an explanation that enchants and enlightens. But they are rather lovely. Beauty, unlike truth or nature, is something we make ourselves.[26]

This is, in a sense, my whole point.

Mathematical equations

Except, the beauty we find in the world is not *just* something we make ourselves. It is, also, something we find to be really there, despite the fact we're making it up, and one of the standout examples of that is the capacity of mathematics to preconceive the structures of our universe – far outside our everyday perceptions, the world of medium-sized objects.

Mathematics is a language developed by human beings to define relationships and to equate one aspect of a system with another. We will take a very simple case, the equation describing the free energy in a system, G. The change in G, or ΔG, can be equated to the change in two other quantities, the enthalpy (or heat, H) of a system and the entropy (or disorder, S) of a system, in this way:

$$\Delta G = \Delta H - T\Delta S$$

First-year biochemists learn to apply this simple equation, which says (obviously) that the change in free energy, ΔG, can actually be described from two different aspects – change in heat (did the system/reaction get hotter (+) or colder (–)?) and change in disorder (did the system get more (+) or less (–) disordered?). Apart from H and S, G is also (as you can see) a function of the temperature, T, of the system – in this case, the absolute temperature.[27] So, we can measure the heat of a system and we can talk about how the occurrence of a reaction in a system changes its level of order.[28] *However*, the interesting thing this equation says is that thinking about heat or disorder on their own is an inadequate

way to describe what's going on; a much better overall description – which tells you in fact whether at, say, a given temperature the reaction described by our equation will actually occur – is to put them together, weighted *by* that temperature, to give you G. If G is positive, the reaction will not occur spontaneously; if it is negative, then it will, because the system will contain all the energy needed for the reaction to take place.

A very simple example, but playing with symbols allows you to find different ways of relating or equating quantities (such as H, S and G) to each other. For example, you could talk, not about the change in H, or ΔH, but about the rate of change of H, dH/dt (where t = time). The integral of dH/dt is a mathematical function that describes the 'rules' governing that rate of change and can also provide a summary of the system (for example, how many molecules are involved in a process). Differential calculus allows us to describe how something is changing, and integral calculus allows us to calculate the mathematical relationship governing that rate of change. Integrating under the curve describing the rate of change gives the area under that curve, a measure of the total contents of the system.

Thus, calculus provides better ways to capture what's going on in a dynamic system than individual measurements of particular quantities (such as heat) at individual times could. But, such feats of symbolic tool development allowing new kinds of analysis are not particularly novel phenomena – complex mathematics didn't become possible only in 1600. In fact, the mathematical tools needed to formulate hypotheses of deep inference began in various parts of the ancient world. 'Not only did Archimedes all but invent the integral calculus nearly two millennia before Newton and Leibniz, but he also came within a whisker of pre-empting them on differential calculus too.'[29] The genealogy of the mathematical tools needed for Newtonian physics, and indeed much simple understanding of the rates of processes in the physical and biological sciences, pre-dated conditions that forced them out into the open owing to the pressure of data, by 2,000 years.

Here are two other examples, which both look like quite simple relationships. One is a theorem proposed by Pythagoras,

$$x^2 + y^2 = z^2$$

to relate the lengths of the sides of a right-angled triangle. Maybe that doesn't count as a deep inference, though it is a useful thing to know. The other is what you could call an anti-theorem associated with Fermat,

$$x^n + y^n \neq z^n$$

where n is an integer greater than 2, so that it will never be the case that what is true for the squares of the sides of right-angled triangles is also true for any other higher power term, for any number. That is deep inference, and Fermat himself famously wrote that he had a proof in his mind but that he didn't

have space to write it down. Andrew Wiles provided such a proof in 1995, an achievement recognised by the award of the top international prize in mathematics, the Abel Prize, in 2016.[30] How such proofs are found is often said to relate closely to an aesthetic sense. Henri Poincaré is one mathematician who was clear in saying so:

> It may appear surprising that sensibility should be introduced in connection with mathematical demonstrations, which, it would seem, can only interest the intellect. But not if we bear in mind the feeling of mathematical beauty, of the harmony of numbers and forms and of geometric elegance. It's a real aesthetic feeling that all mathematicians recognize, and this is truly sensibility . . . The useful combinations are precisely the most beautiful.[31]

In his work, Poincaré saw himself as selecting from a range of possibilities present to him as 'sensual imagery' the most fitting answer:

> Invention, Poincaré maintained, is selection. But the intuitions that guide the mathematician in his work are extremely subtle and delicate: a special sensibility – 'a sort of aesthetic emotion' – helps him separate out that which is 'harmoniously arranged' and filled with 'elegance' and 'beauty'.[32]

The proof of Pythagoras's theorem is more easily made than the proof of Fermat's Last Theorem, using geometric arguments as beautifully described in the recent book (mentioned briefly in Chapter 1) *A Beautiful Question*, by Frank Wilczek.[33] Wilczek begins his book by asking two related questions, which are:

> Does the world embody beautiful ideas?

and

> Is the world a work of art?[34]

His ultimate answer is, unsurprisingly, Yes, and throughout he is keen to explore in particular the ways in which what is Ideal to our thinking turns out to be what is Real in the world, in which what we think would be pleasing chimes with reality.

Pythagoras provides the starting point for Wilczek's exploration of the role of our appreciation of beauty in the understanding we have of the nature of the universe. He begins with Pythagoras's conviction that All Is Number, that numbers and the relationships between them underpin reality, as revealed in the way in which number gives us a way to understand the nature and organisation of matter.[35] In addition, Pythagoras found simple mathematical relationships between the length and the tension of strings within musical instruments when

the notes they produce are heard by us to be in harmony with one another. The ratio of the lengths of two vibrating strings that seem in harmony to us are in small whole numbers, and 'tones are in harmony if the tensions [of strings] are ratios of *squares* of small whole numbers'.[36] Wilczek argues that tonal frequencies are represented in our brains by frequencies of nervous activity, and that the *pleasure* we gain (the harmony we hear) derives from our capacity to predict the ratios of small whole numbers found in the tones.[37] This is one example of why and how our sense of beauty is general, and of how, whether we are contemplating music or the harmony of a possible unified theory of everything, our personalities are delighted in equivalent ways.[38] Thus, Wilczek has come to think that the 'promotion of learning underlies, and is the evolutionary cause of, our sense of beauty in important cases'.[39]

The importance of Wilczek's view of music for his scientific discussion is made clear by the fact that the equations that describe the (very) fine details of atomic structure and also the operation of light are essentially the same as those that govern musical instruments and sound.[40] They depend on the frequency of wavelike systems in confined spaces. This is not a trivial observation, and *A Beautiful Question* enables Wilczek to explore some possible equations that may provide a unified description of the fine structure of the universe. As a musician *and* a theoretical physicist, he is quite justified in his assertion that, 'Atoms are musical instruments, and the light they emit makes their tones visible',[41] as he explores the sense in which atoms *emerge* from laws[42] and do so as beautiful objects that gladden the observer with their beauty and their truth. Wilczek discusses the work of Niels Bohr on the structure of the hydrogen atom, whereby prediction of the differences in energy between different electronic states enabled correct prediction of the colours of the spectrum of light emitted by hydrogen (for example, when burnt). This is what Albert Einstein had to say about Bohr's work:

> That this insecure and contradictory foundation was sufficient to enable a man of Bohr's unique instinct and tact to discover the major law of spectral lines and of the electron-shells of the atoms . . . appeared to me as a miracle – and appears to me as a miracle even today. This is the highest form of musicality in the sphere of thought.[43]

One aspect of music that echoes, in a sense, its fundamental construction out of sounds of different defined frequencies is the impact of repetition in its construction, one aspect of which is the impact of rhythm, another being the use of a leitmotif, a third being the use of a ground bass to underpin the rest of a composition. Structured repetition such as this has a kind of symmetry to it, providing a formal framework to define the interrelationship of the tones or phrases undergoing repetition. And yet, each time a phrase is repeated, it is *not* the same, because its location in the composition is different. We hear it differently as the music builds; it changes, but also stays the same in some recognisable way – which is the whole point of repetition. 'Change without

change' is Wilczek's shorthand for symmetry, especially the kinds of symmetry that define the relationships on which he works in theoretical physics, and in fact symmetry of this kind is the dominant theme in his book asking his beautiful question. This is symmetry that equates one thing to another, related by a specific operation, whether it's a rotational and translational kind of operation in 2D or 3D space, or a transformation of the internal states of motion of subatomic particles in ten dimensions.[44]

An equilateral triangle has threefold rotational symmetry in two dimensions, in which its vertices are related by 120° rotations ($3 \times 120 = 360°$); an icosahedron contains points of fivefold symmetry related by 72° rotations ($5 \times 72 = 360°$), but those rotations occur in 3D space, not the 2D occupied by the triangle. Interconversion of protons and neutrons is a function of a Galilean (named after Galileo) transformation and constitutes a change in the motional properties, or energy, of a system while it maintains the same local structure, or mathematical relationships; proton ↔ neutron interconversions occur in 10D space.

Wilczek considers Platonic solids as examples of early types of symmetry that got people's pulses racing, as a starting point for his exploration of how symmetries, hand in hand with their mathematical expression, allow us to propose structures for physical systems that explain the way they behave. Our love of symmetry begins as a love for the balance and proportion and – as with musical appreciation – predictability of physical structures, and leads us to higher and higher levels of symmetry, in which the relationships between equivalent regions of space are locked together in more and more complex ways.[45] Plato's intuition was 'that the physical world must, fundamentally, embody beautiful concepts. And this beauty must be of a very special kind: the beauty of mathematical regularity, of perfect symmetry'.[46] Frank Wilczek's aim is to show quite how profound Plato's intuition, like that of Pythagoras, was. So:

> we are led to a small number of special structures from purely mathematical considerations – considerations of symmetry – and put them forward to Nature, as candidate elements for her design . . . The far-fetched idea that *symmetry dictates structure* . . . has become, at the unmapped frontiers of the unknown, our guiding star.[47]

As he says later:

> We have learned to work from symmetry toward truth. Instead of using experiments to infer equations, and then finding (to our delight and astonishment) that the equations have a lot of symmetry, we propose equations with enormous symmetry and then check to see whether Nature uses them. It has been an amazingly successful strategy.[48]

The physicist Wilczek admires most is James Clerk Maxwell, whose equations enabled understanding of the interrelation of forces that had previously

been considered separate, such as magnetism and electricity. They again rely on Galilean symmetry – in which the symmetric transformation consists in the motion of an otherwise unchanging system: the rotation of a magnet generates electricity. The four laws already known before Maxwell's time that he interrelated with his equations are the electric Gauss's law, the magnetic Gauss's law, Faraday's law (why rotation of a magnet generates electricity) and Ampère's law. This enabled Maxwell to add a fifth, his own law, which simply says (in another Galilean transformation and Faraday's law put back to front) that, 'when electric fields change with time, they cause magnetic fields to swirl around them'.[49] The beauty of Maxwell's equations, says Wilczek, 'derives from many sources: from the way they were discovered, from their shape, from their power to inspire other good ideas',[50] including his own. They are 'a *great* work of art'.[51] They stand alone, like a great painting, exceeding the intentions of their author, with 'an independent existence and an intelligence of their own . . . wiser than we are, wiser even than their discoverers . . . we get more out of them than was originally put into them'.[52] Einstein agreed and saw the beautiful symmetry of Maxwell's work to have autonomy, a life of its own.[53] In turn, in the quantum chromodynamics that Wilczek himself describes, far more emerges from his theoretical calculations, tightly constrained by their multidimensional symmetry, than is actually put into them.[54] The beautiful ideas about relationships between entities that Wilczek describes have their own creativity. The same is true for the beautiful and revelatory proof that Andrew Wiles provided of Fermat's Last Theorem.

In his review of Wilczek's book, Graham Farmelo pointed out that Picasso had commented in the 1940s how he hated 'the aesthetic game of the eye and the mind' about beauty; beauty does not exist, he said.[55] You can argue that beauty as such does not exist, and I could agree – the perception of beauty is a property of the mind. Like other reflections on the subjectivity of aesthetic judgement, this I think underscores the usefulness of the questions I am asking in this book, as it highlights the very odd way in which *thinking something beautiful* can also be for us a medium of truthfulness and understanding. Cait McPhee, in her review, also homes in on the challenge to arguments such as Wilczek's and mine posed by the subjectivity of finding something beautiful, on the fact we have a right to our own sense of what is beautiful. But, as a biophysicist herself, she sees the way in which unpicking the structure of reality does help us to understand how very beautiful the world is, from a human perspective at least: 'by unweaving the rainbow, we add to its beauty rather than detract from it'.[56] And, in his review, Martin Kemp sees that Wilczek's argument shows how, though there is 'an ordering impulse in all of us', some:

> extraordinary scientists (and artists) have been able to satisfy our needs at incredibly high levels. Our incessant quests for order in science and art can be grouped under the collective term 'structural intuitions'. The historical progression is from static patterns to orders that involve dynamism,

> process, fields of energy, and the duality of waves and particles, moving decisively beyond the narrow observational span of the frequencies of light that we can actually perceive.[57]

It is a historical progression driven by a developing taste for beauty of wilder and more intricate and extreme forms (a bit like learning to appreciate atonal music). Kemp interestingly points out how Wilczek's attempts to explain the meaning of his work in terms of visual 'metaphors' should really be seen as an analogical process – which introduces a new level of aesthetic appreciation into the work being described. Not only is the work beautiful to the theoretical physicist, he is making use of aesthetic judgement in the way in which he seeks to communicate what he understands about reality to the general public. Maybe this is the sense in which the beauty Wilczek sees in a systematic description of the basis of atomic phenomena is analogous to the appreciation anyone can have for a work of art 'in which narrative, various kinds of content, viewing contexts, psychological noise and expectation play such an influential role'.[58] Maybe 'any concept of beauty that strives to embrace the scientifically geometrical and the humanly ragged becomes so fuzzy as to be uninstructive',[59] but the cultures and the psychologies that produce works of art have to start somewhere, and where they start is with the common human experience of pleasure in the world around us. The capacity to use playing with numbers and their symmetrical transformations to identify the physical basis of atomic properties started in the same place, based on the same basic evolutionary inheritance and emerging from the same system of human cultures. Its power is extraordinary – and anyone can see that from the excitement that accompanies experiments which prove theoretical conjectures correct, whether the Higgs particle and field (or fluid),[60] or the existence of gravitational waves 100 years after Albert Einstein's prediction.[61]

Molecular structure

The kind of imagination and selection of a most fitting solution, and appreciation of its beauty, which seems to be so important in mathematics, is no less important in the molecular sciences. Jean-Pierre Changeux points out how his friend Jacques Monod was helped to understand biomolecular processes by imagining himself to be a protein molecule, just like Einstein and Poincaré solved the problems they set themselves via the enjoyment of mental states in which the problems are reconstructed in their minds: sensory imagination, a kind of 'melody'.[62]

The beauty I see in molecular structure is the reason I became a biochemist. I remember vividly the appreciation I had for a rather simple structure – ethylene diamine tetra-acetic acid, or EDTA, in a chemistry lesson at school (Figure 3.1a). EDTA binds metal ions, curling around them to clasp them multiple times. I had been given a molecular modelling kit by a family friend that had belonged to her father, and I went home and made myself a model of

EDTA, just for my own aesthetic enjoyment, but one that helped me understand better its properties as well.

When I realised, also at school, that whole protein molecules could obviously be understood at the same level of detail, and with the same delight I found in the isolated EDTA bound to its metal, this in combination with an interest in evolution led me strongly towards the scientific studies I then followed at university and have kept on with since. What is it that is so beautiful about a molecular structure? Mathematicians talk of the elegance and symmetry of their work; Andrew Wiles described his realisation of the way in which Fermat's Last Theorem could be proved as 'so indescribably beautiful . . . so simple and so elegant'[63] – and as a non-mathematician I accept his testimony. How would I explain the beauty I find in molecular structure?

Part of the answer is to do with symmetry, again, but only part. Another set of molecular structures I encountered while at school were buckyballs – buckminsterfullerenes, spherical carbon, named for the American architect Buckminster Fuller who built using symmetrical ideas related to those they possess, where hexagonal and pentagonal arrangements of carbon atoms create closed shells (Figure 3.1b). This is a symmetry type we have met several times before, the Platonic icosahedral symmetry, and C_{60}, the simplest fullerene, follows it perfectly. Larger numbers of carbon atoms create larger buckyballs, with distorted global symmetry, but the use of the same local rules (sheets of hexagonally arranged atoms that can curl to become closed shells owing to the inclusion of pentagonal arrangements as well) and the same distorted application of local symmetry allows the protein clathrin to enclose vesicles of different sizes inside living cells and the core structure of HIV to form a fullerene cone.

Protein molecules such as those that are used to construct viral capsids and clathrin-coated vesicles have their own elegance and aesthetic appeal, though they lack the repetitive structure of a symmetrical object. For example, I find elegance in the economical way in which they enable the presentation of chemistry on a controllably dynamic surface. In catalytic converters, noxious gases from car exhausts are reacted with oxygen from the air to produce less toxic compounds, such as carbon dioxide, assisted by platinum, which acts as the catalyst. To make the reaction efficient, the surface area of the platinum is maximised via a porous meshwork-like arrangement; the reaction occurs at the air–solid interface, on the metal surface. Although catalytic converters are static objects made of metal, and proteins are always on the move, proteins similarly carry out their reactions at their surfaces or within cavities on their surfaces. In addition to their capacity to change shape, however, the complex chemistry of the protein (being made out of twenty different amino acids in a combination and sequence unique to the particular protein in question) and the inherent malleability and responsiveness of the protein surface result in an exquisite and elegant compartmentalisation and specificity of chemical reactivity. Perceiving this elegance is inherently thrilling for a structural biologist like myself.

An example of the aesthetic appeal of a protein structure is the way in which the backbone of the protein is threaded and twisted, like a ribbon used in a

dance (Figure 3.1c). The ribbon of the protein backbone can twist and thread in any number of ways, in principle (though there is likely to be a rather limited number of ways in which they actually are). The precise topology of the way the ribbon is woven around itself then defines the type of protein structure and provides the basis of its function. Two proteins with the same or similar

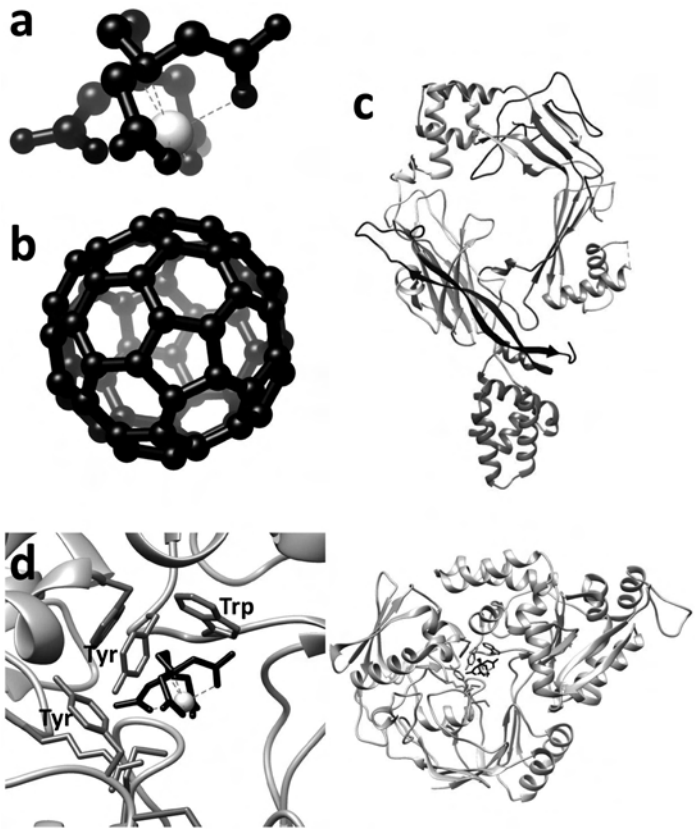

Figure 3.1 a: The structure of EDTA (black and grey) bound to an iron ion Fe^{3+}, taken from the structure of the nickel transporter NikA from the bacterium Brucella suis.[64] All the molecular structures shown were drawn using the freeware *Chimera*.[65] b: C_{60}, a buckminsterfullerene. c: The structure of astrotactin-2 endoluminal domain, recently solved by my colleague and former student Tao Ni. d: The structure of EDTA in the context of the NikA protein, interacting with three aromatic amino acid sidechains, one tryptophan (Trp) and two tyrosines (Tyr). The left-hand image is a close-up of the right-hand one. Depictions such as those shown in this figure and also in Figure 3.2 prioritise particular features of what we want to show; we make choices to highlight what we think is significant.[66]

topology are very likely to have a common evolutionary ancestor, and the more complex the topology they share, the more likely this is.

At higher resolution (in finer detail), at the atomic scale, the beauty in a protein structure is found in the organisation of the sidechains that project from its backbone (Figure 3.1d); their precise configuration is the basis of the chemical specificity of both the protein fold and its function, including the way in which it recognises other proteins or other kinds of molecule it must bind as part of its activity – enzymes bind their substrates, protein hormones (such as insulin) bind their receptors, and so on. Part of the aesthetic appeal a protein structure possesses is the capacity it provides us to predict its function, to form hypotheses on the basis of the details it reveals, and so to explore the way in which its chemistry and biology interrelate via a testing of those hypotheses. Another part is in the way in which the protein structure is found to *fit* its function – and if that involves the binding of another molecule then literally the way the two *fit together* (Figure 3.2a). And, such an appreciation of fit reminds us of the fact that, however much I enjoy the experience of seeing the entwining of molecules with one another, the embrace of one by another, the interpenetration of molecular species, there are hard scientific inferences to be made at the same time. The more I enjoy appreciating the interaction of two molecules, the more likely I am to keep my gaze on them long enough to make the connections I need in order to gain a new understanding of the bit of biology I am looking at. And, once I find a convincing way to vocalise and explain that new understanding, and to publish it, it no longer belongs to me but instead is held in common ownership by the community of scientists and others who learn about it and come to share my understanding, and then improve on it.

The structure of DNA is another molecular structure with substantial aesthetic appeal and yielded one of the most important interpretative leaps made in the twentieth century (Figure 3.2b). The paper by Watson and Crick describing the structure is couched almost entirely in idealistic terms, constrained by some basic pieces of information such as the relative ratios of the DNA bases that pair with one another down the backbone of the famous double helix.[67] The fact that genomes universally show a 1:1 ratio in the use of adenine and thymine and of guanine and cytosine (Chargaff's rule) indicates that they must be paired, somehow: an artistic way to make that work is an antiparallel double helix. Crick and Watson end their paper: 'It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material'. A low-key statement on the face of it, I suppose, but their structural model of DNA unlocked a whole world of understanding for the basis of heredity.

DNA is not the only nucleic acid we can understand in atomic resolution terms. Its older cousin RNA is generally believed to have provided the starting point for all existing life: like DNA, it can exist in a double-helical structure and, like DNA, it can template its own replication because of the same kind

of base-pairing mechanism that Watson and Crick stumbled across (except that thymine is replaced with uracil). RNA is, however, a more complicated molecule in that it can more commonly exist in single-stranded as opposed to double-stranded forms, and it contains an additional hydroxyl (-OH) group, which gives it greater chemical reactivity. On this basis, it is thought to have provided the origin for all existing life, as it could both *encode* inheritable sequences of nucleic acid basis and also *enact* the chemical reactions that characterise 'life'. DNA is a rather inert substance bearing 'information' – if the chemical sequences it contains can be read appropriately by specific proteins that bind it, for example. RNA is a rather reactive substance that both bears 'information' and provides for the 'reading' of that information, for example by

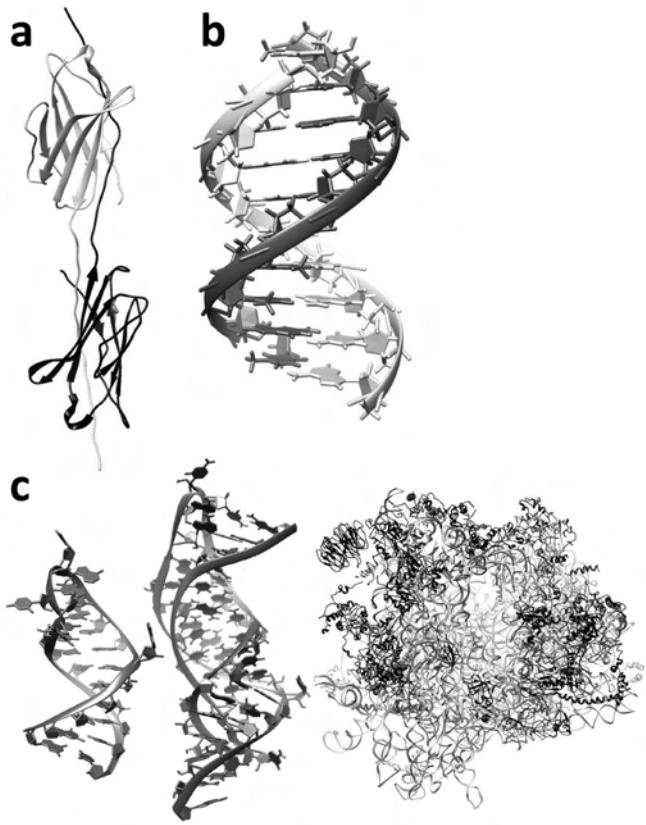

Figure 3.2 a: The structure of the T-cell co-receptor protein CTLA-4 in a 'strand-swapped' form, as solved some years ago by my former student Andreas Sonnen. b: The structure of B-form DNA. c: From left, an RNA stem loop, an RNA pseudoknot and the structure of the yeast ribosome in which three rRNA molecules (in grey ribbon) are complexed with many proteins (black).[68]

carrying out enzymatic reactions.[69] It exists in a more diverse range of conformations than DNA – stem loops, pseudoknots, and yet more complex tangles, all defined by the specific base sequence the molecule has (Figure 3.2c). RNA and DNA, like proteins, exemplify the way in which the aesthetic appeal of molecular studies enables discoveries of the most fundamental kind for biology, medicine and technology.

The interior of the living cell

Cell biology, the study of the processes of gene expression and of the molecular interactions that determine cell shape, cell growth, cell division, cell movement, cell polarity, and so on, involves the construction of complex models that put the various data available together into as coherent a scheme as possible. The individual bits of data can often be rather noisy, acquired by painstaking experimental repetition and statistical analysis – for example, showing that, when the expression of one particular protein goes up, the levels of another particular RNA molecule with a signalling role go down, and vice versa. The manual, practical work required can keep the experimenter up all night and drag them to the lab at the weekend so that they can run their experiments again and again and work towards a satisfying verification of the hunch they are testing. Such experimentation (and the same goes for the day-to-day work of a chemist or physicist) involves basic scientific practices that exercise our human aesthetic responses and that we shall look at in Chapter 4 – playing games, using toys, indulging in make-believe and what-if speculation, and telling stories. For physicists, a satisfying simplification in our understanding of reality or application of it (for example, in the development of superconducting magnets) is a common goal: codification in aesthetic, pleasing terms of simplicity, or the construction of a new kind of substance or technology. For chemists, the mapping of new routes to the synthesis of useful or just plain interesting substances, whether organic or inorganic, or the development of new physical methods and technologies is a common goal. It is as if chemists are working to define the rules of completely new games, such as how to get a desired substance more simply, which can be played again and again (to make more and more – for example, more drug or more synthetic polymer).

In terms of game playing, cell biologists, like physicists and chemists, are working towards a new synthesis, a new understanding, a neatening-up of reality that satisfies. But, whereas many chemists and physicists are often working towards something concrete, that they will actually make, the cell biologist has more in common with theoretical physicists such as Frank Wilczek than she does with many of the physical scientists who, like her, get their hands dirty in the lab. At extremes of natural science – on the one hand, the messiness of biology, with its cell culturing and harvesting and its bit-by-bit dissection of cellular and organismal function, on the other hand, the ten-dimensional symmetry of Wilczek's unified theory – there is a common searching for a synthesis of data that gives a route *to* understanding and to the sharing *of* understanding.

And yet, whereas the syntheses of theoretical physics have a drive and a tendency towards simple elegance (not that ten dimensions is especially simple), the syntheses of cell biology have a tendency towards complexity. In fact, the models for regulation of signalling networks with which cell biologists nowadays have to work are sometimes too complex for a diagrammatic representation in an ordinary sense and require computational encoding to enable understanding, and the data are sometimes now of such volume and variety that they can only be analysed usefully by computational and statistical methods. The 'systems biology' movement is now morphing into the field known as 'Big Data', where statistical analysis is as key as it was for the genetic information we considered earlier in this chapter.

And yet, even if the models derived from cell biology data are getting to be sometimes too unwieldy to be put down on the page, and the data that feed them are becoming too complex and potentially noisy to make sense to the casual observer, cellular and developmental biologists are looking to make a synthesis, to construct a model, and those syntheses and models are in themselves aesthetically very pleasing for the balance and harmony they express, and for the meaning they communicate (Figure 3.3a). They are like poems made from symbols and connecting lines of relationship (this makes that, or this switches off that). Cell biologists draw together their accumulated knowledge and use the construction of a model, which neatens and provides understanding and a basis for prediction, to take breath and prepare for the next set of studies. The models constructed by cellular and developmental biologists are equivalent for their research to the 3D atomic structures of structural biologists and biophysicists.

The 3D framework within which cell biologists construct their models is shaped by the actual contours and compartments of a cell. Our knowledge here is enabled by direct imaging using a suite of microscopic techniques. Electron microscopy has historically allowed us to carve up the inside of a cell – to spot this feature or that, to identify subregions of the cell nucleus, to trace the network of tubules and enclosures dividing reactions from one another and maintaining a complex ecology of alternative environments: acidic, oxidative, reducing. Nowadays, cryo-electron tomography is allowing us to do this in unprecedented detail, and to understand in new ways just how it is living cells manage to do what they do (Figure 3.3b). By cooling a cell at a rate of 10,000 degrees per second (with the help of liquid ethane), we can capture freeze-frames of multiple views of the same event happening and use that information to come to a new understanding. If the cell is a bit thick to get electrons to shine through efficiently enough to allow imaging, we can etch away and carve out a thinner patch using something called a focused ion beam of gallium ions – so this means we can now dissect cells manually.

The problem with electron microscopy currently is that the sample must be dry, because it needs to be mounted in a vacuum. This is why, in cryo-microscopy, we cool the sample – the water in the specimen becomes supercooled and effectively solid, and so effectively dry. Glass is a supercooled

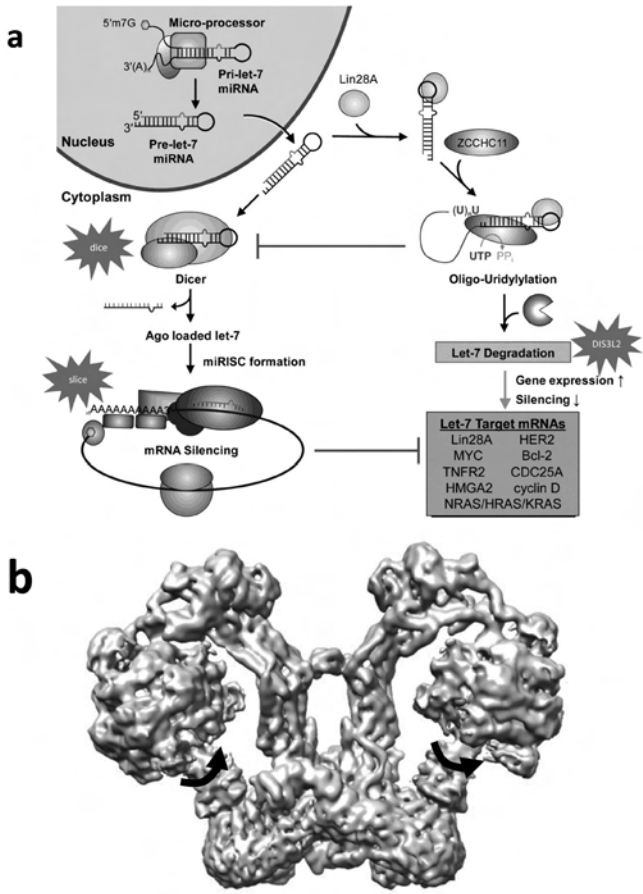

Figure 3.3 a: Signalling schematic for the control of a series of tumour-promoting proteins (Lin28A, MYC etc.) by microRNAs (miRNAs) of the let-7 family. b: Isosurface representation of electron density for a mitochondrial ATP synthase dimer, the basic unit of aerobic energy production in all nucleated cells. This structure was determined from cryo-electron tomography data.[70]

liquid at ambient temperature, so we term this state 'vitreous'. Often, though, we would like to image a process in real time – and light microscopy allows us to do that. Low-powered light microscopes allow us to see inside cells, but without anything like the detail electron microscopy allows. The development of super-resolution microscopy techniques, which gained Eric Betzig, Stefan Hell and William Moerner the Nobel Prize in Chemistry in 2014, allows us to see in much finer detail the beauties of cell biology, in real time, picking up the

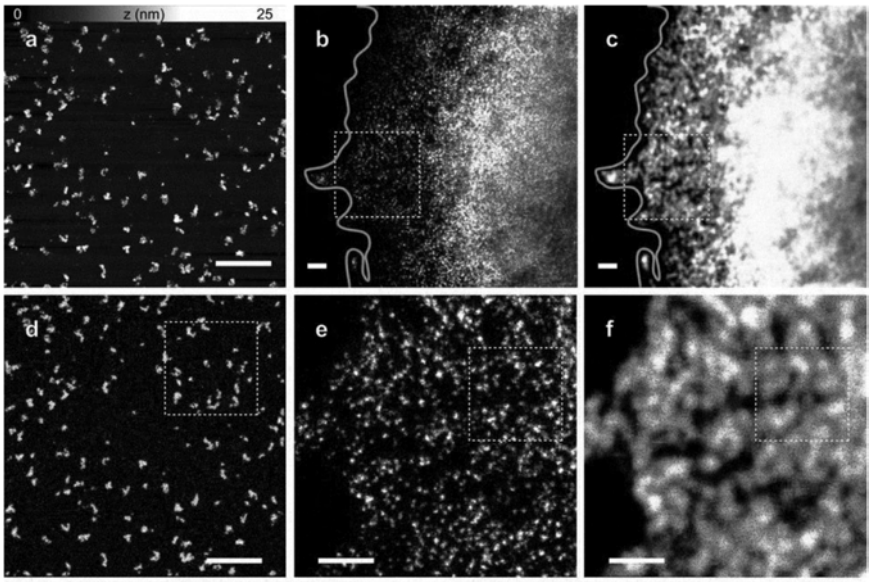

Figure 3.4 a: Atomic force microscopy image of small clusters of ribosomes (polysomes), which are the protein-producing factories of cells. b: Super-resolution (STED) image of ribosomes inside a breast cancer cell line cell. c: The same area as panel b seen with standard confocal scanning laser light microscopy. The higher resolution (increased granularity) of the STED image is clear. d: The image in panel a manipulated to have the same data transfer profile as the STED image. e: A close-up of the area boxed in panel b. Individual ribosome clusters can be resolved. f: A close-up of the area boxed in panel c. Individual ribosome clusters cannot be resolved. From a paper published in collaboration with Gabriella Viero and Alessandro Quattrone.[71]

location of individual molecules owing to specific fluorescent tags with which they have been equipped (Figure 3.4). This provides a scientist such as myself with opportunities to image the fine structure of the interior of a living cell – a thing of great beauty.

Physiology

The diagrams developed by cellular and developmental biologists will sometimes simplify their presentation down to the single cell, so that the viewer can get their understanding in gear, even though the reality of a system involves the whole body functioning as a living organism. At other times, the interconnections involved require a whole-body depiction. Scientific physiology seems to have started with art, or at least what we would now regard as art.

William Harvey's drawings of the circulation and Leonardo da Vinci's drawings of the human body, of human faces and of organs from within bodies, such as his drawings of the bovine heart,[72] were exercises in understanding. They are now iconic. But Leonardo's drawings were a simultaneous exercise in aesthetic appreciation and scientific discovery – wonder seeking understanding. Art and science were one in Leonardo's mind: 'The artist-scientist extracted rules from nature and could then remake nature in his own works as the ultimate confirmation of natural truth'.[73] This obviously echoes our previous points about analogy and model-making (world-making). Martin Kemp sees Leonardo as sharing 'with many contemporary scientists an ability to move with complete freedom between science and symbolism, between observation and signification, and between fact and fable.'[74] Leaving out the fable, things are I think not very different today – we have to switch backwards and forwards between the scrutinising of data and the constructions of models to explain the data, and often the construction of diagrams that help us think things through, much like Darwin used diagrams to think through natural selection (see Chapter 5). For Leonardo, drawing was simultaneously a form of exploration and of expression – expressing what he could see in the best way he could, while simultaneously seeking an explanation for it in terms of function.[75] Kemp judges the heart studies made in 1513–15 as 'the climax of [Leonardo's] attempt to understand internal functions . . . The heart, in keeping with his vision of universal science, could only be understood in the light of dynamic law and mathematical "necessity"'.[76] Via depiction of the cusped valve at the base of the pulmonary artery, da Vinci found 'a perfect illustration of "necessity" in geometrical action'.[77]

Central to Leonardo da Vinci's art was the use of perspective to give depth and a sense of the actuality of what he was depicting – whether a bovine heart or in the *Mona Lisa*. Perspective was a source of understanding (more, of making-understanding) and of communication, in the depiction of people, bodies, faces, the internal structures of tissues and of organs. To do this he built on a science of art that also enabled him to explore mechanical engineering and the physics of processes such as water flow. 'The mechanical and organic worlds are nowhere to be divorced in Leonardo's science and art.'[78]

In the modern day, there are artists or 'artists' who make use of anatomy for a form of art – such as Damien Hirst and Gunther von Hagens – but the true descendants of Leonardo are the physiologists and technologists who provide striking and moving images of living systems and of their modes of acting. The infant in the womb imaged using hospital ultrasound is one of the most beautiful things many expecting parents will have seen; more advanced modern technologies have allowed us to visualise in unprecedented detail the life of a living foetus *in utero*. Computerised tomography with X-rays (CT scans) and magnetic imaging of tissues via MRI provide ways in which we can image the state and functioning of individual organs in living humans. Functional MRI (fMRI) of the brain is making contributions to our understanding of the roles of its different subregions in distinctively human activities, helping us to move towards an understanding of how meat and meaning meet.

To compare the technologists such as Peter Mansfield (see Chapter 2), whose advances have made fMRI possible, or the manufacturers of CT scanners to Leonardo da Vinci may seem strange, but Leonardo's efforts in drawing a bovine heart, while at least as much art as science, were also at least as much science as art. He wanted to communicate what he could see: he put his skills at the disposal of the communication of understanding and the discovery of new features of reality. The development of fMRI and CT scanning is similarly about the combined discovery and communication of new understanding. And, I would assert that there is something rather beautiful, rather aesthetically engaging, about the kinds of image fMRI or CT scanning produces, and there is obviously something beautiful-and-truthful about the living movements of a foetus in a womb. Such visualisations move us and communicate understanding at the same time. Although the status of a medical image in terms of human artistry and skill may be quite different from that of a Leonardo sketch – for example, the humans arts and skills in use are not the same at all – in either case it has required a human being to make the image and it requires a human being to interpret it and react to it.[79]

'I have a powerful sense that effective art and science both begin at the points where knowledge breaks down. Visual intuitions are one of the most potent tools we possess for feeling our way into the unknown.'[80]

The behaviour of animals

I emphasised above how some of the more recent advances in biological imaging have enabled movies of biological processes to be shot directly. For example, individual vesicles containing defined contents can be observed migrating along the cytoskeletal filaments structuring the inside of cells. But, ethologists have long studied animals in real time, of course, observing their behaviour and providing interpretations of it. In forming those interpretations, they have made much use of principles of analogy, and to do that they have relied on an engagement of their subjective enjoyment of an understanding of animals at work and at play.

To what extent is the use of tools made by animals equivalent to the way we humans use tools? There are similarities, but there are differences. A similarity is the way in which both humans and other animals are resourceful in applying things they find lying around in a mechanical application, as tools: sticks and stones. Another similarity is the way in which humans and other animals can improve on the usefulness of a tool by working the original object. For example, New Caledonian crows – well-characterised avian tool users – will generate hooked tools from sticks and also blade-like stepped-cut tools from *Pandanus* sp. leaves. These tools can be deployed carefully or energetically by the bird and can be laid aside while it feeds its young and then taken up again,[81] much like the way a parent might turn off the vacuum cleaner to see to the needs of an anxious child.

It has been claimed that New Caledonian crows are the most sophisticated non-human manufacturers and users of tools, exceeding even chimpanzees in

ingenuity and dexterity of tool use and manufacture.[82] However, a side-by-side comparison of the crows and chimpanzees indicates that, although it is clear that both are 'excellent makers and users of tools', the chimpanzee shows more sophisticated behaviour.[83] Tool use is categorised in twenty-two categories (those of Shumaker and colleagues).[84] Chimpanzees show all of these forms of tool use, though two (cut and hang) only in captivity. New Caledonian crows have five modes of tool use: drop, pry/apply leverage, probe, reach and jab. Of these, reach and pry/apply leverage have only been observed in captivity. Four kinds of tool-making have also been defined: detach, reduce, reshape and combine – again by Robert Shumaker and colleagues. Chimpanzees show all four modes of manufacture: detach, reduce and reshape, but 'there seems to be no record of crows joining or connecting two or more components to make a single tool'.[85] Even among non-human primates, tool use is by no means universal: most of the more than 200 species of primate 'never or rarely' use tools and, '[w]hen they do, most cases are typically one-off anecdotes or idiosyncratic aberrancies, such as human-reared individuals'.[86] Even among apes tool use is rare, and, although chimpanzees and Sumatran orangutans use tools, the respectively closely related species bonobos and Bornean orangutans do not. Fascinatingly, '*all* great ape taxa experimentally tested in captivity *are* proficient tool-users when placed in facilitating, scaffolded circumstances'.[87] In this way, apes show, again, the power of culture to produce understanding.

Culture has produced the human capacity to make and use tools and to teach tool use, and, in turn, our thinking has been affected by the ways in which we have relied on tools as we developed over the last two-and-a-half million years from primitive hominids into the people we are today.[88] But, for animals such as chimpanzees and New Caledonian crows, there is no culture of this kind of extension or duration – there are family groups, but tool use is not the expression of a culture and it is not generalisable. Of course chimpanzees use tools, but not like us: 'animals do not practice or teach skills. In no case is the use of the tool a local expression of a global sense of personal possibility'.[89] Only humans understand the *concept* of a tool – only humans *have* concepts – and only we recognise that one tool can help you make another, and make use of secondary tools.[90] This is an evolutionary advantage for non-human animals, because it means a parent does not have to teach its young *how* to make a tool: it is an innate capacity acquired reproducibly on the basis of the neuroanatomical complement possessed by certain species, including New Caledonian crows and chimpanzees.

You and I do not think like crows or chimpanzees, but we understand what they are doing with tools by analogy to what we do when we use a tool. This plugs into our aesthetic appreciation – even anthropomorphisation – of their activity. This would perhaps be angrily disputed by ethologists, but the fact is that what we know is human culture, and what they know is nothing like human culture. Yet, it is a human culture that has arisen over millions of years that provides us with the capacity to understand, virtually if not actually in an instant, what the crow or chimp is doing. Gavin Hunt's 1996 paper on tool

use by the New Caledonian crow is explicitly narrative[91] and demonstrates the fact that a snap judgement is made about what one seems an animal doing – as when I see a young deer and fox playing together in the grounds of Magdalen College in Oxford (see Chapter 4). And, this power of our culture is two way: place an animal with a certain level of capability *into* that culture – in what William McGraw calls a facilitated and scaffolded circumstance – and it can acquire a tool use that may be wholly foreign to it in natural circumstances. We emerge from our cultural backgrounds equipped to make sense of the world in all sorts of ways, including the manufacture and use of tools. This allows us to make sense of what an animal is doing with a tool, because we see the fit, the elegance, the 'ingenuity' of its use. Reciprocally, take an animal who knows nothing of human culture and place it within the world we have constructed and, hey presto, it acquires capacities from that culture. Each time that happens will be a first time, and it demonstrates powerfully the structuring impact of culture on the capacity for action and understanding.

In this chapter, we have looked at a series of examples of ways in which scientific humans find beauty everywhere. This has ranged from the mathematics of the cosmos to the observation of crows in South Pacific islands. In each case, I have tried to show how the human capacity to appreciate beauty enables new forms of understanding to be gained. In the next chapter, we will look at one specific kind of human aesthetic enjoyment of the world – playfulness – as a key aspect of the way scientists work.

Notes

1 Grayson Perry, *Playing to the Gallery*, p. 15.
2 The conductor Daniel Harding on Richard Feynman, in the video introducing the Swedish Radio Symphony Orchestra's series *Interplay*. See: www.askonasholt.co.uk/mediaplayer/artist/daniel-harding/video/1037. I am grateful to his father, John Harding, a parishioner, for making me aware of this project.
3 Marcus Du Sautoy speaking as part of the SRSO's *Interplay* series. See note 1 above.
4 See Airlie McCoy, 'Liking likelihood' (*Acta Crystallographica*, *D60*, 2169–83. http://journals.iucr.org/d/issues/2004/12/01/ba5064/ba5064.pdf), for an explanation of Bayesian statistics using the example of predicting the origins of numbers obtained by throwing a handful of dice, each of which has a different number of sides.
5 Stephen Leslie, 'The fine-scale genetic structure of the British population', *Nature*, *519*, 309–14 (2015). www.nature.com/nature/journal/v519/n7543/pdf/nature14230.pdf
6 Robin Dunbar, *The Trouble with Science*, pp. 68–9.
7 Mary Douglas, *Jacob's Tears*, p. 134.
8 Mary Douglas, *Jacob's Tears*, p. 143: 'anything can signify anything else unless there is some quasi-contractural understanding about what signifies what. Ambiguity is always rife. / Reason is defended against ambiguity by its rooting in practice.'
9 Mary Douglas, *Jacob's Tears*, pp. 144–5.
10 Nelson Goodman, *Ways of Worldmaking*. See Chapter 1.
11 Nelson Goodman, *Ways of Worldmaking*, pp. 97–9.
12 Nelson Goodman, *Ways of Worldmaking*, p. 91: 'Of course, we must distinguish falsehood and fiction from truth and fact; but we cannot, I am sure, do it on the ground that fiction is fabricated and fact found.'

13 Nelson Goodman, *Ways of Worldmaking*, pp. 93–4.
14 'And thus that the philosophy of art should be conceived as an integral part of metaphysics and epistemology', Nelson Goodman, *Ways of Worldmaking*, p. 102.
15 Nelson Goodman, *Ways of Worldmaking*, p. 132.
16 Nelson Goodman, *Ways of Worldmaking*, p. 133.
17 Nelson Goodman, *Ways of Worldmaking*, p. 138.
18 Günter Wagner *et al.*, 'The road to modularity', *Nature Reviews Genetics*, *8*, 921–31 (2007). www.nature.com/nrg/journal/v8/n12/pdf/nrg2267.pdf
19 D'Arcy Thompson, *On Growth and Form*, pp. 154–69.
20 Matin Kemp, *Seen/Unseen* (Oxford University Press, 2006), pp. 200–36, on 'Thompsonisms' in art, quotations on p. 236.
21 Herman Weyl, *Symmetry* (Princeton University Press, 1952), pp. 73–4.
22 We will be discussing the fact that we live in a world of medium-sized objects in some detail when we look at the problem of the justification of human knowledge outside that realm in Chapter 7. See, for now, for example, Helen de Cruz and Johan de Smedt, *A Natural History of Natural Theology* (MIT Press, 2015), p. 197.
23 The Fibonacci sequence is simply obtained by starting with the opposites 0 and 1 and making each successive number the sum of the previous two: (0, 1, 1, 2, 3, 5, 8, 13, 21, 34, and so on). See Chapter 1 for more on the Fibonacci sequence and its connection with the golden ratio of ~1.618:1.
24 Philip Ball, 'Beauty is truth? There's a false equation', in the online Aeon magazine. See: http://aeon.co/magazine/philosophy/beauty-is-truth-theres-a-false-equation/
25 Martin Kemp, *Seen/Unseen*, pp. 167ff: Part III, 'Discerning designs', Chapter 6, 'Natural geometries'. As, for example, p. 169, 'There is in a man's body such a rhythm, poise, symmetry and beauty that is it hard to decide whether it was the uses or the beauty of the body that the Creator had most in mind' (Augustine, *City of God*, XXII, 24, 4).
26 Philip Ball, 'Beauty is truth? There's a false equation'.
27 Starting at -273°C, absolute zero.
28 For example, if the reaction is the cutting in half of a polymeric molecule, then obviously the system becomes more disordered, because there are more ways of arranging 2n molecules than there are of arranging n molecules.
29 Robin Dunbar, *The Trouble with Science*, p. 107.
30 'For his stunning proof of Fermat's Last Theorem by way of the modularity conjecture for semistable elliptic curves, opening a new era in number theory.' See www.abelprize.no/c67107/binfil/download.php?tid=67059
31 Henri Poincaré, *Science and Method*, p. 59, quoted in the Introduction to *On Aesthetics in Science*, edited by Judith Wechsler (MIT Press, 1981).
32 Jean-Pierre Changeux, *The Physiology of Truth* (trans. M.B. DeBevoise, Harvard University Press, 2002), pp. 228–9. There may be 'a profound and very real analogy between mathematical apprehension and aesthetic appreciation, whose common features unite the True, the Beautiful, and the Good' such that an 'unfolding sequence of representations' in the mind is akin to a melody (p. 242).
33 Allen Lane, 2014; see pp. 20–6 for discussion of Pythagoras's theorem.
34 Frank Wilczek, *A Beautiful Question*, p. 1.
35 Frank Wilczek, *A Beautiful Question*, pp. 4–5.
36 Frank Wilczek, *A Beautiful Question*, p. 29.
37 Frank Wilczek, *A Beautiful Question*, pp. 31–6.
38 Frank Wilczek, *A Beautiful Question*, p. 14: 'Successful perception involves sophisticated inference . . . When we form expectations that turn out to be correct, we experience pleasure and satisfaction. Those reward mechanisms encourage successful learning. They also stimulate – indeed, at base they *are* – our sense of beauty.'

39 Frank Wilczek, *A Beautiful Question*, pp. 15–16.
40 Frank Wilczek, *A Beautiful Question*, p. 8.
41 Frank Wilczek, *A Beautiful Question*, pp. 169ff.
42 Or regularities – see Chapter 7.
43 Quoted in Frank Wilczek, *A Beautiful Question*, p. 181.
44 Converting, for example, a proton to a neutron. Frank Wilczek, *A Beautiful Question*, pp. 247–62 and 299–302.
45 Frank Wilczek, *A Beautiful Question*, pp. 4–16, 47–64.
46 Frank Wilczek, *A Beautiful Question*, p. 47.
47 Frank Wilczek, *A Beautiful Question*, p. 48.
48 Frank Wilczek, *A Beautiful Question*, p. 139.
49 Frank Wilczek, *A Beautiful Question*, pp. 130–3; quote p. 133.
50 Frank Wilczek, *A Beautiful Question*, p. 117.
51 Frank Wilczek, *A Beautiful Question*, p. 130.
52 Heinrich Hertz, quoted by Wilczek, ibid. pp. 134–5.
53 Frank Wilczek, *A Beautiful Question*, pp. 199–202.
54 Frank Wilczek, *A Beautiful Question*, p. 259.
55 www.theguardian.com/books/2015/aug/01/a-beautiful-question-natures-deep-design-frank-wilczek-review
56 www.timeshighereducation.com/books/review-a-beautiful-question-frank-wilczek
57 www.the-tls.co.uk/tls/public/article1622078.ece
58 Martin Kemp, review of *A Beautiful Question*.
59 Martin Kemp, review of *A Beautiful Question*.
60 Wilczek, *A Beautiful Question*, pp. 264–73.
61 http://mediaassets.caltech.edu/gwave
62 Jean-Pierre Changeux, *The Physiology of Truth*, p. 229. 'It is tempting to suppose that the coherence and resonance generated in this fashion are exploited in both artistic and scientific creation.'
63 http://simonsingh.net/books/fermats-last-theorem/the-whole-story/
64 H. Lebrette, C. Brochier-Armanet, B. Zambelli, H. de Reuse, E. Borezée-Durant, S. Ciurli and C. Cavazza, 'Promiscuous nickel import in human pathogens: Structure, thermodynamics, and evolution of extracytoplasmic nickel-binding proteins', *Structure*, *22*, 1421–32 (2014).
65 www.cgl.ucsf.edu/chimera/
66 Martin Kemp, *Seen/Unseen*, pp. 312–17.
67 Francis Crick and James Watson, 'Molecular structure of nucleic acids; a structure for deoxyribose nucleic acid', *Nature*, *171*, 737–8 (1953).
68 The ribosome structure was reported by Ben-Shem et al., Science, 330, 1203–9 (2010). The RNA stem loop is from the bacteriophage PP7 (Chao et al., Nature Structural & Molecular Biology, 15, 103–5 (2008)) and the pseudoknot from human telomerase (Kim et al. Journal of Molecular Biology, 384, 1249–61 (2008)).
69 Thomas Cech and Sydney Altman received the Nobel Prize in Chemistry in 1989 for their discovery that RNA could carry out catalytic reactions, i.e. could act as an enzyme – just a ribozyme rather than a protein-based enzyme of the normal kind. A whole slew of Nobel Prizes have been awarded for RNA biology, all of which, in a sense, build on Crick and Watson's DNA structure breakthrough: for example, to Aaron Klug (1992), Andrew Fire and Craig Mello (2006), Elizabeth Blackburn, Carol Greider and Jack Szostak (2009), and Ada Yonath, Thomas Steitz, and Venki Ramakrishnan (2009). There will be more.
70 Allegretti et al., Nature, 521, 237–240 (2015).
71 Viero et al., Journal of Cell Biology, 208, 581–96 (2015).

72 Martin Kemp, *Leonard da Vinci: The Marvellous Works of Nature and Man* (Oxford University Press, 2007). See also, Martin Kemp, *Seen/Unseen*, pp. 175–7.
73 Martin Kemp, *Leonard da Vinci*, p. 137.
74 Martin Kemp, *Leonard da Vinci*, p. 140.
75 Martin Kemp, *Leonard da Vinci*, pp. 279, 284.
76 Martin Kemp, *Leonard da Vinci*, p. 286.
77 Martin Kemp, *Leonard da Vinci*, pp. 287–8.
78 Martin Kemp, *Leonard da Vinci*, p. 129. 'Geometry and natural science were inseparable entities in his mind' (p. 248).
79 Martin Kemp, *Seen/Unseen*, pp. 321–2.
80 Martin Kemp, *Seen/Unseen*, p. 330.
81 Gavin Hunt, 'Manufacture and use of hook-tools by New Caledonian crows', *Nature*, *379*, 249–51 (1996).
82 For example, Gavin Hunt *et al.*, 'Innovative pandanus-folding by New Caledonian crows', *Australian Journal of Zoology*, *55*, 291–8 (2007), and Christian Rutz *et al.*, 'Restricted gene flow and fine-scale population structuring in tool using New Caledonian crows', *Naturwissenschaften*, *99*, 313–20 (2012).
83 William McGrew, 'Is primate tool use special? Chimpanzee and New Caledonian crow compared', *Philosophical Transactions of the Royal Society B*, *368*, 20120422 (2013). http://rstb.royalsocietypublishing.org/content/368/1630/20120422 Other statements in this paragraph derive from this article.
84 Robert Shumaker, Kristina Walkup and Benjamin Beck, *Animal Tool Behavior, the Use and Manufacture of Tools by Animals* (revised and updated edn, Johns Hopkins University Press, 2011). The categories are: absorb (sponge use); affix, apply, drape; bait, entice; block; brandish, wave, shake; balance and climb, prop and climb, reposition, bridge; club, beat; contain; cut; dig; drag, roll, kick, slap, push over; drop; pound, hammer; hang; pry, apply leverage; probe; reach; scratch, rub; stab, jab, penetrate; symbolise; throw; and wipe.
85 William McGrew, 'Is primate tool use special?'
86 William McGrew, 'Is primate tool use special?'
87 William McGrew, 'Is primate tool use special?', italics original, and citing McGrew, 'Why is ape tool use so confusing?' In *Comparative Socioecology* (eds V. Standen and R.A. Foley), pp. 457–72 (Blackwell, 1989).
88 De Cruz and De Smedt, *A Natural History of Natural Theology*, p. 30. They argue that the adoption of a 'design stance' about the world – that it was *designed*, for example by God – helps in our development of the capacity to work things ourselves and so develop tools. This makes belief in a designer God an evolutionary advantage, even if it is false. 'Without the design stance, we would not possibly learn to use and name hundreds of tools and other artifacts, but would perhaps be limited to the less than ten tool types a typical community of wild chimpanzees entertains' – see *A Natural History of Natural Theology*, pp. 67–8.
89 Raymond Tallis, *Aping Mankind*, pp. 158–9.
90 Raymond Tallis, *Aping Mankind*, p. 222.
91 For example, 'In rainforest on Pic Ningua (950–1,300 m above sea level), I observed non-banded, non-aged and non-sexed crows between November 1992 and March 1995. . . . On 52 different occasions between 07:00 and 15:30 I observed tool behaviour by one or more (up to four) birds. Observations were made of four crows manufacturing tools and 68 crows using or carrying tools.' And, 'In the breeding season I observed an adult with both food and a tool in its bill land next to a juvenile, transfer the tool to its feet, feed the juvenile, then pick up the tool and fly off with it', Gavin Hunt, 'Manufacture and use of hook-tools by New Caledonian crows', pp. 249–51.

4 Playful beauty

In 1938, the Dutch historian Johan Huizinga published a book titled *Homo Ludens*. In it he argued that human culture is grounded in play, that we have an 'imperishable need . . . to live in beauty' only satisfied in play.[1]

The young fox and the fallow deer

'Young dogs and small boys fight "for fun", with rules limiting the degree of violence.'[2]

In the summer I sometimes go for a stroll at dusk. I can think calmly back over the day, I can enjoy the privacy brought by the lowering light and the scents of evening. Sometimes I get to see a shy animal – I see a heron taking to the air, or I surprise a wild roe deer or a naturalized muntjac minding its own business by the side of the river. One evening, a year or two ago, I saw a game being played by a young fox and a young fallow deer. Or rather, a young fox trying to play, while the deer was having none of it.

The fox's gamble was to run towards the deer and then lower itself with its front forelegs in a move familiar to anyone who has seen a dog doing the same as it acknowledges the superiority of its master or mistress. The fox would then quickly turn away and scamper off, and my interpretation was that it hoped to be chased by the deer in turn. But the deer stood there impassive – uninterested, really, in what the fox was up to.

I stood quietly in the dusk, leaning the side of my head against a tree to watch, and I know what I saw, and over and over again the fox approached the deer, went down on its front legs and then quickly turned back. When the deer failed to follow, the fox tried again. I think we know animals play, and that we can appropriately assign that word to the kind of activity I had seen. My dog's favourite game is to catch a ball before it lands, mid-flight; the fox was wanting to play chase-me with the deer.

Because I knew what I had seen, and I was amazed, I told some friends about it. They laughed at me – it was ridiculous to see this as play, because foxes are carnivorous animals, and it was just practising for the day it would be running in for the kill, not trying to play a game.

But, what's the difference? Huizinga compellingly and relentlessly argues that play is at the foundation of human culture, and wholly permeates it.

> The spirit of playful competition is, as a social impulse, older than culture itself and pervades life like a veritable ferment. Ritual grew up in sacred play; poetry was born in play and nourished on play; music and dancing were pure play. Wisdom and philosophy found expression in words and forms derived from religious contests . . . We have to conclude, therefore, that civilization is, in its earliest phases, played. It does not come *from* play like a babe detaching itself from the womb: it arises *in* and *as* play, and never leaves it.[3]

Huizinga's cultural breadth of reference is huge and, naturally, it includes science, and Huizinga's approach to play is aesthetic. Take the example of sacred rites and the use of precious objects in them – sacred object on a Polynesian island, or in a Romanesque cathedral, it's the same – and at the root is an 'imperishable need of man to live in beauty' only satisfied in play.[4] Art is itself a form of play[5] – and art itself is only a subset of the aesthetic – but art and the aesthetic are at one and the same time game-like and intensely serious. Many of the most profound features of human culture relate directly to play.

'The concept of play merges quite naturally with that of holiness. Any Prelude of Bach, any line of tragedy, proves it.'[6]

Again and again, at play, we can name things it is hard to speak about directly. Why else can the *plays* we perform on stage become touchstones for our understanding of human nature – the Oedipus complex, the tragedy of Lear, the jealousy of Iago and the existential angst of Hamlet? And it works the other way, too – playfulness, lightness of touch, seems to provoke human understanding in new ways, at new levels. One of the most remarkable sections of Huizinga's book is an extended reflection on the wig as an object of fashion. He notes that the seriousness and originality of Descartes, Pascal, Spinoza, Rembrandt and Milton occurred as part of the age of the wig.[7] The playfulness of a culture that also produced wigs as an item of fashion and symbol of power and wealth provoked the creativity of men we remember, not for their hairdos, but as great thinkers and artists.

Huizinga asks at the start of his book, 'what actually is the *fun* of playing?'[8] – why are we taken up by a game, why do we become absorbed in play? It seems to me that the answer is, because it fascinates us, because it draws us in, and we wrap our minds around it, or pour ourselves into it, and allow it to permeate our consciousness. The answer is, because it elicits our sense of what is fitting and poised, what is harmonious and works alongside the other, of what is beautiful. The equation of beauty, the aesthetic, and play is not a direct one, but the role of our aesthetic sense in play is strong – much play is beautiful, and art is playful. Huizinga refers to the 'mirth and grace . . . the beauty of the human body in motion . . . saturated with rhythm and harmony'.[9] Dance – whether the ballet, the ceilidh or street dance – engages our sense of beauty.

Like dance, games have rules, and, like dance, the orderliness of play gives it its aesthetic quality, its 'tension, poise, balance, contrast, variation, solution, resolution . . . Play casts a spell over us; it is "enchanting", "captivating"'.[10]

The universality of play within the animal kingdom reminds us that we are animals, albeit linguistic and ceremonial ones. Even animal play has rules – catching the ball before it lands, approaching so far in a game of enticement and no further – but, with our language and our sense of ceremony, we codify play. And then, play becomes the code – we derive a system of justice – and then, Christianity believes, play saves us. The Swiss theologian Hans Urs von Balthasar argued for an understanding of Jesus's life, death and resurrection as a drama of salvation, a drama about the basis and meaning of human existence summing us up, explaining us to ourselves, offering us a new way of life and opening for us the door to the kingdom of God.[11]

But, however grand play becomes, and however meaningful, or however defining of meaning from the point of view argued in Balthasar's theology, it reminds us that we are animals and, as such, combine the rational and irrational. It also reminds us that animals are like us in some ways, not just that we are like them in others. Animals are *not* just mechanical, *because* like us they play.[12] And, like us, animals play to learn, like my fox wanting to play with the deer. What I saw the fox doing was *both* a game *and* a preparation to hunt, pounce and kill. Even human play may be deadly, and still be play.[13] The Romans knew that – their games included watching men fight to the death – and so did the ancient Hebrews; Huizinga gives as an example the passage in the second book of Samuel where twelve men fight twelve others in the Battle of Gibeon and all twenty-four are killed[14] – and he points out that the word used for the contest relates to laughter,[15] the men with Ish-bosheth, the son of Saul, and their opponents, the men of David, are *playing*. Play can be deadly, for animals and men.

The difference between human play and animal play is, I think, that only humans play deliberately; only humans set out to play a game or with someone else; and only humans play *with deliberation*, to mean something because we mean it. On this point, we can compare play with other activities that humans and animals both engage in. Most obviously, all animals eat and all animals have sex. Only humans do either thing deliberately, to celebrate an occasion or to mean something, such as, I love you.

Scientists are like children at play

Play is fundamental to human activity: simply historically, as we grow up, but also as the origin of human culture. Language is a play on words, new forms of language are a playing with words, and the meaning of language is found in the language game, the context and the transaction of our relationships with each other, whether we are buying apples[16] or negotiating for peace. Words mean what they do in the context in which they are used, within the agreed system of symbols within which they operate. Metaphors are fundamentally playful,

the play of one word against another, and the playfulness of a metaphor is the source of its power and impact.[17] The role of play in the shaping of language, together with the dependence of our capacity to think on the language we use, places something subjective, and some sheer enjoyment, at the root of our capacity to be rational and to objectify – to be objective.[18]

I say *sheer* enjoyment – we enjoy the capacity to express ourselves and to say what we think. We may forget the delight we experienced as toddlers when we learnt how to objectify the world by finding words for this and that and how to put them together to make ourselves understood, but we can see it in the young we know and reflect that the difference between us and them is just a matter of degree. When, as adults, we 'get' a joke, it relates back to that basic way in which humans first get a grip on the world – 'getting a joke' hammers a reference point or a handhold into a social situation; getting to grips with the world through language gives the young child a way to handle reality, it gives the child a handhold *in* reality. We also see this critical value of language, but also the joy of finding the right word for something or to apply in a situation, at the end of life too. How frustrating and upsetting it must be to forget what the word for something *is* or what an object referred to by a word is *for*, and what relief it can bring to manage to remember, how much it represents a reconnection with reality.

Language might be a play on words, but it is no less serious a business for that; just because science might have a core element that is play, that does not make it an unserious or superficial activity. As Rowan Williams points out, every parent or teacher knows that language is partly learnt through play, and this is vital:

> because to learn language is to discover, by trial and error, what I can seriously be committed to when I open my mouth, what I'm ready to answer for. This is something I cannot begin to do with intelligence or confidence unless I am allowed to make utterances that I *don't* have to answer for.[19]

Children must be *free* of adult choices if they are ever to learn how to *make* adult choices,[20] and the games we engage in as adults, the play we enjoy, is a way of maintaining that freedom throughout our lives.

The overall thrust of Huizinga's argument is to see play as irreducible and as outside comedy or seriousness, sense or folly, good and evil, right and wrong: as something that just *is* and that gets applied as we human beings see fit. We play with the world.

In science, we play with the world. Huizinga addresses this directly and notes that it is important to see a difference between science as *a game* and scientists as operating by the means of play. Science is not a 'game', not isolated from reality and just operating by internal rules, like a game of chess or of tennis. But that does not stop *play* being fundamental to how science *works*.

This is an essential distinction, but perhaps no more essential than the equivalent distinction to be made when we talk about art as playful. The scientist is

constantly *checking in* on reality, constantly relating what he or she is doing by way of an experiment or in developing an understanding of the world to how the world, actually, is. I think the artist would say the same, and the composer and the poet – they are *playing*, and *not*, at the *same* time. Or rather, they (and the scientist) are playing with serious intent, using play as a means to an end, as a way of getting to grips with the world and to understand or depict the world in their own way. I guess one of the big differences between the play of children and the way adults use play is that adults use play as a means to an end, whereas children do it for its own sake. Huizinga is right in his diffident suggestion that, 'science is . . . liable to indulge in play within the closed precincts of its own method'.[21]

The playfulness of scientists is very good for the effectiveness with which humans get a realistic understanding of reality. After all, the first and most fundamental characteristic of play is that it is free, that it operates freely.[22] We need that in science, to be open-minded – and by being playful we find a more effective route to free thought: play is a form of free thought. Science is also (supposed to be) disinterested, as is play,[23] and science is something we do 'apart' from the ordinary world – like play. We play cards at the card table, tennis on the tennis court, justice in a court of law, music on a stage – operating by the rules of the game. Play brings order into a world of chaos and gives regularity to human activity: science is a definition of that order. Like science, play is 'an act apart' taking place in 'temporary worlds'[24] – in the laboratory, at the particle accelerator, away at a conference.

Let me give a concrete example. In 2010, the Nobel Prize in Physics was awarded to a pair of Russians working in the United Kingdom, Andre Geim and Konstantin Novoselov, for the isolation of graphene, a hexagonal network of carbon one-atom thick. The importance of graphene derives from its versatility, its conductivity, its porosity and its tremendous strength. Geim and Novoselov make playfulness a basic feature of their research and occasionally amuse themselves with 'Friday night experiments'. One of these provided a key breakthrough – the use of Scotch tape to isolate the one-atom-thick graphene sheets.[25] The subsequent demonstration of the exceptional electrical conductivity of the isolated graphene represented the 'Eureka!' moment in which Geim and Novoselov realised their breakthrough.[26]

Here is playfulness in science, and it is most effective.[27] The playfulness of Geim had got him lampooned before, when he levitated a frog above water using a strong magnetic field to harness the animal's inherent diamagnetism.[28] The levitating frog bagged Geim an IgNobel prize[29] – IgNobel prizes are ways of making fun of irrelevant research, but also perhaps a way of pointing out how scientific advances arise from unexpected sources. The relevance of demonstrating the practical capacity to levitate living animals using diamagnetic forces seems a fairly fundamental one, and it is something that physicists continue to investigate: it does not seem so irrelevant to me, and, irrelevant or not, it is precisely the attitude of playfulness that made a frog float above water and that led to the isolation of graphene and a Nobel Prize, still the greatest recognition a scientist can receive.

Nor is playfulness in science a modern phenomenon. In the previous chapter, we considered the work of James Clerk Maxwell and the way it has inspired Frank Wilczek, as acknowledged in the latter's book *A Beautiful Question*. Wilczek comments, 'for Maxwell imagination and play, guided by a sense of mathematical beauty, were prime tools of discovery'. The play can even be trans-generational: Wilczek can play the same kinds of game as Maxwell, to great effect – Maxwell's equations 'can be written pictorially, in terms of flows. When so presented, they depict a sort of dance. I often visualise them that way, as a dance of concepts through space and time, which is a joy'.[30] One game Maxwell played was to take Michael Faraday's idea of the world as a system of fluids to think through what *force* is and why it works the way it does. Faraday's fluids became, for Maxwell, 'wonderful toys, and [he] was happy to be patient as he played with them'; in another example, Maxwell used a simple spinning top with differently coloured segments to think through the basis of colour perception.[31] Wilczek himself has played with the same idea of fluids to work up his exposition of the core theory of fundamental physics.[32]

Scientists use play in their work in an everyday way, and not just when they make fundamental new discoveries. In later sections in this chapter, we will look at some practical examples – the use of the imagination, of playing 'let's pretend' in the formulation of hypotheses; the playing of games or, in other words, experiments; the value of toys or, in other words, scientific equipment; and the role of a basic, childlike fascination in scientific work. Play is everywhere in science – from the way you design an experiment, to the title you give the article you publish. Giving your publication a punning or witty title (or one you think is punning or witty, anyway) is one way to get your work noticed, but also encapsulates some basic aspect of what you are wanting to say. I guess it's the power of metaphor, again.

But, even in its more formal activities, science appears to be rather playful. It has its rituals – the Nobel Prize ceremony (and Ball), the convocations of the Royal Society – and its societies and academies have their secrecy and their exclusiveness, like a gang of children. One can take these things very seriously (some of my colleagues do), but the human activity underlying them is not significantly different from the play of a religious ceremony or of national pomp. They, too, have their significance, but they are part of a culture imbued with play. 'You're nothing but a pack of cards', said Alice.[33] She could have been saying that to the Royal Society of London, the assembled majesty of Oxford University at Encaenia,[34] the House of Lords in uproar at a new governmental insult, or the ranks of peers and peeresses at a coronation. It makes no difference that all these groups of people are *playing*: what is going on is also in deadly earnest – but all are still packs of cards, being played in a game.

And is science always fair play? In my experience, decidedly not. Scientists do not always play nicely together, and in fact can display the most outrageous selfishness and dishonesty in their dealings with one another. It's all a game, but a pretty deadly one in which bullies do best. One of the greatest ironies about science is that, as the human activity supposed to celebrate objectivity

the most, it is riven with subjectivity, both of a delightful, charming kind – as in the playful elegance of an experiment or the appreciation of a beautiful discovery – and of a mean and unkind form, in which I will not share my toy with you, and I will not allow you to play my game, and you are not in my gang. One of the strongest objections to Christianity is the disunity within the Church: how can people claim that love is the key to life and then be so unloving to one another? But – sorry – one of the strongest objections to the claim of scientists to tell the truth is the frequency with which they lie about one another. 'Science, as some one has not unjustly said, is polemical.'[35]

For many modern scientists, work structures the whole of life. Why are scientists so content to make their work their way of life? Because their work is play, and life is played.

Playing by the rules

As a preface to thinking about the role of the imagination, of games of make-believe, in the creation of scientific hypotheses, I want us to focus on how play, and obeying the rules of the games we are (supposed to be) playing, could be (or is) the way to be a particularly good scientist.

Rowan Williams's book *Lost Icons*, subtitled *Reflections on Cultural Bereavement*, focuses on those aspects of human being that seem lost in North Atlantic culture. He wrote it during the 1990s, but its message is certainly no less relevant now than it was then. We have lost, he says, an understanding of childhood and choice, of charity, of remorse and of what it means as a human being to be an embodied soul or, in secular terms, a subject.[36] For Williams, the term 'charity' here has a sense of *civility*, of honest common life recognising affectionately the humanity of the people around us. For Williams, charity is about grace and social cohesion, it is (in a phrase he borrows from John Bossy) a 'social miracle'. Charity is a situation in which we suspend 'relationships characterised by competition, rivalry', agreeing 'to speak the same language and listen to the other as an equal'. Charity in this sense is very like a game, unproductive in itself but creative in the extreme.[37]

It is very important for the social game that makes for charity, for honest common life, to be played by the rules and not to be seen as *for* anything other than itself. The example of commercial sport is given – where high financial rewards emasculate the idea that the game is 'just' a game. Unfortunately, this in turn makes it less of a game and more a route to riches and a sense of fulfilment, or an engine of financial growth, or even a way to engage in violent rivalry (rather than the rivalry limited to the game itself). And, Williams argues, 'games in themselves dangerously mock and relativise other sorts of competition'[38] because they are better played than the games we engage in that *do not* follow rules, or not mutually agreed ones anyway. The rules we *do* agree on must be preserved, but, 'if you treat them as optional . . . the game is over'.[39] In science, an example of such a rule is the one about not having a conflict of interest with the work of someone else you are reviewing for funding or

for publication. This is mostly an absurd idea – because the people best qualified to judge the quality of a research proposal or a paper are precisely those who are at risk of a conflict of interest with it – but it is an idea we cling to, or (in reality) ought to cling to, though many don't. Many a reviewer will happily tick the 'I have no conflict of interest' box without examining their conscience and without the honest recognition that actually, yes, they do have a conflict here. But, how wonderful it would be – and, yes, how wonderful it is, when it happens – if someone can suspend their personal interests and play by the rules of the game. It's wonderful, among other things, because it fundamentally serves the advancement of science and the improvement of our understanding of the world. One of the overarching rules of the scientific game is that you receive the wisdom of others, engage in a collective seeking after truth and then bow out when your time comes, leaving the game (and the prizes) to others. Science is not the product of isolated geniuses, but of inspired individuals working together with others. This is not to downplay the role of the personal: after all, that is the whole thrust of this book, that what makes science scientific is that *we* do it, people do it, that it is a very *personal* thing. But, it is to say that people do not exist in isolation and do not come from nowhere. Recognising *that* means that I have to recognise that I will find some people difficult, such as people who want to claim the same experimental result or insight into a biological mechanism that I do, but that I must resist the temptation to use my power as a reviewer or in an appointment process to shut them out of the conversation.[40] I need to have the imagination to be creative and to play by the rules of the game.

Imaginary worlds: Hypotheses and ideas

'The eternal gulf between being and idea can only be bridged by the rainbow of imagination.'[41]

One of the games internal to science is to make hypotheses and test them. We need to understand that they *are* hypotheses (just because *we* thought of them doesn't make them true), and to respect their value, because you need leaps of imagination, over the rainbow, as Huizinga says, to get from where you are to the understanding you want to have. I think we have to recognise that there is in science a need to make such leaps, and to allow the imagination an appropriate level of freedom, to be open to flights of fancy.

Where do these hypotheses come from? One answer is to say: from a partial awareness of the world around us, from a dim perception of what's what. Hypotheses take a partial understanding and put it in the form of a clarified picture, a model or a simple idea. The gravitational force between two objects declines as the square of the distance between them.[42] New species derive from the variation of their predecessors, selected naturally by the environment – 'I think . . .', thought Darwin, and drew a famous drawing setting out a hypothesis, the hypothesis of the descent of species from ancestral forms that gives us our modern-day understanding of the tree of life,[43] what Wittgenstein called a fertile point of view.[44]

There are various things going on when we make hypotheses. Sometimes we think of the systems we are working on as purposive in some sense and of their components as having a kind of anthropomorphic autonomy. That is, sometimes we personify the world – and personification of the world, myth-making about the world, is a basic human cultural phenomenon, and a kind of play.[45] Indeed, the role of the mythic personification of nature at the origins of human culture is for Huizinga a sign of the foundational role of play.[46] We see it also in the way young children personify things – not just animals or even cuddly toys and dolls, but non-anthropomorphic physical objects as well. We make sense of the world by relating to it as *people*, from the very start.

Sometimes we use pictures or diagrams (as Darwin did) to help our thinking. Sometimes we borrow an idea from another area of science, or even another area of life, to help our model take shape. Sometimes just a phrase we get in our heads can give us a new point of view – some neat idea that puts things in perspective. It's a very personal thing, forming a hypothesis, anyway – I have some of my better ideas cycling up the hill to work, presumably because (a) my brain is full of oxygenated blood and (b) I'm not thinking about anything very much and so my mind has a free rein. Huizinga says that play always has (however hidden) an element of 'let's pretend' about it,[47] and hypothesis formation is a sort of game of 'let's pretend': How would it be if . . .? Can we imagine a world in which these data make sense? It is a kind of game played with the facts we have to hand.

Playing games: Experimental process

There is something very satisfying about experimentation. I don't get to do so much of it as I used to, but when I do I enjoy the physical nature of it very much – the way in which it engages me, body and soul. I grapple with stuff, things – I set up situations in which I can poke the world and see how it responds. It's a lot of fun, a splendid and wonderful game. So here, too, with a basic process behind most scientific advances I think we are faced with something like play, the kind of play adults can justify to themselves.

Poohsticks is a game that people play, invented (I suppose) by A.A. Milne for his son Christopher Robin and played by Winnie the Pooh, Eeyore, Tigger and Christopher Robin (according to *The House at Pooh Corner*). It's a matter of whose stick emerges first from under a bridge, having been thrown into a stream. I guess the factors determining whose stick comes out first include the speed of the flow of water, the weight of the stick and its shape (if it is significantly bowed this might affect how it moves) and (certainly) any rocks or other things in the way that the sticks might encounter on their journey.

Analytical ultracentrifugation and native mass spectrometry are scientific games with similar kinds of determinant where finding out the speed at which objects move is much more profoundly satisfying (I think) than how sticks float under a bridge.

In analytical ultracentrifugation, we place a sample of purified protein in a transparent container – a metal tube with see-through quartz or sapphire windows at either end to seal it. We put the sealed tube into a centrifuge and we spin it, very fast – often at 40,000 revolutions per minute. The gravitational field that the proteins experience when spun causes them to start to move centrifugally, away from the centre of the spinning rotor, and we can use short wavelengths of light to image the proteins as they go. This means we can follow their speed of movement and see how different sizes of protein move at different rates. The factors determining their rates are not dissimilar to those determining the rate of movement of sticks under a bridge. The weight of the protein matters – the heavier it is, the faster it will move – and so does the shape of the protein (if it is roughly spherical, it will move faster than if it is elongated, just as a bent stick moves at a different rate to a straight one). Also, what the protein bumps into will affect how it moves – if the protein concentration is high, then it will bump into other copies of itself more, and this will slow its movement, and the presence of compounds making the solution it's in more viscous would make it move more slowly again.

I don't know if this is the kind of game you'd like to play, but it's one of the games I enjoy, seeing how fast proteins move. This is a game that allows me to say whether a protein binds to itself to generate a cluster of identical molecules that will have a different way of functioning than the isolated protein copies alone. If I mix the protein and a bit of DNA, it allows me to say whether the protein binds to the DNA, and how tightly, and how many copies bind.

Native mass spectrometry has some similarities to analytical ultracentrifugation, but has a higher resolution. What I mean is that we can in many cases tell more about the molecules or collections of molecules we are looking at by native mass spectrometry than we can by analytical ultracentrifugation. In native mass spectrometry, a very fine spray of proteins or complexes of proteins is injected into a long tube using something like a perfume atomiser. The long tube is partially evacuated, but the vacuum leaves some water molecules stuck to the surface of the protein so that it does not become completely dehydrated. This allows complexes of proteins with each other, which would fall apart if we dehydrated them completely, to stay intact. Electrical fields inside the mass spectrometer result in ionisation of the droplets and their forwards movement. Overall, their time of flight is measured, and this tells us about their mass-to-charge ratio, from which we can work out their mass alone. The power and impact of native mass spectrometry in the life sciences are steadily increasing; using this approach and varying the accelerating voltage applied to the samples allows us to dissociate the complexes formed by proteins with each other, with DNA and with lipids, within the spectrometer, and this allows us to – literally – dissect their composition, but in real time, and also to infer something about their shape due to their 'collisional cross section'. This is a similar idea to the way in which the 'crowdedness' (actually a scientific term used in this context) and shape of the molecules in a sample undergoing analytical ultracentrifugation affect the forward movement of a protein *and* to the way in which rocks

in the stream bed and competition with other people's sticks can affect the rate at which *my* stick gets under the bridge.

This is a simple pair of examples from the life sciences. My colleagues in other disciplines would, I think, be able to give examples specific to their own fields. Mind you, the Poohsticks analogy isn't bad: you could (at a stretch) apply it to the Large Hadron Collider too.

Toys: Equipment and infrastructure

The Large Hadron Collider (LHC) has grabbed the public imagination in recent years. Part of that – a significant part – has related to the role it has played in 'proving' (in the sense that proof is possible) the existence of the Higgs boson. The use of theory, in the 1960s, to predict the existence of the Higgs boson stands alongside many other kinds of theoretical thinking, many other kinds of hypothesis (many other kinds of flight of imagination) as an example of the power of the aesthetic in advancing science. But that is not my point here – my point here is the excitement elicited by the fact we need a very, very large machine in order to detect the existence of the Higgs boson.

Stories about the huge bits of kit, such as the LHC, that empower modern science get told as much in the scientific literature as in mass-circulation newspapers – and not just because of concerns it could create a black hole under the Alps. The LHC is one; the use of a cubic kilometre of water to detect neutrinos is another;[48] another, which elicits quite some excitement in my own field, is the potential of X-ray free-electron lasers (XFEL) to (as we often say) shine new light on the atomic basis of biological processes. An XFEL is being constructed in Hamburg, Germany: it is a 3.8 kilometre-long X-ray source that will produce 100 femtosecond (10^{-15} second) pulses of X-rays 10,000 times brighter than conventional X-ray sources. This infrastructure, this new machine, will enable a new level of understanding in biological and physical science. To call it a toy might seem disrespectful – this is in no way my intention. I have emphasised the fact that play is a deadly serious business – it is so serious that Rowan Williams sees in our loss of the capacity to play appropriate games a mortal threat to our humanity – and the fact that scientists enjoy their work in a way analogous to the enjoyment of children leaves untouched the seriousness and profundity of that work. Nevertheless, the sheer joy that scientists experience as they put together new technologies such as the LHC or an XFEL, joy at what can be done, joy at our understanding, is different only in degree and not in substance, only quantitatively and not qualitatively, from the joy of a child building a tower of wooden blocks or grasping hold of reality through the learning of a word.

Naturally, the use of analytical ultracentrifugation and of native mass spectrometry has required the development of specific machines for us to play our version of Poohsticks. The analytical ultracentrifuge was invented by Théodor Svedberg, who thus opened up a new way to understand molecules and their interactions. We name the unit of their movement as we watch them in his honour. Native mass spectrometry was developed by, among others,

my colleague Carol Robinson.[49] I hope she won't mind my saying it, but the way she tells the story is very much that she thought she'd try something out, that is try attenuating the strength of the vacuum in her mass spectrometer to see what happened. Not exactly a game, but not entirely unlike one either; not so far, or no different in a qualitative way, from the child blowing bubbles into water with a bicycle pump. Carol Robinson's work has justly been recognised nationally and internationally.

The Diamond Light Source near Oxford is a synchrotron X-ray source we use for determining the structures of crystallised proteins, and another example of a very large toy. Indeed, the enjoyment I see in my colleagues and that I can share in making it work to tell us the truth about molecular structure seems to me to have a childlike quality to it. This doesn't stop Diamond being the largest scientific investment in the UK for 40 years; this doesn't stop it being a place of intense commitment to the objective study of reality, and to the discovery of new physical processes, the development of new vaccines and drugs, the exploration of new techniques. These days, experimentation at facilities such as Diamond is increasingly automated – you could even sit at home and perform your data collection remotely.

I want to end with a historical example that relates to one of the main reasons why the Diamond Light Source now exists. One of the problems with applying crystallography to biological macromolecules was, once it became clear you could crystallise them, working out a way to stop them becoming dehydrated when you were collecting data from them. John Desmond Bernal and Dorothy Crowfoot (later Hodgkin) were the first to work out that, in order to prevent this, you must place the crystal in a piece of capillary glass and allow some moisture to remain.[50] Brilliant, very practical and a game-changing move for structural biology, but also something like play: fiddling with things to make them work better for a particular purpose. As mentioned in Chapter 2, the result has, to a very large extent, been 'structural biology', with its many Nobel Prizes and its transformative effect on our understanding of life and what we can do about it in terms of pharmaceutical and biotechnological innovation.

In scientific research departments, you will frequently find 'research scientists' supported by 'research technicians'. I have come to feel that many of the workers who get branded as technicians are, in fact, much better scientists than those who claim that title. Many a 'technician' is a more brilliant and more insightful interpreter of reality than their professor. The fact that the 'technician' actually bothers to get their hands dirty and play the game (rather than standing on the sidelines trying to manipulate the rules) gives them a major advantage in this.

The fascination of children

'Really to play, a man must play like a child.'[51]

Huizinga is thinking here of the (rather complicated) card game bridge. I don't play bridge, I'm not capable enough, but I think I know what he means.

The 'innocence' of children, meaning the way they enter wholeheartedly into games (of all kinds), and the respect they have for the rules enable them *really* to play. And, I feel that we should extend the relevance of his comment to the play element in science: really to play at understanding the world, which is what scientists are doing, men and women must play like children. So, they should obey the rules, they should leave their agendas behind and engage in the game. If they do this, they may worry that they are running the risk that someone else will win – someone else will get the resources they want, someone else will claim the insight they have – but this is a contingency that they must live with. Not to is to be childish (as opposed to childlike). To be childlike is to grow towards greater maturity; adults can be at their most attractive when they are childlike – simple, focused, honest, joyful.

To be playful is to aim for many of the better things about being human. If people were more playful, more often, then life for human beings everywhere would be better. As Rowan Williams points, out 'oppression is a situation where people don't talk to each other; where people don't find each other difficult'.[52] A playful attitude gives us a safe way to engage in finding each other difficult and so locating a better understanding, together. The internal qualities of playing a game well are on their own healthful and enabling, providing for a kind of social miracle, the overcoming of difference, and for the existence of charity.[53]

Playfulness is an aesthetic activity, and I think this is something most people understand. The elegance of play, the *play* of play, is a source of sheer joy when we are engaged in it and a source of wonder when we observe it. In the next chapter, we will begin by looking at other ways in which the aesthetics of science is constantly being played out in public.

Notes

1 Johan Huizinga, *Homo Ludens*, p. 63.
2 Johan Huizinga, *Homo Ludens*, p. 89.
3 Johan Huizinga, *Homo Ludens*, p. 173.
4 Johan Huizinga, *Homo Ludens*, p. 63.
5 Johan Huizinga, *Homo Ludens*, p. 168. Huizinga points out that Plato understood creativity as play; and that the Renaissance was a sphere of tremendous play, however serious the minds of Leonardo and Michelangelo were as well.
6 Johan Huizinga, *Homo Ludens*, p. 24.
7 Johan Huizinga, *Homo Ludens*, p. 184.
8 Johan Huizinga, *Homo Ludens*, p. 2.
9 Johan Huizinga, *Homo Ludens*, p. 7.
10 Johan Huizinga, *Homo Ludens*, p. 10.
11 For example in *Mysterium Paschale* (T&T Clark, 1990).
12 Johan Huizinga, *Homo Ludens*, p. 4.
13 Johan Huizinga, *Homo Ludens*, p. 41.
14 2 Samuel 2:12–17. All Biblical quotations are taken from the *New Revised Standard Version*.
15 Johan Huizinga, *Homo Ludens*, pp. 41, 48–9.

16 Ludwig Wittgenstein, *Philosophical Investigations*, I (trans. G.E.M. Anscombe (Blackwell, 3rd edn, 1968).
17 Irving Massey, *The Neural Imagination*, pp. 147–8. He focuses on the use of metaphor by Patrick Leigh Fermor, where 'meaning is created by the way words make contact with each other outside and beneath syntax'. Examples from Laurie Lee: the arrival of the filled Christmas stocking is 'like the opening of a flower in the dark, the sudden ripening of fruit on the bough'; the child's 'drowsy hand in the cold of the winter's dawn reaching out as a test of hope, then suddenly finding itself filled with this weight of love, bestowed silently while it slept' (Laurie Lee, *Village Christmas*, Penguin Books, 2015, p. 9). Winston Churchill's Lying in State in Westminster Hall: 'a vaulted barn, roofed by Sussex timber, amber-shadowed by its few dim lamps. The harvest is done and the barn seems empty, save for the husk of this mighty seed' – an astonishing piece in which every word tells, every word lands like a punch.
18 Johan Huizinga, *Homo Ludens*, p. 4.
19 Rowan Williams, *Lost Icons* (T&T Clark, 2000), p. 12.
20 Rowan Williams, *Lost Icons*, p. 27.
21 Johan Huizinga, *Homo Ludens*, p. 203.
22 Johan Huizinga, *Homo Ludens*, p. 8.
23 Johan Huizinga, *Homo Ludens*, p. 9.
24 Johan Huizinga, *Homo Ludens*, p. 10.
25 Frank Wilczek, *A Beautiful Question* (pp. 216–18), discusses this work too: 'A bit of nineteenth-century science that somehow escaped into the twenty-first century. They started with pencil smudges, which typically contain several carbon layers, consisting of graphite. Then they applied adhesive tape to strip some layers off, and transferred the smudge traces to thin microscope slides'. Wilczek's point is that the markedly differing properties of the subtly different carbon nanotubes this enables us to isolate are precisely predictable using theoretical quantum mechanical applications.
26 Andre Geim, 'Random Walk to graphene', Nobel Prize lecture in Physics, 2010. See: www.nobelprize.org/nobel_prizes/physics/laureates/2010/geim_lecture.pdf. Konstantin Novoselov et al., *Science*, *206*, 666–9 (2004).
27 'This playful approach is fundamental to how Andre and Kostya work, seen as both a useful way of maintaining interest in a field as well as a means of generating new ideas.' See: www.graphene.manchester.ac.uk/explore/the-story-of-graphene/a-discovery-at-manchester/
28 Michael Berry and Andre Geim, 'Of flying frogs and levitrons', *European Journal of Physics*, *18*, 307–13 (1997); Andre Geim, 'Everyone's magnetism', *Physics Today*, *51*, 36–9 (1998).
29 www.improbable.com/ig/winners/#ig2000
30 Frank Wilczek, *A Beautiful Question*, p. 118.
31 Frank Wilczek, *A Beautiful Question*, p. 124.
32 Frank Wilczek, *A Beautiful Question*, pp. 236–7.
33 Lewis Carroll, *Alice in Wonderland*, Chapter 12, p. 157 (Puffin Books edn, 1946).
34 When Oxford awards honorary degrees and everyone dresses up in their most extraordinary academic robes for a garden party. The best sights are those who have degrees from the University of Salamanca, whose light blue robes include headgear with a long fringe that makes it look like an extreme lampshade. An article in the *Spectator* magazine many years ago said that Encaenia involved a condensation of international academic ability so intense it actually refracts light. That's what the participants like to think, anyway.
35 'But it is a bad sign when the urge to forestall the other fellow in discovery or to annihilate him with a demonstration, looms too large in the work done. The genuine

seeker after truth sets little store by triumphing over a rival', Johan Huizinga, *Homo Ludens*, p. 204. Then, many scientists appear not to be seekers after truth.

36 Rowan Williams, *Lost Icons*, p. 149.

37 Rowan Williams, *Lost Icons*, p. 56.

38 Rowan Williams, *Lost Icons*, p. 58.

39 Rowan Williams, *Lost Icons*, p. 59. See also p. 61.

40 'Oppression is a situation where people don't talk to each other; where people don't find each other difficult' (Rowan Williams, *Lost Icons*, p. 113). Shutting another scientist out of the conversation because they are your rival is a form of oppression.

41 Johan Huizinga, *Homo Ludens*, p. 133.

42 Robert Hooke's perception – see Stephen Inwood, *The Man Who Knew Too Much* (Macmillan, 2002).

43 See Elizabeth A. Johnson, *Ask the Beasts: Darwin and the God of Love* (Bloomsbury Continuum, 2014), pp. 59–65, for a narrative. See http://darwin-online.org.uk/EditorialIntroductions/vanWyhe_notebooks.html for the original.

44 'The real achievement of a Copernicus or a Darwin was not the discovery of a true theory but of a fertile point of view', Ludwig Wittgenstein, *Culture and Value* (trans. Peter Winch, Blackwell, 1998), p. 26.

45 As in the Ancient Greeks' personification of nature, for example, in gods, dryads and water sprites. Of course, the point of Christianity is to cancel all that kind of thinking, thus ushering in the possibility of modern science. Still, Jacques Monod imagined himself to be a haemoglobin molecule (Jean-Pierre Changeux, *The Physiology of Truth*, p. 229).

46 'The play attitude must have been present before human culture or human speech existed', Johan Huizinga, *Homo Ludens*, p. 141.

47 Johan Huizinga, *Homo Ludens*, pp. 22–4.

48 www.km3net.org/home.php

49 Justin Benesch et al., 'Protein complexes in the gas phase: Technology for structural genomics and proteomics', *Chemical Reviews*, *107*, 3544–67 (2007).

50 J.D. Bernal and D. Crowfoot, 'X-ray photographs of crystalline pepsin', *Nature*, *133*, 794–5 (1934).

51 Johan Huizinga, *Homo Ludens*, p. 199.

52 Rowan Williams, *Lost Icons*, p. 113.

53 Rowan Williams, *Lost Icons*, p. 83.

5 Worldly, natural and real beauty

Common points of view: Cosmology, geology and evolution

When I have spoken to others about the writing of this book and have explained the basic ideas behind it, the response has always been one of recognition. There has been quick understanding of what I'm talking about and why it matters. There seems to be something universal here: I have been speaking to Oxford undergraduates reading biochemistry, or Oxford graduates from politics and philosophy or history programmes who are now London barristers or work in citizen organising; to the Baptist Ladies Fellowship on a Tuesday afternoon in a village parish, or a group of Oxford theologians, or a group of pupils in a North London school; to a Dominican friar. The idea that scientists find beauty in their work is something that everyone seems ready to grasp.

This is played out in the popular media, most prominently with respect to mathematics and physics, where voices such as those of Jim Al'Khalili and Marcus du Sautoy, among others, and of the BBC Radio 4 programme *Start the Week* or Melvyn Bragg's *In Our Time* have regularly featured exactly the idea that there is something extraordinary about the role an estimation or appreciation of beauty plays in scientific advance and discovery. In fact, when I was a teenager, one key programme that played a role in the start of the stream of consciousness that has led to my writing this book was an edition of the BBC2 programme *Horizon*, which focused on spherical carbon, or buckminsterfullerenes, C_{60} and related structures, and on the Nobel Prize-winning work of Harry Kroto in their discovery. I still have the booklet of the programme I wrote off for at the time.

I wish now to look at three major areas where the popular imagination is inspired by the beauty in science, before moving on to a fourth, neuroscience, where our knowledge is more novel, but where the aesthetic again plays a role in popular reception. This will then allow us to start thinking about some of the challenges that might be raised to my argument, principally on neuroscientific and evolutionary grounds. Indeed, cosmology, geology, evolution and neuroscience are battlegrounds in the conflicts between scientific and religious views of the world *precisely because* they are vividly present in our culture and our minds.

Cosmology and the structure of the universe

The study of the heavens easily captures the popular, the public and the personal imagination. More than many other areas of science we study, the origins, evolution, structure and workings of our solar system, our galaxy and our universe fill us with wonder and with awe. We study these aspects of reality *because we can*, *because they are there*, and *because we want to*. When we try to justify the utility of this work we say that they enable us to develop technologies that are then useful on Earth – Teflon, for example – but really, we study these aspects of reality *because we think they are beautiful*. Mathematics, too, is something we do *because we can* and *because it's beautiful* – and meanwhile it develops tools that are useful, of course. Particle physics is something we do, again, because we can, because it's beautiful – and after all, it gave us the Internet, didn't it?

When cosmologists produce material for general consumption, they want to show us what it is they have found and to share with us their joy in discovery. We are glad to join them, and our media enable it – most recently, as I write, in the confirmation of the gravitational waves predicted by general relativity, via the measurement of the disturbance of space–time caused by the collision of two black holes. Cosmologists show us pictures of exceptional beauty – the images of nebulae provided by the Hubble telescope being among the best known. In another recent example, closer to home, images of Jupiter have again reminded us how wonderful and exotic the objects even of our own Solar System are. We have been shown how a brilliant aurora plays over the Jovian North Pole and makes our own Northern Lights pale by comparison. There is no doubt that members of the general public, like me, can appreciate the beauties of cosmology for ourselves.

Geology and the construction of our world

The stories that geologists can tell us about the way our world came to be are stories with a strong emphasis on the way things fit together, on aesthetic organisation. We learn of the evolution of the world via plate tectonics, of how the primordial Gondwanaland broke up to form the continents we know today, and how the abrasion of tectonic plates produces earthquakes and the collision of tectonic plates has produced mountains. We look at a global map and see how Africa would fit into the curve of South America, on the other side of the Atlantic, and we realise how it all makes sense: visualising how things came to be from seeing how they are.

The beauty of mountainscapes and of island archipelagos is not lost on us today – I write this looking out from St Martin's in the Isles of Scilly towards Tresco – and the understanding we have of where such places come from is bound up with our appreciation for the way they are now. And, when as a child I am told that the reason there are fossils from prehistoric marine animals lying in the mountains is that they once lay under the sea, I am wide-eyed, filled with awe: there's a terrible beauty to the knowledge.

Natural selection and the evolution of species

In no area of science is the popular and public imagination more fired up than when it comes to evolution. The beauty of equations and of space, and the pleasing fit of a geological view of our planet are wonderful, but it's in evolution that terrible beauty seems to have most impact on our thinking. There's a real grandeur to the vision of life possessed by evolutionary biology and shared with non-specialists through television and popular science writing. But, it is not, I think, just in the whole process that the grandeur and the beauty are to be found, but also in the forms, the specific and unique forms revealed – and elsewhere in this book and especially in Chapter 3 we have thought about some of those. Both senses of the beauty of evolution – the awesome grandeur and the exquisite fit – are found, of course, in the thinking of Charles Darwin himself:

> There is a grandeur to this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.[1]

This is a point of view adopted and explored by many of the most popular writers on natural history of the last 50 years, including Stephen Jay Gould and Richard Dawkins. I mention these two gentlemen specifically because they just happen to have been formative for me, and to have laid the foundations for the point of view I have today. Stephen Jay Gould's writing on the peculiarities of biological form – hen's teeth, horses toes, the panda's thumb – were key things I learnt from wider reading in the sixth form at school, and alongside them I learnt much also from *The Selfish Gene* and Dawkins' other books. Dawkins himself has continued to emphasise the wonder he feels at the world's endless forms and, indeed, to use them as a kind of argument of sufficiency for a purely naturalist outlook: if the world is *this* beautiful, why do you need to invent some additional and imaginary sources of beauty, such as the beauties of faith? Shouldn't the beauty of nature be enough?

The beauty of nature points beyond itself,[2] which is part of my point in this book. And, an emphasis on the terrible aspects – from a human perspective at least – of the beauty of the natural world can be the source of another argument against the existence of God, not about sufficiency but about justice. How can a God of love allow the suffering natural selection entails? The problem is, this is a question about a theoretical god and not the God of revelation, of Judaism and Christianity and the other monotheisms; this is a question about an idol, the kind of idol god of whom it can also be asked: 'If god made the world, who made god?'; the kind of idol that we might rationally expect to need to be more 'complex' than the world if it is to have been the maker of the world.

But, leaving these well-trod foothills of argument aside, the fact is that the natural beauty of the natural world is plainly something that is appreciated by very many people very easily, whether it's David Attenborough or Richard Dawkins showing the way. Natural selection is perhaps the most accessible route to appreciate the way in which recognition of the world's beauty empowers scientific discovery. Apart from anything else, this echoes the origins of evolutionary theory in the first place: the recognition of endless forms, most wonderful and most beautiful.

Neuroscience and the structure of the brain

Modern technology allows us access to new forms of beauty, which our ancestors saw something of but we see in greater detail and with more variegation. In Chapters 2 and 3, we have mentioned the development of imaging techniques such as fMRI, and fMRI, alongside other complementary methods, has given us a whole new level of understanding about the beautiful workings of the human brain. The popular imagination is already excited by these new insights, and part of what fascinates are the undeniably attractive – and again somehow awesome, terribly beautiful – images of which parts of the brain are involved in particular kinds of human activity, which can be shown lit up with activity when we do one thing but not another. So, neuroscience is now joining cosmology, geology and evolution as an area of science to which many of us have access, and of which many of us have some understanding. They are communicated to us and explored for us in various media by image and analogy and metaphor, and in fine words too, as experts invite us to join them in wondering through our own eyes and with our own minds at the beauty they themselves see.

Evolutionary accounts of the capacity to perceive beauty

It goes without saying that the human capacity to perceive and appreciate beauty is an evolved trait, as we are evolved creatures in an evolving universe. Our evolution has physical aspects and social aspects: the physical has given us the hardware with which to process an understanding of the world around us; the social has given us a further set of tools that are learnt as we grow and passed on between generations. These social tools are protected by culture, by collective memory and by collectively held skills and abilities. It is no problem for my argument that our capacity to perceive beauty, whether in another person, in a landscape or in a set of equations or a molecular structure, is evolved. In fact, if our capacity to perceive beauty evolved as an advantage in the getting of mates of the right kind – if sex, in this example, lies behind our aesthetic pleasures – then the usefulness of this same feeling for the making of scientific advances in our understanding of the world is a pretty outrageous perversion.

Certainly, sexual selection is one of the main proposed explanations for our sense of the beautiful. Four theories set out by Helen de Cruz and Johann

de Smedt in a recent book, for the origins of our sense of beauty, are indeed, (1) sexual selection, (2) evolved sensory bias, (3) the biophilia hypothesis and (4) the prototype approach to awe.[3] Sexual selection, of course, refers to the ways in which animals have evolved gorgeous plumage or pretty singing as a way to attract mates and/or prove their biological fitness. The peacock says: if I can grow a tail this fabulous, then I must be intensely fit, I must be a vigorous and healthy mate.[4] This particular interpretation is that of Alfred Russell Wallace; a more modern and leading understanding associated with Amotz Zahavi turns the logic around: such ornaments are a *handicap*, and so to be capable of carrying them safely one must be good at escape from danger and defence of one's safety: the peacock says, my genetic complement is one that will safely protect yours. In either case, such displays seem unlikely to explain our aesthetic pleasure at seascapes and cherry blossom.[5]

Evolved sensory bias theory argues that reward centres of the brain – sources of a physical sense of pleasure, like orgasm – are engaged by aesthetic experience. And it is true, there is something erotic about aesthetic engagement, whether with music or a molecule. Networks of brain areas are involved – and part of the pleasure we feel in an aesthetic experience *is* that sense of integration, of a single-minded experience, focused just on one thing, as we are in lovemaking (and you can see why that might be to our evolutionary advantage). Research indicates that there is a reward-driven and emotional response to art that especially involves the right anterior insula of the human brain.[6] But, again, however true this all is, it fails to explain the appreciation we feel for natural beauty.

The biophilia hypothesis was proposed by E.O. Wilson and argues that we prefer natural environments – we recognise them as an appropriate kind of home. Humans do, it seems, feel better when they live in a natural environment – when they can buy a home in the country – and will pay more to inhabit a pleasant context. But, de Cruz and de Smedt point out that biophilia is also problematic, because we also as humans will happily destroy beautiful places, and we also find places beautiful that are not helpful to us – raging seas and precipitous mountains, for example.[7] On the other hand, I suppose appreciation of the sublime beauty of a starlit sky could have proved useful as basis for navigation and so been selected for by that means.

Our appreciation of the sublime – mountain and ocean – is linked in us to a feeling of awe that de Cruz and de Smedt argue is also felt in the face of scientific theories and discoveries. There is something awesome about general relativity, I suppose, but the feeling scientists have when they understand something in a new way, and are conscious they are perhaps the first to have done so, is not so much awe as mild pleasure. I am mildly pleased when I understand and then move on to the next thing - the next challenge. 'Eureka!' moments (which are real enough – see Chapter 8) are rather quiet affairs for many scientists. An evolutionary explanation of our feeling awestruck is hard to pin down – the sublime confronts us with excess, for example vastness, and we need to assimilate that experience or accommodate

it to our sense apparatus, through a process of subordination. But, we feel awe at very divergent experiences – starry nights, music by Palestrina – which makes an evolutionary explanation of this sensation hard to frame, as evolution occurs, not in tension with general classes of experience, but in tension with very specific and concrete selective pressures. De Cruz and de Smedt conclude that it is hard to provide a naturalistic explanation for why we see nature as saturated with beauty.[8] Alvin Plantinga would concur, it is hard to understand why the beauty we see in a 'craggy ocean seashore' or a 'tiny highly articulate flower' has a selective advantage. Like music (in the view of Steven Pinker), seeing such beauty is useless.[9]

Even though our capacity to recognise beauty surely does arise from a combination of physical and social evolution, this does not allow us to write it off as an adaptively useful but meaningless trait. It does not mean that the reasons why I find you beautiful, or that music beautiful, or the sunset over the sea beautiful, just come down to evolution. Evolution gave me the capacity to see beauty, but now I am free to see it for myself. As with love for another human being, or love for one's children or nephews and nieces – originally, no doubt, with origins in selection for reproductive advantage and social stability – the love of the beauty of creation has long ago loosed its biological and sociobiological grounding and gained personal freedom and independence via our capacity to talk about it and make sense of it. In our families, we assert boldly that we love one another, and we mean it. These days, when people love one another, they do *not* do so because of the selective advantage it confers; they do it for itself. So, the *capacity* to find things beautiful might be (is) evolved, but that does not mean that when we find something beautiful we aren't in an important sense quite right. It is not just a matter of opinion, or a convenient fantasy, or something we can only see because it helps us reproduce (though, of course, in specific cases it does), but something rather factual, at least for us. It is also something rather basic – yes, we find nature beautiful (and terrifying), and we find human artefacts designed for our visual pleasure beautiful, but we can also find a car beautiful, or a synchrotron beamline, or a chemical synthesis.[10] There is something unromantic about the beauty that matters, and the role of beauty in science strongly supports the idea that the beauty we see is somehow real.

This does not stop devotees of neuro-evolutionary ethics arguing that prosaic selective advantage lies behind the fantasy of art, just as prosaic selective advantage is purported to explain the capacity to entertain religious beliefs or to act kindly. Raymond Tallis has rightly and forcefully attacked such arguments, which make a nonsense of human value and of the fact some art is good and some art is simply bad.[11] Our *capacities* may have evolved, including our capacity to love and our capacity to maintain values, but our love and our values are real enough. Again, the scientific understanding we gain by making those values the basis for our actions supports such a view.

Art (and all aesthetics) is not about reproduction but about itself, and a celebration of our lives and our world. Artists do not create artefacts to

maximise their chances of reproduction, rather obviously, and the unique qualities of unique works of art – written, drawn, composed or sculpted – are wholly independent of neuroscientific considerations, saving the fact they have to be processed through our common, inherited and evolved neural hardware.[12] We find meaning in art and in our aesthetic sense and we at the least live *as if* that meaning were truthful. Meaning is something we express verbally; language is the vehicle of much that is factual and itself also a vehicle of beauty: language itself can be beautiful. Indeed, the perception of beauty and the perception of meaning interpenetrate one another – the meaningfulness of a poem derives in part from the beauty of its phrasing. The meaningfulness of language will be a focus of Chapter 7, but here I wish to discuss the evolutionary emergence of such language and such meaning.

Talking about beauty

The French neuroscientist Jean-Pierre Changeux, famous in my own field for his work on the mechanism of proteins such as haemoglobin, wrote a book with the provocative and optimistic title *The Physiology of Truth*. In it, he argues for an understanding of the emergence of science as a natural function of the human brain, whereby cognitive science, alongside philosophy, economics and politics, contributes to an understanding of how a scientific viewpoint emerged.[13] Changeux sees a physiological commonality in the ways in which humans classify the world, and finds evidence for this in 'primitive contemporary societies'. Such a convergence leads him to conclude that, 'the human brain, through a combination of common innate predispositions and habits of learning by trial and error, extracts regular features from perceptual experience of the natural world and organizes them as a series of basic conceptual categories'.[14] There is a remarkable consistency in the use of colour terms across cultures, and the origins of modern scientific abilities in number, accounting and symbolism can be identified around 3,000 BC; the 'conjectures and hypotheses' thrown up by the human mind generate a 'surplus of meaning', a set of interpretative and epistemological possibilities, before a best course is identified.[15] Changeux identifies the origins of modern science in Ancient Greece, whose gods he contrasts with Jehovah and Marduk as allowing space for naturalistic explanations to emerge.[16] It is very odd indeed to equate Jehovah and Marduk. I seem to remember that the former repudiates human sacrifice, whereas the latter demands it, and actually it is the belief in creation from nothing – primarily a Judaeo-Christian belief – that gave rise to a vision of the world as free, and hence gives rise to modern science (see Chapters 6 and 8 for more discussion of this point). Changeux's is a very sunny vision of science,[17] whose emergence is seen as arising from an 'unstable equilibrium' between two alternative world-views: the empiricist/experimental approach of Aristotle, Bacon, Locke and Hume, and the rationalist/theoretical approach of Plato, Descartes and Kant.[18] There is no doubt truth in this, but Changeux's bizarrely optimistic faith in science as a liberator

seems to place the cart before the horse in terms of rationalism and scientific understanding. It's not that the 'scientific mind' enabled a rational understanding of the world;[19] instead, a free rational ordering of thought enabled science to evolve. So, Changeux asserts that, 'the longing for freedom is inarguably one of the most distinctive features of the search for truth',[20] whereas surely it's the case that the search for truth is one of the distinctive features of human freedom. In a way, Changeux sees this, as he notes how scientists make use of their imagination and recount original ideas coming to them in dreams.[21] These are both expressions of human freedom, just like the freely chosen selection of the beautiful as more likely to be the true.[22]

The language scientists use to talk about the beauty of their data and, indeed, the understandings they have, their models for the workings of physical systems, are very frequently metaphorical – like all truthful speech, grappling with the sensory overload of existence.[23] Irving Massey suggests that the 'tendency to perceive in metaphors' may be a 'secondary sexual characteristic of *Homo sapiens*' with survival value.[24] Metaphors are erotic, with the associated excitement, and 'in the erotic state, one simply *sees* more'.[25] Metaphors are incubators of ideas and sources of suggestion.[26] As we will discuss in Chapter 7, the metaphoric mode of science is absolutely essential,[27] but so is the fact that we make sense between ourselves and not just in our own heads. Consciousness is in some ways private, but the most interesting aspects of consciousness are public, in our shared physical and linguistic exchange.[28] We will return to this in Chapter 9 and to the ways in which the public nature of our 'consciousness' (i.e. the sense in which it is *not* private and *not* internal to our minds, still less our brains) is fundamental to our making sense of the world as creatures in the image of God.

Any intelligent understanding of the ways in which language works has to account for the fact that language is embodied, it is *we* who use it. Scientists like to pretend that their language has a purity other discussions lack, but the fact is it is evolved like any other way of talking. There are two things we are therefore left to accept alongside each other: (1) that the evolved origins of language make it questionable as a vehicle for communicating things that are absolutely (rather than locally) true; (2) that scientists *have* to assume that their language – for example, about how beautiful the world is or their data are – is somehow telling the truth. Unfortunately, we are not able to justify the way language works for science externally/objectively, because the same language is the basis on which we make our arguments. So, if you are looking to science to explain why you can think coherently, you run into the problem that coherent thought is the precondition for your understanding anything and cannot offer an explanation for itself. This is a famous problem particularly focused on by Alvin Plantinga to argue on an evolutionary basis against naturalism; it is also something that worried Darwin himself.[29] You cannot offer an explanation as to why your speech is meaningful (such as why something is beautiful) *and* assume the meaningfulness of what you have to say – there really is a circularity here,[30] albeit one we are forced to live with. Although language and the expression of meaning (like a sense of the beautiful and its expression

in art) may be something evolved, it is not actually explicable in evolutionary terms. There is something game-changing about what humans mean by 'the beautiful', just as there is something game-changing about what we mean by 'the true'. These just are not the things that animals might target in a process of sexual selection, because they are parts of processes of representation and appropriation to specifically human understanding.[31] To see the beauty scientists see is to see into the objectivity of things; animals, by contrast, exist simply in a world of appearances.[32] Just because a false belief is adaptively useful to an animal does not make it objectively true; for a scientist, false beliefs are unacceptable, however adaptive they might be.

The questions evolution begs about our understanding of beauty can equally be asked of our scientific understanding. Human language about beauty and about science both have to be understood as evolved and as fundamentally embodied,[33] fleshy, and this begs questions for science just as it does for the arts and for the things we say to each other every day. The psychosomatic system we use in each context is the same one for every kind of thing we apprehend, know, understand or argue, and not even a scientist (if he or she is particularly egotistical, *especially* not a scientist) is set apart from this. The view from nowhere, the independent perspective, is no-one's prerogative – to the extent that we have it, it is something we share:[34] something between us, something about meaning, something spiritual.

Our capacity to perceive beauty, and our capacity to talk about it to each other, is no more a phenomenon of ourselves as physical beings with a long evolutionary history behind us than is science. Scientific intelligence has no special status here; it is as much a product of selective pressures as what I happen to find gorgeous; it is as much subject to the messiness, the selfishness and the desires of life as the aesthetic. We shouldn't object to this but celebrate it, and wonder (as we will in Chapter 7) what unanswered questions it poses.

So, we can look up, recognising our desires and partiality and wondering how it is that we can also be so good and understand so much. But, we can also look down: we know how good we can be and how much we understand (and what we don't) and we recognise that our intelligence makes sense of how things have evolved.[35] And we are amazed, because from both perspectives we are reflecting on the fact that there is no material division in the universe between matter and mind:[36] we might be able to do a lot with our minds that is immaterial, but they are not made of different *stuff* from the rest of creation; instead, they are of a different order, the order of meaning: meaning found, meaning made and meaning shared.[37] Our scientific reasoning is no less a product of evolution than our capacity to find things beautiful or have religious beliefs, and to adopt a fundamentally sceptical attitude to one – say the judgement something is beautiful or the belief that God loves me – just because the human mind has evolved requires a similarly sceptical attitude to science and our whole capacity to reason. It can be countered that, in science, one experiments and looks to falsify incorrect reasoning or knowledge, but there is a robust philosophical point here that should be acknowledged and that has been

made many times by people from very different perspectives (e.g. theistic and atheistic).[38] And, in any case, as argued at the end of Chapter 2, I am unconvinced that prayer and science are very different kinds of activity anyway. Indeed, *if* you want to be sceptical about the value of an aesthetic judgement or a religious belief *because they can be shown to have evolutionary explanations*, then you are committing yourself to be as sceptical, not only about scientific beliefs you happen to hold, but also about your belief you love your spouse and your children, the belief that murder is wrong, and the belief that all men are equal. You cannot have it both ways, there are no special bits of human mentality – if you want to disrespect things people do with their minds that are demonstrably of aesthetic, moral or spiritual value, then you are committing yourself logically to disrespecting everything they do.

> Metaphysical naturalists cannot simply surmise that all religious beliefs are false and then proceed to observe that evolutionary processes give rise to false religious beliefs. Evolutionary debunkers will have to specify why natural selection would lead us to adopt false beliefs in the religious domain, whereas it allows us to adopt true beliefs under many other conditions.[39]

Faking it: Couldn't I be tricked into thinking something beautiful?

This raises the possibility, nevertheless, that I could think something beautiful but be mistaken, or think something beautiful because of my lack of education or my poor taste, or even be tricked into thinking something beautiful. What then of the capacity of my sense of the aesthetic to guide me to scientific truths?

Virtual reality is an area of technology in which being tricked into thinking something real is the basic intention. Participants in virtual reality experiences are knowingly allowing their minds to be tricked, for the enjoyment of the sensations involved – or for educational value. Using virtual reality to learn how to fly a plane or, as in the computer game Minecraft, to build a virtual world has clear educational value. In the former case, it involves gaining technical skill; in the latter, an expanded understanding of possibility and an improved capacity to work imaginatively and spatially. We know they are not 'real' experiences, but in such cases the virtual reality we encounter is of profound educational value.

Other virtual reality experiences – such as the possibility, already openly discussed, of virtual reality sexual intercourse, or the possibility of sexual intercourse with robots – may have much less value. It seems to me that thinking about this particular kind of virtual or manufactured reality is helpful in addressing the sensible point that I could be *wrong* in some particular sense to believe something beautiful, or in any other kind of belief, including the one about beauty in science being a guide to the truthful. What I have in mind is a simple thought experiment, which is to compare the experiences of someone actually engaged in sexual intercourse and the same person immersed in a

virtual sexual experience. For the purposes of the argument, we should assume that the experience is indistinguishable in terms of sensations experienced by the individual. In this case, are the two experiences identical?

There are people who would say they were. But, it seems to me that the two experiences – the real experience of making love to someone, and the virtual reality experience of the same process – are wholly different. How do they differ?

First, in the real experience there is a genuine relationship between two independent realities – myself and the person to whom I am making love, for example. In a virtual reality experience there is not a genuine relationship of this kind – except maybe the rather sinister one between the human participant in virtual experience and the human or humans who wrote the software and built the devices that are giving them a false impression. That is not a relationship of equals, whereas there is, by definition, a relationship of equality between two people making love.

Second, in the real experience there is free will (on both sides), with a mutual exposure to risk and uncertainty. In virtual reality there is risk only on one side, at best.

Third, in the real experience there is a history to the interaction – the two people involved have known each other for some time – and the interaction we have now will extend into a future that it will help create.

Several other distinctions could be drawn: we will each be changed by the experience, the experience is totally unique to us and to this encounter between us; we can change our minds; there is no finite length to the process. And so on.[40]

There is a world of difference between the virtual and real experiences. And, the relevance of this example to our discussion of a recognition of beauty – whether in data or in a work of art – is to suggest that it isn't the possibility we are wrong that should concern us. Assuredly, we *might* be wrong, just as I might be wrong to think you love me, or mistaken in my stated belief that I love you. What matters is that we believe it is possible there is something beautiful here, and that we are willing to respond honestly to it. Then, because I can tell others what I find beautiful, and compare it with their perceptions, I can gain confidence that I am right, here is a thing of beauty, or indeed accept that I might be wrong – my tastes need further education. As we have discussed before, you can find Mozart's music wondrously admirable, or dislike it intensely, but, as we said, what matters is that humans *can* and *do* respond in a set of identifiable ways to the recognition of beauty. You and I might rejoice in different kinds of aesthetic – it doesn't make either of us *wrong*.[41] Just as you and I might love different people – indeed, two men might love each other in the same way that a man and a woman love each other – both couples are still, as we say, *in love*. What is common is the *possibility* of love and all that it speaks of. When I see something beautiful, what is common with anyone else's experience of the aesthetic is that we believe something beautiful to exist – this thing, or that. What underpins all this is, of course, our common nature as physical beings, as incarnate souls, embodied minds, lovers of creation.

But isn't my perception of beauty something I get from my culture?

Surely, it is, or can be. For the same reasons already explored, this should not concern us unduly – what matters is not that I find particular things beautiful (for example, the music of Mozart), but that I am sensitive to beauty anyway. Indeed, the fact that my appreciation of beauty is culturally affected (and effected) reassures us that those who would like to reduce aesthetic appreciation to the cyclical outworking of hardwired neural processes – and so, I think, to reduce their significance to little or nothing – are looking in the wrong direction. Of course our brains are important – are essential – to our perception of the lovely and the gorgeous – and no one is going to pretend that damage to the brain may not affect our capacity for perception, reception and understanding, or that taking drugs or our experiences in life will not provoke or restrict our aesthetic abilities.[42] But, just to say that, for example, certain neurons respond to straight lines tells us nothing about the content of the object that is being looked at:[43] are we looking at a pylon (attractive in its own way) or a Bridget Riley painting? My eyes respond particularly to the straight lines of pillars when the light is low; the experience has nothing to do with aesthetics, but is just a rather odd sensation. Or, in another good example, are we seeing the dots from the technology used to print a colour magazine, or are we looking at a pointillist painting, such as Georges Seurat's *A Sunday Afternoon on the Island of La Grande Jatte*? – the subject of a Stephen Sondheim musical that makes the pointillism aural – not something anyone would be likely to try with the technical basis of magazine production (or maybe Steve Reich has already?). But apparently, Margaret Livingstone says she finds the pointillist effects of enlarging colour magazines as aesthetically pleasing as pointillist paintings. Irving Massey says, and I agree, that, 'this conclusion . . . almost deliberately weakens the purchase of neuro-criticism on aesthetics'.[44] Another example is the claim that, in looking at a series of curves where we can perceive pairs of brackets – () – or an hourglass form –)(– we tend to prefer closure and therefore 'see' preferentially the former rather than the latter.[45] Except that I don't; given this array – ()()() ()()()()()() – my attention is drawn to the hourglass and not the brackets.

Every case in which human aesthetic perception is studied faces a fundamental problem: 'no matter how many neurobiological universals we may identify as contributing to our general response to art, they never determine our particular response to any particular work'.[46] Is my friend right to dislike the music of Mozart, or am I right to appreciate its beauty? Though it pains me to admit it, we both are. Neurons do not see or hear or understand; they provide a basis for each of these things, but it is we, as people, who engage in each kind of activity.[47]

> A scientific approach to the arts could imply that neurology has something to tell us about the arts that we need to know, that neither artists not audiences can do their job properly without the information that the sciences can provide. Such a belief would be both pernicious and wrong.[48]

Amen to that; and yet, irony of ironies, the arts *do* have something to tell us about the sciences that scientists need to know, if they want to understand what they are doing and thereby do it better.

Beauty and science: Leaping from subjectivity to objectivity

The experience of beauty is a boundary moment, a transition point in scientific study in which we make a decisive move from the subjective to the objective. Seeing no pattern in our data, finding ourselves unable to make sense of what we see in front of us, we reach an impasse. When the pattern comes in view – we see brackets or hourglasses, the meaning of our data clicks into place in our minds – at that moment we experience an aesthetic joy. Or, if we have been at a loss as to how to test our hypothesis and we work out what experiment would give us a way in, we again experience a gladness and a joy that are aesthetic. My colleague Robin Dunbar puts it well:

> The pursuit of science, as any active scientist will tell you, entails as much appreciation of the beauty of nature, of the elegance of ideas, as any artistic or literary endeavour. To see the exquisite beauty of a supernova through a large telescope, to watch the drama and tension of a wolf-pack at hunt, to find the delicate shades of a wild orchid tucked away in the crook of a tree root – these are the daily emotional fare of scientists the world over. They are the things scientists look forward to, that give them pleasure and sustain them through the dull and tedious business of normal science. It is that same sense of achievement one gets from placing the last piece in a giant jigsaw puzzle, or from finally managing to play a Paganini violin concerto without making a mistake – that same sense of satisfaction at completing a painting, or writing the last difficult line of a poem or preparing an exquisite dish. Here was a problem, something we did not understand; and now, by careful examination and the application of pure logic, combined with the experimental equivalent of green fingers, it has been possible to determine why the world *has* to be like that.[49]

The aesthetics of the process are not peripheral but central. Seeing beauty in our data and the way an experiment is done provides us with the open-mindedness and imagination to make new sense, to advance understanding in a fundamental way. Thinking figuratively, pictorially, non-literally and metaphorically helps us to claw our way from one cage of understanding to another – to break out of the strait jacket of a previous world-view and see things afresh. The artist's view that scientists have is necessary for their world-making.[50] The process gives us perspective, a capacity to see things laid out before us or in the round, which enables us to see the puzzle complete and how we solved it. In a way, it just doesn't matter why this approach works – it's obvious that it does, and there doesn't seem to be another kind of science to the one that involves humans as people engaging affectively with what they are studying. The approach works, and in itself this

should make us respect our own and other people's sense of the aesthetic in a new way – as an experience that is showing us the way to a better understanding of the truth of the matter. We are led to acknowledge 'the very continuity and unity, the very affinity, of art and science and perception as branches of worldmaking' such that to equate beauty or aesthetic rightness with truth *and* to say that they are incomparable with truth are equally misleading statements.[51] By other means, we have found that they show us the way to truth, but obviously a statement that something is beautiful is not the same as saying it is true. We just see how things fit together and we see how a certain description or model fits the data, we put things in a different medium – a sketch, a mathematical equation, a 3D molecular model – we find new ways to fit our data.[52] *Then* we test them, but to have the basis for a test we had to make the sketch, equate those terms, build our model, make that world in the first place. 'The line between artistic and scientific judgement does not coincide with the line between subjective and objective'[53] – subjectivism and objectivism are both required for science to make any advance, but it's the subjective, the way you are affected by your data, that provides the energy and the basis for a new kind of understanding.

Sharing our understanding of beauty in a shared world

'The way we know and understand is by representing, and then risking the form of our representation in shared discourse as time unfolds.'[54]

Our representation of the beauty we find in data is a responsive act that enables us to share our point of view. The way Titian, Rembrandt or Bruegel the Elder saw the world – saw people, saw communities, saw human life – coupled to their artistic giftedness enabled them to show us what they understood. The modelling and representation scientists engage in help them to tell others what they have seen. They provide a medium of communication that is risky and could mislead or confuse. But this is necessary – how else can I communicate what I have found than by talking about it, representing it and modelling it? The aesthetic representational response of the scientist enables others to participate in their understanding, to share their world. We make an aesthetic response to an aesthetic experience – what could be more appropriate? – and the outcome is a shared perspective. If I had to describe quite what I meant in simply factual terms, it would be unfaithful to the process whereby I gained my understanding and would just be less effective as a means of communicating with you. Painting the picture my data reveal enables me to take your hand and show you what I have seen, sharing my understanding of beauty in a newly shared world.

But, where does that world come from?

Notes

1 Charles Darwin, *The Origin of Species* (1859) p. 490.
2 A key part of the argument of Elizabeth A. Johnson in her recent *Ask The Beasts: Darwin and the God of Love.*
3 Helen de Cruz and Johann de Smedt, *A Natural History of Natural Theology*, pp. 138–51.

4 Raymond Tallis has rightly pointed out (in *Aping Mankind*, p. 304) that this argument is chauvinist. Some, like Geoffrey Miller, would want to argue that sex is the origin of 'art, music, language, kindness, intelligence and creativity' (p. 303), but this is surely a category error.
5 de Cruz and de Smedt, *A Natural History of Natural Theology*, pp. 138–40.
6 de Cruz and de Smedt, *A Natural History of Natural Theology*, pp. 140–2.
7 de Cruz and de Smedt, *A Natural History of Natural Theology*, pp. 142–5.
8 de Cruz and de Smedt, *A Natural History of Natural Theology*, pp. 145–8.
9 Avin Plantinga, *Where the Conflict Really Lies* (Oxford University Press, 2011), p. 132.
10 Pope Francis, encyclical *Laudato Si'* (2015), 103: 'Technoscience . . . can also produce art and enable men and woman immersed in the material world to "leap" into the world of beauty. Who can deny the beauty of an aircraft or a skyscraper? Valuable works of art and music now make use of new technologies. So, in the beauty intended by the one who uses new technical instruments and in the contemplation of such beauty, a quantum leap occurs, resulting in a fulfilment which is uniquely human'.
11 Tallis, *Aping Mankind*, pp. 287, 297.
12 Tallis, *Aping Mankind*, pp. 283–8, 301–4. See also Irving Massey, *The Neural Imagination*, pp. 163–8.
13 Changeux, *The Physiology of Truth*, pp. 213–14.
14 Changeux, *The Physiology of Truth*, p. 215.
15 Changeux, *The Physiology of Truth*, pp. 216–18.
16 Changeux, *The Physiology of Truth*, pp. 221–2.
17 And negative view of religion: 'The critical skepticism to which theories are subjected depends on a particular set of social and political conditions – free discussion, intellectual competition, an atmosphere of tolerance, institutions devoted to research, uncensored publication of results, and so on – that inevitably bring scientific investigation into conflict with religious belief' (p. 234).
18 Changeux, *The Physiology of Truth*, pp. 226–8.
19 Changeux, *The Physiology of Truth*, pp. 237–8.
20 Changeux, *The Physiology of Truth*, pp. 238–9.
21 Changeux, *The Physiology of Truth*, pp. 241–2.
22 Changeux, *The Physiology of Truth*, p. 244.
23 Rowan Williams, *The Edge of Words*, p. 117.
24 Massey, *The Neural Imagination*, p. 96.
25 Massey, *The Neural Imagination*, pp. 96–7.
26 Massey, *The Neural Imagination*, p. 93, p. 147.
27 Furthermore, 'Einstein puts it more simply: "Imagination is more important than knowledge." In the end, our responsibility is not to learn to know what we imagine, but, as Shelley said, to learn to imagine what we know' (Massey, *The Neural Imagination*, p. 100).
28 Massey, *The Neural Imagination*, pp. 99–100.
29 Frances Young, *God's Presence* (Cambridge University Press, 2013), p. 65.
30 Williams, *The Edge of Words*, pp. 56, 101. See also Thomas Nagel, *Mind and Cosmos* (Oxford University Press, 2012), pp. 76–81, and, with a focus on consciousness, Tallis, *Aping Mankind*, pp. 93–4.
31 Williams, *The Edge of Words*, p. 60: 'animals do not make representation of their environment that may be more or less adequate.' They are good at representing their environment, or they aren't, there isn't a discussion to be had about whose view is better. It has taken human society and the continuous and not episodic experience of consciousness possible because we have a history to enable the human mind to achieve its astonishing qualities of perception and coherent thought – see Tallis, *Aping Mankind*, pp. 11–12 and 217–38, and, again, Williams, *The Edge of Words*, p. 80.

32 Nagel, *Mind and Cosmos*, p. 73.
33 And thus can be physically impaired. See Williams, *The Edge of Words*, pp. 95–103.
34 'The view from nowhere' is Thomas Nagel's poignant phrase and the title of his book, which has been very influential in theological epistemology; see Chapter 7 for more discussion. Tallis, *Aping Mankind*, p. 113.
35 Williams, *The Edge of Words*, pp. 63, 102.
36 Williams, *The Edge of Words*, p. 107. See also Chapter 7.
37 Rowan Williams, *On Augustine* (Bloomsbury, 2016), p. 166: 'since I cannot (again, logically cannot) think of my mind as one of my mind's objects, I can be shown that – whatever I *think* I am saying – I cannot in fact believe that my mind is a piece of stuff. There is no sane way of behaving that would display such a habit.'
38 Nagel, *Mind and Cosmos*, pp. 75–81; Nagel, *The View from Nowhere* (Oxford University Press, 1986), p. 78; Plantinga, *Where the Conflict Really Lies*, p. 136; Tallis, *Aping Mankind*, pp. 11–12, 170–213, 340–56. The same criticism goes for the idea that 'memes', units of cultural reproduction as coined by Richard Dawkins, undermine the significance of our thoughts and reveal an insubstantiality at the heart of what we take to be our personalities. If the role 'memes' play undermines the significance of things we do, science is as prey to the effect as any other human cultural activity (see *Aping Mankind*, pp. 163–8; Susan Blackmore, a proponent of the significance of memes, would agree: see her *The Meme Machine* (Oxford University Press, 2000). If the meme is an insignificant idea (and it has now become, not only a Dawkinsian concept, but a picture you share on line for amusement), then there is no problem, of course; just as there is no problem taking seriously the trust in our minds, the belief in our hearts, the hopes we have the future, and the love we feel for friend and stranger just because the substrate on which we do these things happens to be evolved.
39 de Cruz and de Smedt, *A Natural History of Natural Theology*, p. 188. See also pp. 194–8: attempts to refute the truth-tracking of our intuitions outside the realm of medium-sized objects will debunk science too; 'Generalized debunking arguments lead to a position of self-defeat'.
40 Raymond Tallis, in *Aping Mankind*, notes a comment by Howard Robinson to the effect that, 'hallucinations have nothing in common with genuine perceptions apart from the fact that they seem the same to the person experiencing them' (p. 94). I think this is quite right.
41 Tallis, *Aping Mankind*, pp. 299–304.
42 Massey, *The Neural Imagination*, pp. 4–13. See also Tallis, *Aping Mankind*, p. 29.
43 Massey, *The Neural Imagination*, pp. 39–44.
44 Massey, *The Neural Imagination*, p. 48; see also pp. 136–7.
45 Massey, *The Neural Imagination*, pp. 48–9; see also pp. 138–40.
46 Massey, *The Neural Imagination*, p. 143.
47 Massey, *The Neural Imagination*, pp. 171–82. See also Tallis, *Aping Mankind*, pp. 11–12.
48 Massey, *The Neural Imagination*, pp. 183–4.
49 Robin Dunbar, *The Trouble with Science*, pp. 173–4. Pleasingly, Robin goes on to quote Daniel Dennett in a similar vein.
50 Goodman, *Ways of Worldmaking*, pp. 102–7.
51 Goodman, *Ways of Worldmaking*, pp. 121–2, 132–3.
52 Goodman, *Ways of Worldmaking*, p. 138.
53 Goodman, *Ways of Worldmaking*, p. 140.
54 Williams, *The Edge of Words*, p. 80.

6 Where does the beauty come from?

As was noted in the introductory chapter, the most fundamental questions elicit a feeling of awe. In this chapter and the next, we will consider probably the most important questions in philosophy, the ones on which hang everything else we might want to do with our thinking. We begin with the biggest of all:

Why is there anything rather than nothing?

This is not a question about the making of our world. Nor is it a question about who started things off, because *someone* had to. It is a question about the possibility of anything existing at all. To some, perhaps to many scientists and others who find mechanical analogies of the world useful (and I do myself), this might seem to be mere sophistry – or mere theology (the words have become synonymous for some people). But, from the start of this chapter, it is necessary to assert strongly that talking about creation, talking about why there is anything rather than nothing, is definitively not the same as talking about the world getting made. As Herbert McCabe notes, 'whatever creation means it is not a process of making'.[1]

This might sound odd; after all, we do describe God as a 'maker' and find the term used of him in the Bible, and in turn we use it in our worship. At the beginning of the second creation account in the Book of Genesis (a more ancient version than the one found in the first chapter, the one about the seven days of creation), it says:

> In the day that the Lord God made the earth and the heavens, when no plant of the field was yet in the earth and no herb of the field had yet sprung up – for the Lord God had not caused it to rain upon the earth, and there was no one to till the ground; but a stream would rise from the earth, and water the whole face of the ground – then the Lord God formed man from the dust of the ground, and breathed into his nostrils the breath of life; and the man became a living being.[2]

And, in the Book of Common Prayer, at the General Confession at a Eucharist, we call God 'Maker of all things, Judge of all men', and, in the Apostles Creed,

we say in the sixteenth-century version, 'I believe in God, the Father Almighty, Maker of heaven and earth'.[3] But, when we use the word in these contexts, we do not mean 'make' in the sense that you or I might make something, and in fact do not use the word 'make' here in anything *even approximating*, in any way, to the way you and I might make something. Sometimes we forget that, and many of those who are opposed to religion on scientific grounds don't realise the difference between the different uses of the word 'make'. In worship and in the creeds we say 'make' as a shorthand, because it helps us tell a story (our story) and because it reflects our tradition, it reflects, indeed, Genesis, Chapter 2. But, we do not use it in the same way that anyone makes anything.

The reason why the word 'make' is used in Christian theology in a way completely distinct from the way you or I would use it of something we do is actually quite simple. For us to make something requires us to act, it requires us to take some stuff and mould it into something else, something new, something more organised or more useful or more beautiful. Making something starts with raw materials, and it does not start with nothing. It's very simple science really, the first law of thermodynamics: energy can be neither created nor destroyed. Whenever we make something, we have to start with something else. And, to start with something and act upon it is to exert force upon it, and to be a part of the same system within which it exists. For humans it is, in an everyday sense, to be part of the world of medium-sized objects. So, if we think of God as making the world like we make things, we render him an actor alongside us, we *make* him part of *our* world. And, whether critics of theology like it or not, this is not what Jews, Christians or Muslims, among others, believe. God is not a part of our world. As James Alison puts it:

> When we speak of creation we are speaking of a relationship, a relationship of purely gratuitous giving, without motive, with no second intentions, with no desire for control or domination, but rather a gratuity which permits creatures to share gratuitously in the life of the Creator.[4]

To speak of God making things to be a certain way, the way we make things, is to say that God does violence to what existed before, that God takes something and bends and breaks and moulds it into something else. This is not what Jews, Christians and Muslims believe, because it is to say that God objectifies the world and is an actor within it, when in fact God loves it (into being).

The relational language that James Alison uses captures something of what God is like, whereas language about God acting with force does not. The relational is a very helpful focus here. Look at it this way: when humans use language, we regularly put single words to completely different alternative uses, and quite often we apply words both to mechanical processes (or, processes that *can* be understood mechanically)[5] and to human relations. To say I am attracted to you is a very different thing from saying that a magnet and a bit of metal or two charged molecules are attracted to one another (and to say I am repulsed by you is also different from two molecules repelling each other).[6]

To build a wall or even build up a business is very different from building someone up. To make a chair or a car is very different from making it to be the case that anything at all exists. We sometimes use the word 'make' as helpful shorthand when we speak about God, but we do not mean it the way we use it about activities undertaken by inhabitants of our world; instead, we mean it analogically. And so, to avoid confusion, I want to avoid that word 'make', and concentrate on the other word we often use, synonymously, which is 'create'.

This is thoroughly biblical. The ways in which human beings understand what they can about God have evolved, and one very clear trajectory of thinking is away from thinking of God making the world out of a pre-existing barren land, as in Genesis 2, and towards the idea of God making the world out of nothing, as in Genesis 1.

> In the beginning when God created the heavens and the earth, the earth was a formless void and darkness covered the face of the deep, while a wind from God swept over the face of the waters. Then God said, 'Let there be light'; and there was light.[7]

Maybe 'formless void' is not quite nothing, it's actually watery chaos, but it's closer to nothing than just saying the Earth happened to not have anything growing on it, as if we were talking about Mars. But, even if 'formless void' is not quite nothing (it could, I suppose, be a quantum fluctuation in a vacuum),[8] according to Genesis 1 it did not contain light, let alone anything else specific. The idea of creation from nothing evolved, in the Jewish tradition, based on this sense that anything we might recognise in our world, anything that causes the world to be what it is (light, sea and sky, land, let alone plants and animals) – that is, every way in which things that exist are differentiated from one another and have their own history – depends on God, comes from God's creation of anything and everything. We see it applied to the individual human life in Psalm 139, as it says, 'for it was you who formed my inward parts, you knit me together in my mother's womb . . . your eyes beheld my unformed substance':[9] God creates *us* from nothing. The tradition evolved – in the late and apocryphal second book of Maccabees we find, 'I beg you, my child, to look at the heaven and the earth and see everything that is in them, and recognize that God did not make them out of things that existed. And in the same way the human race came into being'.[10] Frances Young notes that this passage is not only capable of being interpreted as referring to creation from nothing, as it could be read alongside Genesis 2. But, in any case (as she argues), what matters is not this specific text or that, but the overall thrust of Judaeo-Christian thought, and that it is towards the idea of creation *ex nihilo*.[11] In fact, what seems to be decisive for the Christian doctrine of creation out of nothing is Jesus's resurrection, a further emphatic experience for humanity of God's grace. As Frances Young points out, this understanding of creation reinforces the sense that human life is a gift, and also that human life has a physical dignity and is for each person one psychosomatic whole, with no separation

of body, mind, soul or spirit (we will return to this theme in Chapter 7, while considering the meaningfulness of language). The resurrection of a human being is definitively creation out of nothing, and the resurrection of Christ is the eighth day of creation. This is what allows St Paul to speak of God as the one 'who gives life to the dead and calls into existence the things that do not exist',[12] and in the Gospels we have Jesus himself speaking in the same vein when, in an argument, he asserts that the Lord is the God of Abraham, Isaac and Jacob *because* 'he is God not of the dead, but of the living; for to him all of them are alive'.[13]

Early Christian theologians such as Basil of Caesarea and Augustine of Hippo saw in Genesis 1 and 2 the basic assertion that there *was* a beginning, and that God has priority, is *before* the beginning and from all eternity.[14] Genesis 1 is about the creation of the world in relation to God and it is about the freedom of all that exists, about its release into existence by God. This is written plainly in the text – God says, 'Let there be . . .', not 'I am making . . .'. Of course, God relates to the world in Genesis 2, but more as *part of* it than not, walking in the garden in the cool of the evening breeze, to the alarm of a guilty Adam and Eve. God relates far more fundamentally and intimately to the world in the version offered by Genesis 1, giving everything that exists the freedom to be itself and approving it, saying that it is good, that it is, in fact, beautiful. But, God is not a component of that existence. Indeed, this is how God *can* relate to everything that exists – only by being not present *in any particular way* can God *be present to everything*, always.

> For it is out of a longing to relate deeply to the world that God foregoes any annihilating 'presence' to the world. This . . . is the very condition of dialogical intimacy . . . The God of self-giving compassion is in fact the only God that normative Christian faith can claim legitimately ever to have encountered.[15]

To focus on the idea of relationship as a way of understanding what it means to say the world is created is helpful in part because relationships *do* come from nowhere, from nothing. Before two people meet there is literally nothing between them, no kind of relation; when they meet there is a new aspect to reality, which is their relationship. If they fall in love and marry we say explicitly, it is a new creation. The creation of new relationship is one of the ways in which God creates each human life out of nothing.

When we are dead we have no relationship to anything that exists, but only to God, who relates to all people, dead and alive, in love. Otherwise, our bodies hang about for a while, but in every meaningful sense we have ceased to exist. When Christ died, his fate was the same as ours: he was as dead as we shall ever be[16] (though obviously 'be' isn't quite right). For the human person to be dead is to be nowhere and nothing – death has no personal content, it ends our personal story.[17] So, for God to raise Jesus from the grave was as much an act of creation as the first moment of the universe's existence. Jesus's own

resurrection is, for the people who knew him, explicitly the re-establishment of their relationship to him on the back, as it were, of God's eternal relating.[18]

So, I think it particularly helpful to compare relational and instrumental or mechanical uses of the same words (attract, repel, build) to help us understand what God 'making' the world means.

The reason why the word 'make' has become such a problem for theology is that we now live in a world in which it is possible to imagine, in which we pretend to have access to, the possibility of an explanation for anything at all within a single explanatory framework, and for many scientists within a framework understood more or less in a mechanical way.[19] Science has given us this, and the benefits have been immense. We need to remember in this context, however, that it is the very belief in a God who creates *rather than* a God who *makes like we make* that lies behind this possibility at all.[20]

Much of the tension that is believed to exist between a theological and a scientific view of the world derives from the kind of confusion we have been discussing – thinking of God making the world in the kind of way you or I might make a pot (in my case, badly). Of course, God as a potter is an image we find in the Bible![21] But, God is also a rock, sheer silence, fire, a lover and the owner of a vineyard: by using images that are totally immiscible as a way of talking about God, our tradition seeks to underscore that as, obviously, they can't all be in any sense accurate, none of them is adequate, but all capture aspects of the way we experience the relationship that God establishes with us, and that God established with the universe when he created it.[22] We have forgotten how to understand what kind of a book the Bible is – it is the record of an evolving relationship – and treated it as if it were an instruction manual.

The Bible is not an instruction manual as a matter of historical fact, but we came to treat it as one. It seems to me that the arguments over Genesis 1 and 2[23] and how a religious system that takes them seriously can also be said to accept a scientific picture of the world come down, very simply, to a category error, a mistake, a wholly inappropriate use of Biblical literature, because we forgot what it was really supposed to be about. When Genesis 1 and 2 were written, there was no possibility, no imagination that the world could be understood completely as a single quasi-mechanical system. As Terry Eagleton puts it, this is like thinking 'that a novel is a botched piece of sociology' and so concluding that novels are pointless.[24] As Helen de Cruz and Johan de Smedt point out, the pre-modern understanding of natural processes did not conceive of a single framework within which all events could be understood.[25] Critics of religion who argue that Genesis is incompatible with a scientific world-view are being anachronistic.[26]

So, we assert that God created everything that exists out of nothing, meaning that God is 'the condition of the possibility of any entity whatsoever'.[27] This was a point of view that I had to live with for some time before I felt I understood it, and my principal guides were the writings of Herbert McCabe,[28] who could make me see what is meant by asking 'Why is there anything rather than nothing?', and that it means something like 'Why is there stuff?' Not, why

do *I* exist, or the planet Earth, or indeed the whole universe, but 'Why is there stuff?' I am writing this book as a witness to the power of this question in my mind. McCabe was, of course, a Dominican friar and a follower of the thought of Thomas Aquinas, and, in the wake of McCabe and my Dominican friends, I find myself following Thomas's thinking too. Innumerable examples could be given of what this means for our understanding of why there is anything rather than nothing, but the magnificent recent biography of Aquinas by Denys Turner gives a particularly helpful summary. Thomas believes that:

> there is no answer to be found within the things that exist as to why there is not nothing rather than something, not nothing rather than *any*thing at all . . . 'that there is something rather than nothing,' utterly defeats the mind's capacity to comprehend . . . The 'nothing', he explains, governs the 'out of,' so as to say: there is a making here, but it is a making with no 'out of' at all, no process, no antecedent conditions, no 'random fluctuations in a vacuum,' no explanatory law of emergence, and, there being nothing for the 'something' to be 'out of' there can be no physics, not yet, for there is nothing yet for physics to get an explanatory grip on: 'Big bang' is an explanation of the natural laws governing this something that exists. It is not an explanation of how come there is anything for those physical laws to be true of.[29]

I think we need to thank the people who try and shake up our thinking on this (including McCabe, Timothy Radcliffe and James Alison), because they help us start to grasp what Christian theology is actually saying. As someone has said, 'To arrive at the point where the world can be truthfully named in its relation to God involves some grasp of the world as object of pointless, "futureless" love'.[30] As someone else put it: 'The Creation is an abandonment' and 'The Creation itself is a kind of passion. My very existence is like a laceration of God, a laceration which is love'.[31]

This is a view of creation that meshes perfectly with the image of God we find in Christ, a God who 'chose what is low and despised in the world, things that are not, to reduce to nothing things that are',[32] a God who is like a vineyard owner who pays workers arriving an hour before sunset the same as those who have laboured all day in the heat of the sun,[33] a God who is like a wronged father whose love just will not be contained.[34] The only God that normative Christian faith can claim legitimately ever to have encountered.[35]

Scientific language and the precision of our knowledge

> Why should we assume that our language can discover anything simply by playing games with itself?[36]

> The capacity to form cosmological and subatomic theories takes us so far from the circumstances in which our ability to think would have had to pass its evolutionary tests that there would be no reason whatever, stemming

> from the theory of evolution, to rely on it in extension to those subjects. In fact if, *per impossibile*, we came to believe that our capacity for objective theory were the product of natural selection, that would warrant serious skepticism about its results beyond a very limited and familiar range. An evolutionary explanation of our theorizing faculty would provide absolutely no confirmation of its capacity to get at the truth.[37]

This second, famous quotation, from Thomas Nagel's book *The View from Nowhere*, provides a key text for two of the writers with whom we will explore the question as to why our knowledge of the world is reliable, and actually allows us to access or track 'the truth'. It is a question which, for Nagel, as for some other writers, has remained fundamental and, in important ways, unanswered. I want to suggest that there are three key phrases in our quote: (1) 'stemming from the theory of evolution', (2) 'that would warrant serious skepticism' and, the last, (3) 'An evolutionary explanation of our theorizing faculty would provide absolutely no confirmation of its capacity to get at the truth'. And I want to suggest that each of these three statements raises an interesting and possibly important argument.

First, it is claimed that evolution cannot offer an *explanation* for our evolved capacity to think coherently about cosmological and subatomic theories. This is *not* to say that evolution doesn't explain our capacity for thought in the sense that we have, as a matter of fact, evolved. It *is* to say that such a claim or counter-claim is not actually an explanation but a kind of belief. So, Nagel seems to me to be correct – we do appear to have the ability to think coherently about cosmological and subatomic theories, but evolution cannot explain *why* we do, because *when* we evolved we did not need to be able to do such things. One hundred thousand years ago, the idea of atoms was not on the menu, let alone quantum mechanics. So, a priori evolution is never going to 'explain' why we can make sense of such things, because what determines our evolution is natural selection, and natural selection is about our capacity to survive, reproduce and make a home for ourselves in the world. In fact, we don't *need* to be able to understand atoms or quantum mechanics now, either:[38] many human beings who are just like you and me do not, and they get along fine and would if 'civilization' ended tomorrow. I hope that humanity would still be able to make a home for itself in the world; it would just be much harder work, that's all. And so it is reasonable to argue that, although a process of evolution by natural selection doubtless has given us scientific understanding of atomic and quantum phenomena, it also does not explain why this is the case, because there could not have been a selective pressure for it – and so it is also reasonable to ask for an explanation as to why our minds work so well when faced with such matters. It can also be argued that our capacity to reason about *anything* is irreducible – we clearly seem to have it, but there is no non-circular way to justify it, because we keep coming back to an application of the very capacity for reason we are trying to explain.[39] So, currently – and arguably permanently – our capacity to reason not just about atoms and the cosmos but about anything at all lacks a natural explanation, which may or may not be possible.

Second, Nagel claims that any particular belief we hold should be treated with great scepticism if it applies outside the everyday world of a hundred millennia ago against which we were selected. Again, this seems a warranted statement – as we have already said, if the ability to hold truthful beliefs of these kinds were not part of the selective pressures that sculpted our evolution, then why *should* we trust them? We *do* trust them because we are used to the way in which our minds can track the truth, we are used to the way in which our minds *keep on* working well[40] – but it need not have been like this, and just finding that things are a certain way, again and again, provides no kind of an explanation for why they *are* that way.

Third, and most interestingly, it is true that understanding on evolutionary grounds why our theorising faculty works, if we could, would provide no confirmation of its capacity to get at the truth. We could provide a description or a model or hypothesis as to why we evolved to track the truths of the external world with our internal mental states, but we can't use that to validate *any* particular thought we have. After all, sometimes we are deceived, and it seems to me this point can best be appreciated by considering the obvious case of truths we do not yet know (which no one knows) but which are (or rather, will turn out to be) true, and which our minds will turn out to be capable of understanding.

Before discussing the argument of *The View from Nowhere* further, I wish to look at a more recent book by the same author, *Mind and Cosmos*.

Mind and Cosmos is a not uncontroversial book. Its publication led to a set of negative reviews, some of which we will examine, whose sharpness was enhanced by Nagel's status as a great (atheist) philosopher. 'How can *he* be arguing *this*?' the reviews were saying. *What* he argued is that human consciousness, cognition and judgement of value are inexplicable within a naturalistic world-view, but that what plausibly could explain them is if the universe were teleological, had a goal, and were travelling in the direction of it: first with the evolution of life, then consciousness, then cognition, then morality, and so it continues. Nagel is looking for explanation of:

> not only the emergence from a lifeless universe of reproducing organisms and their development by evolution to greater and greater functional complexity; not only the consciousness of some of those organisms and its central role in their lives; but also the development of consciousness into an instrument of transcendence that can grasp objective reality and objective value.[41]

Now, unlike Nagel, I do not think it is implausible that life arose from the random development of pre-biotic organic chemicals, and I do not think that the evolution of the eye (forty times!) requires another kind of explanation than one entirely in terms of natural selection.[42] However, Nagel makes important points in *Mind and Cosmos* that are worth considering, some of which were mostly ignored by his reviewers in their headlong enjoyment of mocking him.

In a section that echoes the quote from *The View from Nowhere* heading this chapter, Nagel observes that:

> the assumption of intelligibility has led to extraordinary discoveries, confirmed by prediction and experiment, of a hidden natural order that cannot be observed by human perception alone. Without the assumption of an intelligible underlying order, which long antedates the scientific revolution, those discoveries could not have been made.[43]

So far, I am entirely in agreement. We assume a level of coherence in the world that matches the way our minds work, the kinds of things they can grapple with; we work with a capacity to find the world intelligible that antedates by one hundred thousand years the scientific revolution in which they came into their own in a new way.

Human beings, all the evidence indicates, have a capacity to reason. And, if there is such a thing as reason, then to apply such a thing as reason to our world we need to accept a set of propositions, as follows, that 'there are objective, mind-independent truths of different kinds: factual truths about the natural world, including scientific laws; eternal and necessary truths of logic and mathematics; and evaluative and moral truths'.[44]

These are the issues on which Nagel focuses, and, leaving aside the demand for an explanation of the physical evolution of organisms all the way up to kinds of organism that are conscious, the fact is, there is a problem here concerning our knowledge of various kinds of truth that is worth discussing and that may be significantly unanswered or unanswerable. And it is this, again: that humans are able to infer and deduce and know facts about the world at levels or from aspects that we did not have any access to when our species, *Homo sapiens*, physically evolved. When scientists use too many parameters in analysing data or apply too strong a model to align data, they can overfit their data, can over-interpret them. *We* 'overfit' our world, we over-interpret our world – but, unlike in science, our overfitting of the world, our over-interpretation, turns out to be truthful.

The ability to use sophisticated mathematics to help us understand the physical nature of reality, the ability to interpret data from radio telescopes, these are extreme examples – and someone might argue that, as nature is the same all the way down, we can take our evolved understanding of the everyday world (the world of middle-sized objects) and apply it on the macro and micro scales. But, first, nature is not the same all the way down – the radical indeterminacy of quantum mechanics being a case in point, in which a completely new kind of understanding of reality has developed, in the *twentieth* century. And now, we apply quantum mechanics, not just to think about electrons or single atoms, but to think about how enzymes work and to develop computational tools for understanding chemistry. Humans evolved to their current state of cognition long before there was a possibility of us having access to the kind of data we interpret accurately today, such as quantum mechanical data, or on the basis of which modern science developed. We overfit our world.

Indeed, one of the key things to emphasise is that modern science has *developed*, that we stand on giants' shoulders. Newton and Hooke perceived laws of gravitation that Newton expressed mathematically; their perception was not wrong. Einstein perceived and encoded laws of relativity, and Schrödinger and colleagues quantum mechanical concepts that, however counter-intuitive in one sense, have proved immensely reliable ways of understanding the world. It is a simple point, and an inescapable one: our mental abilities have proved trustworthy with respect to far more kinds of perception and insight and theorising than they were originally tested against in the process of natural selection.

We will return to our capacity to know things accurately about our world again below, but first I want to briefly discuss Nagel's response to this philosophical problem, which is to argue that, 'mind is not just an afterthought or an accident or an add-on, but a basic aspect of nature'.[45] Nagel is led to argue that mind is a basic aspect of *nature* because he rejects the existence of God, a priori[46] – and this leads him to propose a natural teleology, a natural goal-directing law of the world that is impersonal but that makes knowledge, mind and ethical value fundamental aspects of reality to which the world (and we) are gradually waking up.[47] Nagel sees this as a way of explaining how we seem channelled towards greater ability, greater knowledge, and of explaining how physical creatures were channelled towards the evolution of humankind. For Nagel, this channelling, this goal-pursuit, this teleology is an explanation for our consciousness, our cognition and our moral sense, our sense of value. He is led to this because (a) he cannot accept that our cognitive faculties are the product of blind chance and (b) he cannot believe in God:

> in order to understand our questions and judgements about values and reasons realistically, we must reject the idea that they result from the operation of faculties that have been formed from scratch by chance plus natural selection, or that are incidental side effects of natural selection, or are products of genetic drift.[48]

Of course, our abilities *could* be a rather improbable accident (e.g. side effects or from genetic drift) – they could, in the famous image, be like the spandrels of San Marco in Venice (or the rose and portcullis decorations on the bosses of King's College Chapel, Cambridge), which occupy spaces created by the constraints of architecture but whose application within the overall schema of the building is a secondary matter.[49] But, Nagel demands an explanation because it seems right to ask for one, and God is not available as one. Ironically, if Nagel were a theist, he could (as, in a sense, I do) just accept a naturalistic basis for the abilities we have – I accept that they were 'formed from scratch by chance plus natural selection' – from one aspect that is a perfectly complete picture of how we came to be people – and yet still press his demand for an explanation. Ironically, it is because Nagel is an atheist that he is led to propose a teleological answer, which has attracted such criticism.

We make judgements, for which we have reasons. Nagel wants to affirm the separation of our reasons from the physiological basis on which we think. He wants to give our reasons an independent existence in the sense that, when we reason, we are doing so according to an order that pre-dates us. It is in these terms that Nagel approaches the issue of human knowledge, of human cognition – and to be able to reason about anything he demands that we *need reason*. This approach can be criticised – is it decadent Cartesianism?[50] Certainly, Descartes is the touchstone for Nagel here[51] – but it has an almost tautologous appeal. For, after all, if we have no basis for inferring logical relations, if we have no capacity to 'key in' to the logical structure of reality, if we have no capacity *to reason*, how on earth could we come up with reasons to believe anything at all? Given the appearance of a capacity to reason, coherently, correctly about our world, Nagel admits that it could have been a selective advantage to the developing human – but, he asks, how can it work in the first place? Operation in 'the space of reasons' is inescapable if we are to make sense of the world.[52] This is a more fundamental, a sanity-questioning way of putting a point we already raised at the head of this section: the need to make use of reason to be reasonable about anything, including reason itself.

Nagel's point of view is, among other things, strongly aesthetic; the way we reason, the values we espouse, are aesthetically guided – it is not just our physiology that guides our approach, but value, and aesthetic value at that.[53] This aspect of his approach was noted in one review of his book, which found in it the 'strange and visionary territory' of arguing that perception and reason are distinct (whether that is a decadent position or not). Indeed:

> the book's widest implications involve art and how it helps us to understand the world. If Nagel is right, art itself would no longer be merely the scientist's leisure-time fulfilment but would be (I think, correctly) recognized as a primary mode of coming to grips with the mental and moral essence of the universe.[54]

Given the argument I am seeking to make, I should clearly wish to agree.

Others have not been so kind. The geneticist H. Allen Orr targeted Nagel's evolutionary thinking and his scepticism that natural selection can provide a sufficient explanation for the development of the human capacity for possessing consciousness, exercising cognition and knowing value. I do not object to Orr's position (*contra* Nagel) that the occurrence of life can be accounted for through natural selection.[55] When it comes to consciousness, Orr has faith in science to provide an explanation – and I agree it might be able to, possibly, though not on currently available grounds – but, 'the history of science is filled with such surprising transformations'. The curious thing is that Orr does not really engage with what is the most substantial aspect of *Mind and Cosmos* and indeed of Nagel's argument in this area, which concerns the problems of cognition and value. He simply comments:

> Nagel's chapter on consciousness is a concise and critical survey of a literature that is both vast and fascinating. He further extends his survey to other mental phenomena, including reason and value, that he also finds recalcitrant to materialism. (Nagel concludes that the existence of objective moral truths is incompatible with materialist evolutionary theory; because he is sure that moral truths exist, he again concludes that evolutionary theory is incomplete.)[56]

I suspect Orr gives something away with his comments on moral truths (that he does not believe in them). I would simply observe that his very phrasing underscores the fact that belief in truth as something we can seek – for example, scientifically – is itself an exercise in moral realism. Scientists decry those who fabricate results, and some will denounce those who are dishonest about the origins of data they have obtained via the work of others. Seeking scientific truth is an exercise in moral realism, and so in my view scientists are implicitly committed to belief in an objective moral order. We will particularly discuss our sense of morality in Chapter 7.

In thinking about consciousness, Orr compares its scientific investigation to the way in which physicists work with quantum mechanics. He says:

> Physicists describe quantum mechanics by writing equations. The fact that no one, including them, can quite intuit the meaning of these equations is often deemed beside the point. The solution *is* the equation. One can imagine a similar course for consciousness research: the solution is X, whether you can intuit X or not . . . Even if matter does give rise to mind, we might not be able to understand how . . . the mysteriousness of consciousnss may not be so much a challenge to neo-Darwinism as a result of it.[57]

This is, in a sense, precisely Nagel's point: that evolution, at least as we currently understand it, does not provide an explanation for consciousness, and similarly, nor does it provide an *explanation* for cognition and value. They are either spandrels, by-products, or something more significant.

Orr continues to beg the question:

> There are millions of species of fungi and bacteria and nearly 300,000 species of flowering plants. None of these groups is sentient and each is spectacularly successful. Indeed mindless species outnumber we sentient ones by any sensible measure (biomass, number of individuals, or number of species; there are only about 5,500 species of mammals). More fundamentally, each of these species is every bit as much the end product of evolution as we are. The point is that, if nature has goals, it certainly seems to have many and consciousness would appear to be fairly far down the list.[58]

Agreed, and wouldn't the capacity to understand accurately the reasons for physical processes and to have a sense of morality sufficient to acknowledge some fundamental truths about value seem even further down the list? And, in any case, even if a naturalistic explanation existed for cognition, we would have no grounds to trust our thinking. Nagel demands an answer, Peter Godfrey-Smith says, but 'this is a demand . . . that no evolutionary account needs to meet'. It just is the way it is, and it works (bridges we build using mathematics stay up). So, rather than say that human reason is unexplained, Godfrey-Smith asserts that there is no need to expect an explanation. Our literacy is an add-on to our biological nature, which gives us great possibilities of expression but no obvious way to understand how our expression gains traction with the hidden realities of our world: 'there is nothing in the sheer strangeness of the mind–body problem that points towards a view vindicating confidence in our powers'. Darwinism 'doesn't give us grounds for confidence in our powers of reasoning, but neither does it undermine that confidence. Darwinism offers a view according to which the evolution of awareness and reason is, in a broad sense, accidental'.[59] As with other critics of Nagel, Godfrey-Smith is objecting to the idea that therefore we must infer a natural teleology ushering us towards greater comprehension of our environment, and, as a matter of course, I agree.

John Dupré, writing in *Notre Dame Philosophical Reviews*, questions most fundamentally the way in which Nagel sets up 'materialism' as the overarching perspective of the scientist, noting that, even if this is the view of scientists themselves, that actually does not relate to the way in which they seem to work.[60] My point in this book is to agree with him that scientists do not operate in basically materialistic terms at all – they operate as much as idealists as anything else, whether aesthetically or otherwise. In fact, as Peter Godfrey-Smith comments,[61] 'if materialism *were* somehow true, it would *seem* not to be true' to us – and scientists certainly operate in such a mode. Scientists do not operate as if they were materialists – indeed, although scientists pretend to hold a correspondence theory of truth (that the things we say correspond to physical entities in the world), they actually often operate on a coherence theory (if a statement is not coherent with a set of rules of scientific practice, it is *unscientific* and not in any meaningful sense true).[62] In a similar mode to Godfrey-Smith's, Brian Leiter and Michael Weisberg argue that Nagel's target is misconceived as he is tackling theoretical reductionism, and that that is not how science works – though maybe that is the fault of scientists for misrepresenting themselves, because, they note, 'philosophers of science have long argued that explanation and prediction cannot be fully symmetrical, given the importance of probabilities in explaining natural phenomena'.[63]

And, one of the key components of this asymmetry is the scientist's aesthetic response to what lies before her. On this, if nothing else, Leiter and Weisberg agree with Nagel, writing in *The View from Nowhere* that there is an:

> extremely high ratio of rational to empirical grounds for great theoretical advances like Newton's theory of gravitation or the special and general theories of relativity . . . they were arrived at on the basis of relatively limited observational data, from which they could not be deduced.[64]

Leiter and Weisberg directly target Nagel's moral realism and his recourse to common-sense argumentation,[65] and in Simon Blackburn's review he likewise objects to Nagel's belief that value judgements have truths in their own right:

> The judgement that income distribution in the US is unjust, for instance, is not true in its own right. It is true in virtue of that fact that after decades of lobbying, chief executives of major companies earn several hundred times the income of their rank-and-file workers. It is true because of natural facts.[66]

I think that, as with Orr, Nagel's question about value is being begged here, not put away. I don't know what these natural facts are that make for a judgement that the pay arrangements in question are unjust. Don't such pay arrangements just reflect that some people are in charge and able to reward themselves how they wish, whereas others are not? What you might call the survival of the fittest, perhaps the most natural of facts.

Like Orr (and Blackburn), Dupré affirms that Nagel's doubts about evolution are misguided, and finds a morally realistic stance controversial. As already noted, part of Nagel's argument is to make a distinction between perception and reason – perception as something that is more basic, more animal, and reason as something that is human and distinctive and unexplained. In these terms, what we perceive and react against is seen as an appropriate basis for natural selection (we perceive a fire and run away, we perceive a tiger and climb a tree), but whether we can reason accurately about the fire or the tiger is not relevant to the selective pressures acting on us. As Dupré notes, this might be an odd contrast to make, because perception is itself not simple, and reason or logic has something to do with language. We will look at language in a most fundamental kind of way shortly, but it bears emphasising again that the argument of *Mind and Cosmos* and, even more, of *The View from Nowhere* that our powers of understanding are unjustified is the key claim being made by Nagel – whether it is our powers to understand our capacity to *reason* and to *know* about the world, or our powers to comprehend moral truths. And, whereas reviewers of *Mind and Cosmos* sought directly to dismiss the latter (on the basis that there are no real moral truths), they did not really engage with the former. Whether a naturalistic explanation of consciousness will be found or not, the fact is that it is worth considering the possibility that, 'the subjectivity of consciousness is an irreducible feature of reality – without which we couldn't do physics or anything else – and it must occupy as fundamental a place in any credible world view as matter, energy, space, time, and numbers'.[67] Whether we will explain in terms of natural selection how it is our minds got so good at making

judgements about how the world works, to say it is a spandrel of our minds – decorative but selectively purposeless – is:

> pure speculation . . . We know nothing about how the brain performs the functions that permitted our hunter-gatherer ancestors to survive, nor do we know anything about how it performs the functions that have permitted the development and understanding of mathematics and physics of the past few centuries.[68]

Nagel refuses to offer an alternative explanation, because he does not need to – one does not have to believe anything.[69] And, on morality, he asserts that what we need to contend with is the fact that our moral values are judgements we make that at least pretend to have an independent point of view – and that apply not only to us but in general.[70] As already noted, I believe scientists are implicitly committed to this view.

One of the writers who takes a cue from Nagel's *View from Nowhere* is Alvin Plantinga. His argument that *evolution* gives us grounds to doubt *naturalism* rests on a distinction between the content of a belief and its neurophysiological properties. He asserts that it is the content of a belief that makes it true or false, rather than whatever it is in us that provides the basis on which a belief is held.[71] This allows him to advance the possibility that our cognitive faculties could be adaptive but wrong – we could react to something in a way that helps to preserve our life but that is correlated with, or the reaction to, a belief that is false.

> 'Natural selection is interested in adaptive behavior, behavior that conduces to survival and reproduction; it has no interest in our having true beliefs.'[72]

The content of one of our beliefs does not have to be true 'for the neuronal structure to cause the appropriate kind of behaviour'.[73] Plantinga admits the common-sense question:

> Isn't it obvious . . . that true beliefs are more likely to be adaptive than false beliefs?

And quite possibly they are, but, from Plantinga's perspective, the neurophysiological response we make to some data (something we see, or hear, or feel, or whatever) could be adaptive, could help to preserve our life, and we could even in principle speak about why we reacted in the way that we did, but our interpretation of the situation could be false, and our reasons could bear no relationship to reality. The *content* of our thoughts could be false, and so he asserts that, 'the content of [a] belief is irrelevant to the causal power of the belief with respect to behavior'[74] and is unable to see a necessary relationship between neurophysiological properties and the truthful content of a belief. The result is that naturalists – those who advance an exclusively naturalistic argument for human cognitive ability – cannot believe their beliefs but are committed to a 'crushing skepticism'.[75]

Plantinga understands the key faculties on which we come to hold beliefs as memory, perception, intuition, sympathy, introspection, testimony and induction, and these (with the possible exception of sympathy) are the basis for us to hold scientific beliefs. But, if the reliability of such faculties is in doubt, then so is the content of what we believe.[76] Now, clearly, our cognitive abilities do seem to work well, and among the beliefs we hold is that creatures evolved by natural selection. But, to believe in unguided evolution robs us of a basis on which to trust our thinking, thus refuting evolution in the first place. We cannot sensibly, he says, be naturalists and believe in evolution,[77] and the probability of our cognitive faculties being trustworthy is low given a naturalistic account of the world, but high given a theistic account.[78] Mathematics gives perhaps the best examples for an argument such as this, because it is clearly something with a strong theoretical element and a strong aesthetic component that seems to be far better adapted to explaining the world than can be easily justified in terms of physical survival. For any given mathematical construction, we should ask why the world is 'significantly describable by *these* mathematical structures? Why should these complex and deep structures be applicable in interesting and useful ways?'[79] It is obvious that being able to tell the difference between seven gazelles and two gazelles, and to realise that the former case will provide more meat, would be selectively advantageous in the Pleistocene, but this is not the kind of ground on which modern mathematics functions,[80] and arguing that the estimation that '7 > 2 = more meat' could recursively lead to modern mathematics just begs the question of why modern mathematics should then be a reliable way, not just to model (extreme) data, but to make predictions, and why modern mathematics should find itself capable of developing tools prior to their appropriate application being available. 'What prehistoric woman would be interested in some guy who prefers thinking about set theory to hunting?'[81]

Plantinga's argument is a provocative one – and one that most scientists would summarily reject. They may be right; but there remain some factors in the way that science has developed and in the way that scientists operate that indirectly support Plantinga's point of view and that we need to take seriously. For example, as pointed out by Robin Dunbar, science seems to be a human universal – there are some basic principles of world description common to all humans.[82] Humans do have remarkable observational skills, even out on their own and at their most basic – for example, the capacity of pre-modern humans to navigate across 4,500 miles of sea and the trackless wastes of the Sahara.[83] A utilitarian form of science (at least) is ubiquitous in human culture, and humans have repeatedly come up with the same truthful ideas, the same solutions to the same problems – the Babylonians, Greeks and Chinese all had versions of Pythagoras's theorem and, together with the Egyptians, have versions of π (the ratio of the circumference to the radius of a circle).[84] As Dunbar notes, there's no evolutionary pressure behind these kinds of coincidence. Although he wishes to argue that scientific methods 'are, at root, simply the natural mechanisms of everyday survival', he has to note also the unnatural

nature of science.[85] Three factors in particular grab his attention. First, that scientists are 'prepared to adopt theories that they happily admit are flawed':[86] in hypotheses we say, 'It's as if . . . (but not really)'. In other words, we cheerfully work with imprecision and approximation. Second – and in stark relief – scientists make strong inferences and formulate hypotheses in a very precise way,[87] despite the fuzzy basis on which they may be framed. Such strong inferences have been repeatedly revolutionary in the sciences because they enable the formulation of hypotheses in more precise terms, which makes them compatible with a 'very much narrower range of empirical results than more loosely formulated ones'.[88] What draws us towards these precisely formulated hypotheses is, I would suggest, their neatness, their beauty.

Third, and in harmony with much that has been said in this chapter already, Dunbar notes the unnaturally logical nature of the human mind.[89] Scientific logic is not natural, because 'humans were not designed by evolution to evaluate probabilities carefully, because there was no pressing need to do so'.[90] Of course, science depends on very rigorous rationality and the meticulous (precise) testing of our ideas, but 'although these processes derive from common sense, the rigour with which they are applied in science is genuinely unnatural'.[91]

Ralph Walker's book *The Coherence Theory of Truth* is an attempt to argue that coherence theories ultimately fail to account for the ways in which our thinking appears, as far as we can possibly tell, to have an excellent correspondence with reality. Among the philosophical contributions to the centuries-long discussion as to why our cognitive faculties fit the world we find ourselves in, Ludwig Wittgenstein receives the most assertive response, because his view of language is taken to imply a pure form of coherence theory (as opposed to the mixed theory Walker finds in Kant). Wittgenstein's theory of truth 'is a coherence theory, because it makes truth a matter of what is believed – judged – by the community'.[92] This means that Wittgenstein can observe of the identification of truths: 'Nothing further can be said, except that "It is true, there is great – and interesting – agreement here"'.[93] Walker's response is as follows:

> This will not do. The continued agreement in our natural and unreflective judgements does require to be explained, and Wittgenstein cannot simply shrug off the fact that his theory permits no explanation to be found at the appropriate level [. . .] Wittgenstein's whole account of language and of truth depends on the continued agreement among speakers . . . To say this agreement is inexplicable is preposterous: it is to make the whole of language and coherent thought depend on a continued coincidence.

What Ralph Walker demands, and what we have been considering, is an account that justifies the correspondence of our thinking with reality, and not just the fact that we continue to make sense to one another.[94] It is clear, of course, that we need the capacity to form beliefs that protect us from walking into fires, as we already noted, but the fact seems to remain that, 'animals do not . . . form universal generalizations, study abstract mathematics,

or formulate opinions about quasars, and if the principles on which we rely in doing these things did not reflect the way the world is we should have survived none the less'.[95]

The problem is the same as that formulated in the quote from Nagel heading this section, a quote that Walker, like Plantinga, uses as a key reference as he concludes his argument.

In the next chapter, we will look at two other aspects of our human cognitive abilities that are more fundamental to the way we operate as people than scientific knowledge per se. These are, first, our capacity to know moral truths and, second, our capacity to just *keep on making sense* in language. This will lead us to consider a point of view from which we have both the question why anything exists and the question why we can make sense and go on making sense of our world, simultaneously in our sights. That point of view will be one characterised by an aesthetic response to the exquisite balance and harmony we see in the fundamental physical basis of the existence of our world.

Notes

1 Herbert McCabe, *God Matters* (Mowbray, 1987), p. 6.
2 Genesis 2:4b–7.
3 The modern-language version says 'creator', quite deliberately.
4 James Alison, *The Joy of Being Wrong* (Crossroad Herder, 1998), p. 99.
5 Rowan Williams, *The Edge of Words*, pp. 123, 197.
6 See also Williams, *The Edge of Words*, p. 63.
7 Genesis 1:1–3.
8 See Chapter 2, n. 14.
9 Psalms 139:13,16a.
10 2 Maccabees 7:28.
11 Frances Young, *God's Presence*, pp. 94–106.
12 Romans 4:17.
13 Luke 20:38 and parallels.
14 Young, *God's Presence*, pp. 46–56.
15 John F. Haught, *God after Darwin* (Westview Press, 2000), p. 114, quoted in Young, *God's Presence*, p. 81.
16 Hans Urs von Balthasar, *Mysterium Paschale*, pp. 49–83.
17 Timothy Radcliffe, *Take the Plunge* (Bloomsbury, 2012), pp. 167–84.
18 A series of examples could be given, but see especially John 20 and 21, and also Luke 24:13–35. See also James Alison, *Living in the End Times* (SPCK, 1997), Chapter 8.
19 With apologies to Rowan Williams.
20 Many references could be given for this assertion. Frances Young's *God's Presence* provides some (pp. 56–7). Charles Taylor points out that the Judaeo-Christian tradition is the precondition for the development of the idea of 'ordinary life' and of freedom, both necessary preconditions for the development of science; see his *Sources of the Self* (Cambridge University Press, 1989), pp. 211–47. The world is demythologised by the Christian experience – see James Alison, *The Joy of Being Wrong*, pp. 248–51. See also René Girard: 'The invention of science is not the reason that there are no longer witch-hunts, but the fact that there are no longer witch-hunts it the reason that science has been invented', *The Scapegoat* (trans. Yvonne Feccero, Johns Hopkins

University Press, 1989), p. 204. Demythologisation and desacralisation were central to Jesus's mission – see, just one example of many, Mark 7:1–23.

21 Isaiah 64:8.

22 Rowan Williams reminds us of this, among others. See *The Edge of Words* pp. 148–9. See also Herbert McCabe, *God Still Matters* (Continuum, 2002), p. 27: 'We need a great many images, preferably incompatible images . . . for all this preserves us from idolatry . . . from thinking of God as subject to the limitations of our imagery.'

23 As we've emphasised, two different stories placed side by side – like sheer silence and a lover – to point out the primacy of God *and* his ongoing involvement. To point out that creation means 'Let there be . . .' and is also 'about the ongoing dependence of the universe on its Creator' (Young, *God's Presence*, p. 86).

24 Terry Eagleton, *Reason, Faith and Revolution* (Yale University Press, 2009), p. 6.

25 de Cruz and de Smedt, *A Natural History of Natural Theology*, p. 158, thanking Steven Horst for this observation.

26 This is probably not the place to discuss why the anachronism came about, but I believe it to have been the fault of institutional churches engaged in a contest about power. The Bible was to hand as a weapon to try and assert the supremacy of the Church over states, and it was misused for this purpose. Institutional churches became engaged in rivalrous relationships and, by using the Bible to justify the supremacy of their spiritual authority, they made themselves temporal rulers alongside others. As natural science arose in the sixteenth and seventeenth centuries – and with it the possibility of a single explanatory framework for everything – the Bible was already in place as an alternative source of authority to the natural philosophers of the day, with disastrous consequences that began to be played out in the debates of the nineteenth century concerning scientific and theological world-views. The moral bossiness of the Church, which it retained into the twentieth century, then caused further damage when faced with the personal liberation of people in political, personal and, yes, sexual terms. The Church forgot that God created humans to be free, as Genesis makes plain.

27 Eagleton, *Reason, Faith and Revolution*, p. 7.

28 Especially *God Matters* and *God Still Matters*, though I began (and you could do a lot worse) with *God, Christ and Us* (Continuum, 2005).

29 Denys Turner, *Thomas Aquinas: A Portrait* (Yale University Press, 2013), p. 142. See also Young, *God's Presence*, p. 56: 'In the last analysis the theological claim about the beginning is of a different order altogether from the discernment of the "big bang" through analysis of astronomical evidence. It is truly incomparable, beyond replication, utterly beyond time and space, rooted in the ultimate first principle, the will of God to create something other than the divine self, and to create that other something from nothing.'

30 Rowan Williams, *Grace and Necessity* (Morehouse/Continuum, 2005), p. 127.

31 Simone Weil, *Gateway to God* (David Raper, ed., Collins/Fontana, 1974), and quoted in Young, *God's Presence*, pp. 57 and 79.

32 1 Corinthians 1:28.

33 Matthew 20:1–16.

34 Luke 15:11–32.

35 See n. 15 above.

36 Williams, *The Edge of Words*, p. 135.

37 Nagel, *The View from Nowhere*, p. 79.

38 Williams, *The Edge of Words*, pp. 71–2.

39 This is a point clearly made by Thomas Nagel, Angus Ritchie and Alvin Plantinga in their books we will be considering here, among many others. Rowan Williams also

takes this view, though typically from a more fundamental perspective (Williams, *The Edge of Words*, p. 101).

40 Williams, *The Edge of Words*, p. 225.
41 Nagel, *Mind and Cosmos*, p. 85.
42 Nagel, *Mind and Cosmos*, pp. 6–10, 49.
43 Nagel, *Mind and Cosmos*, p. 16.
44 Nagel, *Mind and Cosmos*, pp. 85–6.
45 Nagel, *Mind and Cosmos*, p. 16.
46 Nagel, *Mind and Cosmos*, pp. 25–6.
47 Nagel, *Mind and Cosmos*, p. 85.
48 Nagel, *Mind and Cosmos*, p. 125.
49 Stephen Jay Gould and Richard Lewontin, 'The spandrels of San Marco and the Panglossian paradigm: A critique of the adaptationist programme', *Proceeding of the Royal Society of London* B, *205*, 581–98 (1979). http://rspb.royalsocietypublishing.org/content/205/1161/581
50 Williams, *The Edge of Words*, p. 107.
51 Nagel, *Mind and Cosmos*, pp. 81–2.
52 Nagel, *Mind and Cosmos*, p. 84.
53 Nagel, *Mind and Cosmos*, p. 114.
54 The Page Turner blog in *The New Yorker*, www.newyorker.com/books/page-turner/thomas-nagel-thoughts-are-real. Rowan Williams actually makes this argument in his *Grace and Necessity* (2005).
55 Or to that of Simon Blackburn, again reacting to Nagel's book: 'The current conception is that, given a purely physical beginning, everything else – chemistry, biology, life, mind, consciousness, intelligence, values, understandings, even science – follows on by natural processes. Particles beget atoms beget molecules beget enzymes beget proteins beget life begets *Homo sapiens* who begets the Royal Society and the rules of tennis', *New Statesman*, 8 November 2012, www.newstatesman.com/culture/culture/2012/11/thomas-nagel-philosopher-who-confesses-finding-things-bewildering
56 H. Allen Orr, *Awaiting a New Darwin*, in *The New York Review of Books*, www.nybooks.com/articles/archives/2013/feb/07/awaiting-new-darwin/
57 Orr, *Awaiting a New Darwin*. Here, Orr is referring to an argument of Colin McGinn.
58 Orr, *Awaiting a New Darwin*.
59 Peter Godfrey-Smith, *London Review of Books*, 24 January 2013, www.lrb.co.uk/v35/n02/peter-godfrey-smith/not-sufficiently-reassuring
60 John Dupré, *Notre Dame Philosophical Reviews*, 29 October 2012, http://ndpr.nd.edu/news/35163-mind-and-cosmos-why-the-materialist-neo-darwinian-conception-of-nature-is-almost-certainly-false/
61 Peter Godfrey-Smith in the *London Review of Books*.
62 Ralph Walker, *The Coherence Theory of Truth*, Chapter II, 'Coherence, correspondence and anti-realism' (London: Routledge, 1989). See below, at the end of this chapter, for a further discussion of this point.
63 Brian Leiter and Michael Weisberg, 'Do you only have a brain? On Thomas Nagel', *The Nation*, 3 October 2012, www.thenation.com/article/do-you-only-have-brain-thomas-nagel/
64 Nagel, *The View from Nowhere*, p. 84.
65 Leiter and Weisberg: 'Whether morality is truly objective is a philosopher's claim (and a controversial one even among philosophers) about which "common sense" is either agnostic or mixed.'
66 Simon Blackburn, review of *Mind and Cosmos*.

67 Nagel, *The View from Nowhere*, pp. 7–8.
68 Nagel, *The View from Nowhere*, p. 80.
69 Nagel, *The View from Nowhere*, p. 81. *Mind and Cosmos* is not offering an explanation but making the suggestion that there is some aspect of reality, which scientific enquiry could in principle decipher, that is teleological. *Mind and Cosmos* is not intended to be an explanation but a stimulus.
70 Nagel, *The View from Nowhere*, p. 135.
71 Plantinga, *Where the Conflict Really Lies*, pp. 332, 336–9.
72 Plantinga, *Where the Conflict Really Lies*, p. 271.
73 Plantinga, *Where the Conflict Really Lies*, pp. 325–35; quotations on p. 334.
74 Plantinga, *Where the Conflict Really Lies*, p. 336.
75 Plantinga, *Where the Conflict Really Lies*, pp. 339–46.
76 Plantinga, *Where the Conflict Really Lies*, pp. 311–12.
77 Plantinga, *Where the Conflict Really Lies*, p. 310.
78 Plantinga, *Where the Conflict Really Lies*, pp. 313–14.
79 Plantinga, *Where the Conflict Really Lies*, p. 284.
80 Plantinga, *Where the Conflict Really Lies*, p. 287.
81 Plantinga, *Where the Conflict Really Lies*, p. 133.
82 Dunbar, *The Trouble with Science*, p. 52.
83 Dunbar, *The Trouble with Science*, p. 54.
84 Dunbar, *The Trouble with Science*, pp. 56–7.
85 Dunbar, *The Trouble with Science*, p. 96.
86 Dunbar, *The Trouble with Science*, pp. 97–102.
87 Dunbar, *The Trouble with Science*, pp. 102–8.
88 Dunbar, *The Trouble with Science*, p. 106.
89 Dunbar, *The Trouble with Science*, pp. 108–13.
90 Dunbar, *The Trouble with Science*, p. 112. The same point in essence is made by Rowan Williams in *The Edge of Words*, pp. 71–2. Clearly, it is an important idea for Alvin Plantinga and Thomas Nagel as well.
91 Dunbar, *The Trouble with Science*, p. 113.
92 Walker, *The Coherence Theory of Truth*, p. 136.
93 Quotation in Walker, *The Coherence Theory of Truth*, p. 142.
94 This more fundamental issue will be considered in the next chapter, as we look at Rowan Williams's book *The Edge of Words*.
95 Walker, *The Coherence Theory of Truth*, p. 224.

7 Understanding beauty

Beautiful, moral lives

Angus Ritchie studied under Ralph Walker, whose discussion of coherence and correspondence theories of truth-seeking, truth-finding and truth-making ended Chapter 6. But, in his important book *From Morality to Metaphysics* and the accompanying published essay from the think tank Theos, *From Goodness to God*, Ritchie considers the modern, common-sense evolutionary explanation of the origins of our human capacity to reason about the world and learn objective facts concerning it to be a sufficient kind of explanation. In formal terms, human cognitive abilities raise three key questions:

(D1) What is the justification for our faith in their reliability?

(D2) What is the historical explanation of their development?

(D3) What is the explanation for their capacity for tracking truth?[1]

And, whereas (D1) and (D2) can be answered with some ease, it is (D3) that requires an answer, and it is (D3) that, in terms of scientific and factual knowledge and interpretation of our world, we were considering in our last chapter. Ritchie wants to claim that, 'we see in natural selection a way in which (D3) can be answered for our truth-tracking capacities for theoretical reasoning and our truth-tracking capacities with respect to the physical world'.[2] And, 'it is highly plausible to claim that humans will be better able to survive and multiply if their cognitive faculties enable them to come to true beliefs regarding explanation, inference and induction.'[3] It does seem reasonable to assert that, 'among competing groups of humans (and their evolutionary precursors) truth-tracking capacities for theoretical reasoning would be beneficial to the survival and flourishing of the collective'.[4] Nevertheless, Thomas Nagel, Alvin Plantinga and Ralph Walker would press the question as to why this ability to be reasonable works, not only at the everyday level of natural selection, but also on the exceptional scale of quantum mechanics and general relativity, or in the private world of pure mathematics. Maybe it is the case that inference at one level can be safely and reliably translated to another – that, as regards

human reason, the world is more or less the same all the way down and all the way up. And, it can be argued that our faith in our basic, everyday, selected capacity for reason is justified by the fact that we have found it to be robust by practical application – we build bridges and they don't fall down. I think this leaves open still the question of *why* our reasoning is so *predictive* – especially our mathematical reason, but also on the more mundane level our talent for hypothesis formation. You can again say that practical experience validates our faith in the usefulness of our theoretical and hypothetical thinking – but I do not think this justifies its power. Certainly, the capacity to *predict* things that will turn out to be *true*, though it may be selectively advantageous, can, for fairly obvious reasons, not actually be justified using natural selection because of the basic fact that those truths do not yet exist or are not yet available for us to know. The ability to know something you haven't yet encountered can hardly exert a selective pressure on how you came to be the way you are – unless you want to claim that the capacity to predict the future is an evolved feature of human cognition, but I find it hard to imagine anyone would in quite the terms necessary to justify our capacity for prediction, modelling and tool development.

There is, additionally, the issue of aesthetics in science. Knowledge causes us to act – and this implies a moral character.[5] As judgements on what is fitting, harmonious and good, aesthetics have a moral character – and certainly the pointless destruction of beautiful objects raises a moral problem. At the time of writing, obscene acts of cultural vandalism are being carried out by Islamist revolutionaries in Syria and Iraq – these are an affront to our human sense of morality. The movement of the petal placed by the mother of A.L. Kennedy on a tray in her hall (see Chapter 1) was also a moral issue – it was, she acknowledged, *wrong* of her to tidy away something beautiful that was giving her mother pleasure. When it comes to morality, Angus Ritchie argues that (D3) above is unmet in a naturalistic or atheistic view of our world. And, as scientific objectivity relies on an implicit belief in morality, that is, in truth and a right way of carrying on (not falsifying data, for example), the status of our moral points of view and moral knowledge would be a key issue for our argument, even if aesthetics were not also, implicitly, an issue or facet of morality.

Ritchie is a moral realist and believes in the existence of an objective moral order that humans beings can know. He defines it thus:

(1) The moral order has certain properties, independent of either human beliefs or conceptual schemes. Indeed, the moral order would exist and have properties even if no human beings existed at all; and
(2) A moral judgement is true if and only if it is an adequate representation of the way the moral order is, where 'the world' is construed as in (1).
(3) Humans have some, albeit fallible, capacity to come to a knowledge of these objective moral truths.[6]

It seems as if human beings can track a moral order independent of what we happen to believe or preferences we happen to have, and this capacity seems to Ritchie to demand a justification, as our capacity for reason about the external world (what you might call natural knowledge) does for Nagel, Plantinga and Walker. As with natural knowledge, with morality in focus, the question, it must be emphasised, is not *why* we hold any *particular* principle or make any *particular* judgement, but why *anything* we assert in the area of morality 'tracks the truth' as to what is right and what is wrong.[7]

Of course, many might object to the contention that there is a system of objective moral truths. Some would do so in terms such as those of J.L. Mackie, and Ritchie addresses in particular what might be taken as a scientific objection, from Mackie's thought, to the belief in moral realism. This objection is that such moral truths need to be both *objective* and *prescriptive*, and that to assert that there are entities hanging around that have these properties is problematic, given the way we now understand the world.[8] Ritchie makes the perfectly sensible point that scientific practice itself appears to rely on truths of exactly these properties – they are objective (scientific judgement is not believed by scientists to be just a matter of opinion) and prescriptive (they tell us things we ought to believe).[9] Therefore, scientists obviously require a kind of faith that they can track the truth, and, unfortunately, there is no way of demonstrating that is the case except by multiplication of examples, which proves nothing (exceptions, in science, do not prove rules: they invalidate them). Humans appear to be unable to stop trying to make sense of our world – whether it's a matter of deciphering how it operates or how we ought to live, given our freedom – and both rely on a commitment to try and track the truth.[10] We consistently work with a process of inferring to the best explanation[11] and rely on a 'capacity to make value deductive inferences' that is indispensable for us to decide at all.[12] As I stated in Chapter 2, I do believe that scientific advance requires human free will, genuine human freedom (at least in operational terms); in the terms used by Raymond Tallis, it requires *intentionality* and *the ability to make other items appear*;[13] we do things *for a reason*.

Ritchie also considers the arguments of quasi-realists such as Simon Blackburn and Allan Gibbard, arguing for a moral relativism because of the emotional and affectively engaged aspects of the ways in which we make moral judgements. He seeks to 'argue that their conclusion is mistaken – and that this kind of affective engagement is part of how practical reasons are grasped'.[14] And, indeed, as scientific truths are also partly identified via emotional and affectively engaged aspects of our responses to data (the argument of this book), and those scientific truths are not relative to anything except reality, this argument falls. As with science, in morality we 'only "pull ourselves up" because we have truth-tracking capacities with respect to an objective moral order which natural selection is unable to explain'.[15] Non-realist approaches to morality have to contend with conclusions such as the following:

(4) If we approved of torturing the child it would be a good act.[16]

In what possible way could this ever be true? And, it being the case that this is not true, and *could* not be true, moral realism must be accepted. Consider slavery: Blackburn rejects the following statement:

(10) Slavery is a bad system. That is an opinion reflecting an independent order of reason.

He does so on the basis that it 'verges on the incoherent, for we have no conception of the nature of this independent order'.[17] Frankly, we have no real conception of some independent order in science, but that doesn't stop us making statements on its basis. Blackburn says that there is no difference between these three statements:

(7) Slavery is a bad system
(8) Our opinion is this: slavery is a bad system
(9) Slavery is a bad system. That is just our opinion.[18]

But I want to ask, how could slavery possibly be a *good* system? Of course, there was a time when we considered slavery to be morally acceptable; we now *know* this to have been mistaken. We once thought the Sun went round the Earth, but, again, we found that to be false. Ritchie gives a further example, concerning the morality of homosexual relationships, to demonstrate that it is quite possible for someone to be unsure whether they consider homosexual relationships to be wrong, but that this is not the same as saying that such relationships are neither right not wrong.[19] So, it is quite coherent to think we may have blind spots in our moral atlas but not be sure what they are; and it is quite coherent for us to have been *mistaken about*, then be *unsure concerning*, and now be *convinced that* slavery is wrong.

The adoption of a relativistic (i.e. non- or quasi-realist) approach to morality undermines 'some of our most deeply held moral convictions', such that 'we have no adequate way of distinguishing tastes from convictions'.[20]

Now, clearly, if I have a friend who dislikes the music of Mozart intensely, I consider that to be a matter of aesthetic taste and not a moral failing. In a debate following the publication of *From Goodness to God*, the philosopher Justin Baggini argued that, nevertheless, aesthetic taste is not just a matter of opinion – he gave the example of his attempting to sing something and the contrast with an expert execution of a Mozart aria. And, of course, Baggini is right: there is some objectivity to aesthetics – actually, I think my friend is wrong to dislike Mozart's music. But, the fact that someone dislikes Mozart does not stop me loving them, whereas, if they lied to me repeatedly, I suspect that that might. There is a difference between acting beautifully and appreciating beauty: the first is a matter of morality, the second a matter of taste. Someone who sings in a discordant way can still be acting beautifully, even though no one finds the result beautiful.

In fact, with morality, it is not the capacity to hold one view or another that matters, but the belief that there is something worth arguing about in the

first place. I respect my friend's dislike of Mozart and so I wouldn't suggest we go to a concert of his music and I wouldn't argue with my friend in the hope of convincing him that he is wrong. Ritchie says:

> What differentiates my preference for a world in which no-one (or everyone) plays soccer from my preference for a world in which no foetus is aborted (or no woman restricted from accessing abortions) is not simply its intensity. . . . Once we come to belief that 'the right attitude to abortion' is chosen, not discovered, and that the wrongness of concentration camps lies in the facts not simply in our judgements, the nature of our moral attitudes is necessarily transformed.[21]

For example:

> A key area in which 'moral progress' has been made is in an expansion of the circle of our moral concerns to include those . . . whose dignity, rights, and needs have previously been obscured. . . . Any account of morality which understands it to be 'made' rather than 'discovered' will be unable to give any serious, non-circular content to the idea that we might 'make' our morality in a 'better' way – where 'better' is analysed as giving a due regard to the interests of beings we have previously oppressed or ignored.[22]

Human beings most certainly act *as if* there were mind-independent moral facts, as demonstrated by our belief in moral improvement, and our belief that people *could behave better* or *be treated better*. This is, ultimately, indefensible without a belief in moral realism. Elsewhere, Ritchie gives the excellent example of Oxford finalists in philosophy who begin essays as good, scientifically minded relativists and then remember the Holocaust halfway through, which forces a dramatic change in the direction of their argument.[23]

Another demonstration of the practical moral realism of human lives is provided by Ritchie's discussion of Robert Nozick's thought experiment about a machine that could provide people attached to it with the sensations of pleasure, without there being any content to the sensations – that is, without the subjects actually *doing* anything – the kind of machine that would convince us we were making love, when we were just lying in a box, wired up.[24] No-one would choose this as a way of life, and this demonstrates that humans believe in their lives being meaningful in some 'real' sense, as having content.[25] Nozick demonstrates:

> that human beings have a concern for *what is actually going on in the external world* in a way that is not solely tied to *what human beings experience* and what goes on in their conscious lives. That is to say, they reject any moral theory that locates value entirely in conscious experience.[26]

Ritchie's argument is that we cannot offer an explanation as to why there is a naturally selective advantage to be had from understanding moral truths,

from believing in a framework of meaning within which we should make free choices and act according to them.[27] Indeed, it does seem to be the case that, 'our sensitivity to moral reality involves capacities that exceed and indeed contradict that which would be of selective advantage'.[28] In response, Justin Baggini has argued[29] that selection 'seeded' morality, but that natural evolution does not need to try and explain how all ethics arises, because that is cultural. This actually begs Ritchie's question anyway – because, if our physical natures don't have to track moral truths for those truths to be explained, why on earth should our cultural evolution? Indeed, as Ritchie argues anyway, moral evolution is itself a sign of moral realism – something we are moving towards a better understanding of.

One objection that could be made to Ritchie's argument is that a belief in 'right' and 'wrong' aids us in our objective knowledge of physical reality, in our capacity to sift data and reach a conclusion. Does this not defeat his argument, because he also believes that we can identify an explanatory selective advantage in our capacity to track objective truths, such as in science? Now, clearly, such a belief in 'right' and 'wrong', a kind of basic morality, is (as already noted) part of scientific method and would be part of a nascent hominid capacity to work out objective truths about the world. But, such knowledge of truth and falsehood could not justify the development of an understanding that some things people do are morally outrageous. They are completely different levels of assertion about or belief in truth. It is both true that I must do my best to interpret data honestly and that the murder of six million Jews by the Nazis, the contemporary imprisonment and killing of gay people, and allowing refugees to drown in the Mediterranean Sea are moral outrages. But, these different kinds of truth, these kinds of morality are not of the same order as truth and falsehood concerning the natural and physical world. Indeed, it just is true that such things are moral outrages. My belief that I should interpret data honestly is a belief about the world of middle-sized objects in which I live; the belief that gay people have rights of self-determination, and indeed have the right to love the person they choose, is not a belief about a world of middle-sized objects. It is a belief about a morally objective system of transcendent truths, in this case a belief in human freedom and dignity.

So, given moral realism, for which I consider the case to be made in the terms Angus Ritchie states, the human capacity to track moral truths is, for an atheist, a matter of faith, a vast coincidence or a matter of amazing good luck.[30] But, for Ritchie, as for me, it is accounted for by the world's being an 'expression of benevolent purpose'.[31] And:

> the claim that our demand for an explanation for the truth-tracking properties of our belief-generating and belief-evaluating capacities is illegitimate – that it seeks an impossible 'sideways-on' comparison – is surely decisively refuted by the fact the demand *can* be met in other cases, namely those of physical perception and theoretical reasoning.[32]

As I have said, to my mind the question remains open as to whether Thomas Nagel, Alvin Plantinga and Ralph Walker are right to demand explanations for our truth-tracking capacity with regard to knowledge of independent facts about the world, or whether this can be argued to be just what you might expect, given that we have evolved. Robin Dunbar provides support for the meaningfulness of their demand from a somewhat unlikely source.[33] Angus Ritchie rejects it, but leaves us with a similar kind of demand for the third of Nagel's topics, value or morality.

In a recent book, Rowan Williams undercuts these discussions with a more fundamental focus on the issue of how human beings make sense of the world. Rather than arguing that specific aspects of the way we know things – whether about the physical universe or about morality – demand explanations, he simply points out that the nature of our language itself, the very way in which we can frame ideas about anything, raises a major question for our discussion.

Why does what we say to each other mean anything at all?

This question, like the questions of why there is anything rather than nothing, why scientific knowledge is possible, and why we are aware of an objective morality, is one that some will reject as meaningless. They might, for example, refer to 'evolution' as an explanation of why our language works well in the world. It's a rough-and-ready and cheerful argument: clearly it will be a selective advantage to be able to describe things, work things out and design things, and language helps with all of these. And it will be helpful to tell other people to avoid fire and tigers.

When it gets to the question of scientific talk, the special language of mathematics becomes salient alongside our use of words – albeit words we usually borrow from everyday usage in which they have quite different meanings, such as 'attract' and 'repel', as discussed in the previous chapter. The kind of language we needed as hunter-gatherers and in early agrarian societies is not the kind of language we need to describe the internal structure of the atom, just as the mathematics we needed to count sheep and navigate along coastlines or by the stars is not the kind of mathematics we need to model and describe physical reality in the way we can understand it today – whether quantum mechanical phenomena, genetic determination or weather systems. Why should the internal workings of our minds accurately track the internal workings of cells, when our minds are adapted to the need to feed ourselves, control social unrest and reproduce? But, even the *meaningfulness* of our language *in the first place* is an aspect of the way we picture and navigate the world whose accuracy needs explaining.[34]

A recent book by Rowan Williams puts this question in the starkest terms, starting where we all are, with what we can and do say to one another. As such, it undercuts attempts to argue that the truth-tracking nature of our minds either can or cannot be justified on the basis of evolution alone, by going to the heart of the matter.

Dr Williams doesn't speculate about how we got where we are; he analyses what we do every day when we speak. At the core of Williams's brilliantly sophisticated but thoroughly grounded argument is the assertion that what we do when we speak is to *represent* the world for ourselves and for others. In other words, as mentioned briefly in Chapter 2, that language is not something that has a direct relationship to 'reality' but something that we use to picture, model or describe reality. In other words, our use of language is triadic, not dyadic. Our use of language is, in classical terms, analogical. We use words as tools to represent the world to ourselves and to each other. Dr Williams's definition of *representation* is this:

> a form of potentially truthful (or 'apt' or whatever) denotation embedded in a symbol system which does not attempt to find simple substitutes for the elements of reality but looks for something like analogical patterning in the element of a different medium.[35]

This is, of course, one of the key things I mean by talking about the role of aesthetics in science. In science, we look for something with a pattern fitting what we observe.[36] For Williams, representation is about the making and intuiting of meaning out of what we perceive, of meaning that is real. So, his argument is, in my terms, an aesthetic one, detaching 'the idea of representation from depiction, description, imitation and so on'.[37] Williams talks about silence – which can be *imposed* but also *adopted* – as one of the edges of language that ask hard questions about *how* language conveys *meaning*.[38] While considering this point he notes that, 'the placing of a single bowl or a flower in an empty room'[39] can be an eloquent statement. 'There are no words . . .' – this is something we say in the face of grief, exultation, betrayal, love. There are no words, but a flower or even an isolated petal can make the meaning of that silence clear, like the rose petal placed on a tray by the mother of A.L. Kennedy (see Chapter 1). There are no words, but a scientific diagram can explain, silently. There are no words, exactly, but the representational language of mathematics can express what we mean. There are no words (yet), but we can play with them to try and say what we mean in poetry or via an equation.

Of course, we can use language about the world in ways that are dyadic – this person is dead, not alive; she's taken the dog for a walk; his hair is blue; that tree is tall – that is, we can describe and depict. We can also imitate – the bark of a dog or the call of a bird. But these are not very interesting uses of language or sound, and the information they communicate is rather basic. But, there are more interesting things to be said. For example:

> 'What does it mean to you that he has died?' 'Oh, I miss him very much. He was my friend.'
>
> 'Why has she taken the dog for a walk? He's already been out twice today.' 'She wanted to clear her head after that phone call earlier.'

> 'Why did he dye his hair blue?' 'Dunno. To make some kind of statement I guess.'
>
> 'Does the tree need pruning?' 'Yes, otherwise it's going to lose its shape.'

The questions and answers I have suggested are quite brief. They are also of variable authority and accuracy. I suppose I am allowed to state I miss my friend – though other people knew them too, perhaps much better than me. The person who dyed his hair blue probably wouldn't consider making 'some kind of statement' a fair or accurate description of their motives, finding it rather dismissive. Rowan Williams points out that actually there is always more to be said, about any situation, and that there are no possible last words in or about our world. There is *always* more to be said, and the things we are talking about can never be *totally* described by our language.[40] This is one of the problems with understanding words – in a sense, there are no edges, there is no point from which to finally get them all in perspective, and our descriptions are never complete. There really is no 'view from nowhere' in our world – no absolute point of view. On the other hand, there *are* hard edges where our descriptive abilities break down, or where we lapse into silence.

What we find, if we think about the way in which we use language all the time, is that there is no limit to what we can say. There is an apparently infinite capacity of human language to represent whatever human beings encounter, and to make sense of it in ways that are not just descriptive or depicting, but actually generate new ways of speaking and new things to be said in turn. In science, we formulate a hypothesis and that leads us to propose an experiment. From the start of his book, Rowan Williams grounds his argument on the point that it looks like our ability to speak has a fundamental *dependence* – dependence on other people from whom we learn language, dependence on the history of humanity, which has developed language, and of course dependence on the physical structures that have enabled our evolution and on which language use subsists. Furthermore, when we think of something to say, then that is itself dependent on what we said before. Williams argues that, if we acknowledge that language has this dependent character, then we are moved to ask whether there is a source of meaning that underwrites the whole lot.[41]

We push on in time, having learnt in time, and this temporal dependence points up the fact that there is an *ultimate* dependency, at the very least. We ultimately depend on the idea that the structure of our language and therefore of our thought has coherence – and Christian theology argues that this dependency is on a 'reality or presence that has no interest to pursue and no selfhood to defend'[42] – what was referred to in Chapter 6 and in Dr Williams's own words as pointless, futureless love. The very interesting point here is that Christian theology *is* capable of justifying everything we do with language in an everyday way, and in the ways we use it in science as well. Christian theology derives, not from a sophisticated philosophical argument, nor from an understanding of what would be needed to justify the way scientists use language, but

from a set of experiences and reflections expressed in the Scriptures. Christian theology derives from a set of apprehended encounters with God and from the experience of relationship to God and to each other. Religious language, religious stories, parables, prophecy *make sense* from a particular perspective – a theological perspective – of *something we do anyway* but that otherwise seems to lack justification, which is the use of language. Our religious language did not arise (was not selected) to allow us to address the question of why our speaking means more, or even anything, and yet it is equal to the task. For example, Christian theology makes it clear we are dependent and vulnerable – and our language clearly is dependent and vulnerable, and yet it is also very robust. Is language an example of the idea that God chose what is low and despised in the world (little words), things that are not (words that do not exist), to reduce to nothing things that are, such as our pride and our sin?[43]

The problem with writing this possibility off is, as we noted in Chapter 5, that you not only reject the meaningfulness of my statements of religious belief, but leave even scientific language without an ultimate justification of its meaning – because, if my beliefs about God are untrue, then so might be my beliefs about other people (for example, that I love a particular person) and indeed my beliefs about science.[44] Clearly, I could be mistaken about any single belief, but the fact is that belief in love and belief in God are two very stable kinds of belief that we are evolutionarily adapted to adopt, and, if you want to argue that either is consistently in error, then it is necessary to explain why some other beliefs we have – about the world and especially scientific beliefs – are consistently more-or-less accurate. The bottom line is that, if you deconstruct the reliability of one set of beliefs that humans demonstrably hold, you run the risk of demonstrating that none of our beliefs is sustainable.[45]

Language is one kind of a system, a means of meaning-making, of exchanging thought and insight and belief. But, if we reflect on the variety of ways in which language is used, then this underscores the point that its reliability cannot just be assumed to be justified because, somehow, it works. One way of looking at this is to reflect that language could be different from what it is – it could have suited us at one level of description or analysis but be totally inadequate at another, or could mean things in a totally different kind of way.[46] As children we all go through a time when certain kinds of description or analysis just aren't accessible to us, and, in science, our capacity to say things about the world now would be incomprehensible to natural philosophers of the seventeenth century. Another is the problem with translation – some languages have acquired many different words describing varieties of things or experiences that other languages have very few words for, such as different kinds of animal.[47] Humans can, deliberately, lie – and lying can in some cases be the least troubling thing to do, it could save someone's life – but, if language has built in the capacity to be dishonest, how do we know when it is being used honestly?[48] How do we know that *we* are using it honestly? But, then, we can also make honest mistakes, and, as this is also fundamental to how we use language and how we learn – for example, in science because we discover we were mistaken

in our model for how something worked, or in an everyday sense that we used the wrong word for something or *didn't* see what we thought we did – this means that we *learn from our mistakes*. Well, of course, but what if we didn't? The unstable relationship between language and the world is what enables us to investigate the world for ourselves and learn things about it, as we build language games for ourselves and in our linguistic communities that aim to get to grips with it more accurately.[49] Indeed, Williams points out, following Walker Percy, that many scientists believe in a system of language in which we make truthful statements about the world (a dyadic view of reality, a correspondence theory of truth), but they operate in a different mode entirely.[50] Scientists work in a milieu of mistakes and errors and interpretations and models and of *what they think might work*, and of *what they think is beautiful*. There's no simple relationship between language and the world 'out there'. Scientists say *new things*, and those new things are risks they take, gestures they make; scientists ask genuinely new questions, they say things for the very first time that have never been said – and every day they use this process to solve a problem 'that absolutely does not have to be solved for our survival'.[51]

We have discussed the fact that science addresses things we did not evolve to need to address, but now we should look at some of the other strange features of language that Rowan Williams identifies as suggesting there *is* an edge to our words, and that what lies beyond it should be reckoned. The edges to language we have to contend with are perhaps threefold. First, our language comes from somewhere, we received it from other people, we did not always possess it; and we cannot actually say whatever we like and make sense. Second, as already stated, there is always more to be said about a situation, the limits (edges) of the language we have available to us are always receding. Third, there is always another perspective to be taken, and it might be a better one than ours; our language might be more limited than our neighbour's. So, we need to constantly be moving on, seeking new applications for and understanding through language, pushing back the boundaries (the edges).[52]

And yet, we are always faced with an inability to complete the job. We *never* fully understand each other, or our world. This is not because there is some magical gulf between what we say (our mental world) and what we have to describe (the world and all its stuff).

> The problem is not that words stand between us and reality; it is that . . . our speech can never close itself off from further response . . . what I now say is not the last word . . . There is no such thing as a fixed relationship between two different things called language and fact.[53]

This, again, is a key thing about language – that its very lack of self-sufficiency, its inability to be fully justified, gives it its meaning *for us*. It's only because we come up against the world, and up against each other, that we learn what it means to pay attention, to show respect and to love. The discovery of both moral/spiritual truths and of objective knowledge is a process bound up with

expression in language.[54] We will return to the idea that scientists love what they study – on the way paying it attention and showing it respect – in the next chapter, but, as Rowan Williams comments, this is also what stops us eating each other too.[55] So, it's useful both in an everyday kind of way and for understanding the space–time continuum.

One of the reasons language is stopped in its tracks and we are prevented from complete understanding is that it is also inherently embodied.[56] Of course, our mental capacities are very smart, but our guts are pretty nerve-rich too, and we need to remember that something not very different in *kind* from a liver is allowing us to think, plan, remember, interpret, hypothesise, conclude, love, and so on.[57] And, what's more, that we came to be where we are sitting today *in time*, which is out of our control.[58] Someone who was blind from birth just wouldn't know what to make of what they 'see' if they had their sight restored – they wouldn't have the language for it, because their body had not given them a way to be aware in that kind of way.[59] Thus, it is not that we have mental ability and our physical nature – they are the same kind of thing, our body.[60] And, 'our presence as communicating beings alongside each other establishes a common world'.[61] One of the deepest ironies of modern science is that researchers operate as if they were Cartesian egos at the same time as their own work shows that that is not what human beings are like. Scientists who denounce the idea of a soul (misunderstanding what Jews and Christians mean by it in the first place) simultaneously operate on the fictional basis that their particular point of view is a little bit of a view from nowhere – a disembodied, objective perspective, whereas, in fact, although scientists certainly have egos, they are indistinguishable from their bodies. 'For the bare fact is that the material world *speaks*. It is . . . material agents who speak, and this speech is not . . . a chance decorative addition to mechanical process, but an activity that is implicated in the entire complex of finite agency.'[62] So, the reason why language works as a way of understanding our world is that it is a natural feature of the universe, which is intelligible 'because the unfolding story of material evolution leads to speech'.[63]

Because we are embodied, we only understand matter 'by analogy with our own conscious systems of recognition and collaboration'.[64] This forces our language to be metaphorical, bringing us back again to the point that scientists actually do not have a language ready-made for what they study and, as a result, have to resort to analogy and metaphor to get their thinking across. The world is inherently interactive, inherently communicative – it is the collision of atoms and the recognition of a piece of DNA by a protein and the passing of an electrical impulse by chemical means from one cell to another that enable first molecular and then biological systems to flourish. So, to make sense of all this interaction, scientists very often have to use (as we already observed) language about relationships. Although scientists like to assume a mode of speaking that is dyadic – we use a particular word for something, and it makes a direct reference to it, it corresponds to it – really, that word (or mathematical symbol) only has the usefulness it does, scientifically, because of a whole web of related

terms that provide context and give it its meaning. Take the word 'atom', for example, and think about trying to explain to a backwards Martian what we mean by it. We operate with symbols, metaphors, images that are linguistically derived and imperfect (genes coding, mRNA is transcribed, proteins are translated, then they fold). Because we operate with symbols, metaphors, images that are linguistically derived and linguistically meaningful, we work with imperfect tools, and the traction they have in understanding reality requires, for Williams, justification in other terms. Scientists (myself included) use mechanistic terms and speak as if what we say describes what's really going on, but really these are symbolic and metaphorical words, picture words – terms we choose because they please us as a way to describe the reality revealed by the data we have. They are a way for us to respond to the overwhelming data we encounter – more than we can make sense of at once.[65] We choose them because they please us, and they have a tremendous power to enable understanding. Surely, this aesthetic choice (which is what it is) requires some form of justification? And, pretending we can talk in isolation as if our mechanistic analogies were true might be useful, but is not an accurate way of understanding how scientific language works, because it works in relational terms, based on our own relational way of understanding our everyday world and demanded by the relational nature of reality.[66] Indeed, we should remember that scientific thinking involves some of the less reliable aspects of human cognition as well, such as imagination (fantasy, make-believe), telling half-truths (approximation; see Chapter 6) and poetry.[67] Our terms break down at some stage, but that is the whole point: we modify our language models, we note where the understanding we're working with breaks, and we take a slightly different tack.

> Advances in understanding come when both theoreticians and experimentalists identify the oddity within 'normal' discourse and press its tensions a bit further – not with the aim of removing all tension but in order to find ways of holding it in a larger structure and discovering new tensions at that level which in turn will generate further fruitful crises.[68]

We always move on, we never get a finally perfect understanding, and we never will. 'There are no last words in what human beings say and no point at which we shall have identified the essential structure of the universe exclusively within one descriptive scheme.'[69] Rowan Williams is concerned that the way in which scientists treat mechanical analogies as if they were true is dehumanising;[70] for my part, I would argue that the fact that these mechanical analogies are aesthetically derived brings the humanity of the scientist back centre stage.

Rowan Williams concludes:

> If our language is systematically indeterminate, incomplete, embodied, developed through paradox, metaphor and formal structure, and interwoven with a silence that opens up further possibilities of speech, it is a reality

> which constantly indicates a 'hinterland' . . . these aspects of language seem to show that we live in an environment where intelligible communication is ubiquitous – where there is 'sense' before we *make* sense.[71]

This hinterland is surely, he says, what all understand to be meant by 'God'.[72] Nevertheless, to see things this way is a choice, or at least one of two alternatives. In the end this is where our argument in this book will end as well. Although language may behave 'as if it were always "in the wake" of meaning, rather than owning and controlling it', we can either regard that as a brute fact, unexplained and inexplicable, or treat it as something which indicates that our language operates in the wake of an eternal, personal and – in some sense – linguistic meaning.[73]

'In the beginning was the Word . . .'[74]

Beauty: Creation and science at a glance

One of the striking discoveries made as a result of the ability of the human mind to know objective truths about the world is the degree to which it seems 'finely tuned' to the emergence of rational, intelligent beings such as ourselves. Many writers have made much of this, and fine-tuning has become a standard argument in favour of the existence of God, in some hands. This relates to the 'anthropic principle' – that to leave enough time for humanity to evolve – for the universe to become conscious – requires a very, very particular set of physical constraints on the universe's possible properties.[75] Because the universe is expanding (indeed, it is thought, at an increasing rate), the temperature and density are falling, but the emergence of life and thereby of humanity requires a certain density for things to come to exist and a certain temperature for biological processes to occur.[76] How was that ensured? Not only this, but elements with greater masses than hydrogen and helium, such as are needed for chemistry and therefore biochemistry, as in life, require at least one generation of stars to cycle and expire in supernovae – thus requiring a universe of the size and age it is for humanity to have evolved. How was that ensured? In turn, a universe that is to give rise to life must be rather cold, because of its expansion, and the energy within it must be very unevenly distributed in order to enable the existence of concentrated pockets of energy in the form of planets and so chemicals and biochemicals. (How was that ensured?) This means that, though the universe might seem inhospitable to humanity owing to its size and the sheer profusion of galaxies within it, in fact universes that are going to sport life must *be* 'big, old, dark and cold'.[77]

A whole variety of hard cases can be given in which what appear hugely improbable odds apply to the conditions determining the existence of the universe for long enough, and in a form, to allow the evolution of life.[78] As Robin Collins summarises it, fine-tuning essentially concerns five required 'laws' or 'constants' of nature: (1) a universal attractive force to draw stuff together, such as gravity; (2) a strong nuclear force to bind neutrons and protons together

into atomic nuclei; (3) an electromagnetic force; (4) something like what we know as Bohr's quantization rule describing transitions in energy; and (5) the Pauli exclusion principle, which prevents identical fermions (e.g. electrons) occupying the same quantum state at the same time.[79] Collins focuses on two particular examples: gravity and the cosmological constant. Now clearly, gravity will not just influence large-scale gravitational effects giving rise to planets and forming solar systems, but will also relate to the electromagnetic force determining the strength of materials, as gravity produces weight, and weights are what we have to bear. It also, though indirectly, relates to other constants helping to make matter what it is, such as the speed of light and the masses of the proton and the electron. So, the different parameters or constants that are focused on in a fine-tuning argument clearly interrelate, and yet one can nevertheless speak of a fine-tuning of gravity with respect to them, such as:

> the fine-tuning of gravity relative to the density of mass-energy in the early universe and other factors determining the expansion rate of the Big Bang – such as the value of the Hubble constant and the value of the cosmological constant. Holding these other parameters constant, if the strength of gravity were smaller or larger by an estimated one part in 10^{60} of its current value, the universe would have either exploded too quickly for galaxies or stars to form, or collapsed back in on itself too quickly for life to evolve. The lesson here is that a single parameter, such as gravity, participates in several different fine-tunings relative to other parameters.[80]

With respect to Collins's other example, the cosmological constant, it must be close to zero and not greater than a limited value either side – John Polkinghorne gives the value $1/10^{120}$ – in order to ensure that the universe did not expand or contract too rapidly for stars to form.[81]

Alvin Plantinga finds in the fine-tuning of the universe some small support for theism; alternative explanations are possible, but the degree to which the constants governing the universe's physical characteristics are rather narrowly fixed if life is to evolve is nevertheless impressive.[82] In his 'restrained English way', Polkinghorne proposes a moderate anthropic principle, 'which notes the contingent fruitfulness of the universe as being a fact of interest calling for an explanation'.[83] Paul Davis would be more positive and find a strong implication that something like a God exists, albeit for him a philosopher's God rather than the God of Christianity, to provide a basis for fine-tuning, a basis for the anthropic principle.[84] 'We are meant to be here.'[85]

It is the ultimate truism to note that the universe exists, and if nothing else then the anthropic principle, or fine-tuning, affirms that, to have existed this long (15 billion years at the limits of our detection), a certain set of physical constraints on its operation are required, which we codify as constants such as the cosmological constant, the gravitational force, and so on. But, is the argument from the fine-tuning of the universe to the existence of God in the end just a 'god-of-the-gaps' style assertion? We can't explain the status quo

now, but one day science will hope to, and to cite God as the responsible agent is just lazy.

Against this possibility, Frances Young points out that really we are not talking about any individual parameters here but the way in which the interlocking physical constraints on the universe's continued existence relate to one another (and the same point is clearly made by Robin Collins elsewhere[86]). One implication she notes from this is that fine-tuning arguments are parallel to the appeal of church fathers such as Basil of Caesarea and Augustine of Hippo to the harmony and beauty of the whole of creation. Indeed, Basil and Augustine see our wonder at the beauty of creation as preparing us to be effective 'auditors', hearers, which I extend to visualisers and interpreters and all the other things that scientists do to make sense of the universe.[87] Furthermore, as the universe is one beautiful harmonic whole, so of course is the human being one psychosomatic whole: a thoroughly modern and scientific point of view, and one that Rowan Williams has already reminded us of.

The constants whereby we codify the constraints on existence that ensure the continuing existence of the universe, which therefore appear to be fine-tuned, are I would argue more accurately described as regularities. When we identify constants, what we are measuring are regularities. In fact, regularity is explicitly the basis of many of our measurements because of the ubiquity of waveforms in the energies of our cosmos. Waves *are* rather regular. It seems to me that, when we talk about the fine-tuning of the universe (in other words, the anthropic principle), we are simultaneously expressing the two questions on which we have been focusing in this chapter and the last:

> Why is there anything rather than nothing?

And:

> Why does what we say to one another mean anything?

These two questions meet, to my mind, in the anthropic principle, or the issue of fine-tuning.[88] Fine-tuning is, in a sense, in-between these two questions. Meditation on the issue of why the universe is so harmoniously configured that it persists and grows and develops in complexity to the point where it becomes conscious is *at the same time* a way of exploring the meaningfulness of our language for science and all other kinds of knowledge about external facts that we achieve, *and* a way of exploring the deep question of why anything exists.

For example, one way of rephrasing the question 'Why does anything exist?' is to say something like: Why *does* existence have a coherence and a harmony that balance the forces acting within it and enable its continuity over many billions of years? And, one way of rephrasing the question 'Why does what we say mean anything?' is to say something like: Why *can* we express the physical constraints enabling the continuity of the universe's existence in such precise terms?

My argument can be put in terms of exploration too. I believe that reflecting on the apparent fine-tuning of the universe is a way of gaining deeper understanding of the mystery of why anything exists rather than nothing at all – because, just as one does not have to believe anything,[89] neither is the existence of anything at all necessary. Interestingly, this is not only logically correct, it is also a position of Christian theology. And, I believe that reflecting on the apparent fine-tuning of the universe is also a way of gaining deeper understanding of the inherent mystery of our capacity to make sense to the extent and on the scales that we can.

This point can be phrased more provocatively. I think we have fetishised some aspects of our capacity to know things, and indeed hypostasised them – that is, turned them into *things* in their own right – when really we are scrabbling to make sense of a reality that enabled our existence and is astonishingly susceptible to our capacity for thought, but is not subject to us and remains in some fundamental ways a mystery. We have turned our appreciation for the regularity and logical consistency and mathematical beauty of the physical basis of existence into 'Laws' – and laws are a kind of *thing*. *Excessive* talk of fine-tuning is a symptom of this.

My point can be phrased more theologically. Some of the foundational stories of humanity's meeting with God are those of Moses on Mount Sinai, where the tablets of the Ten Commandments are received. A key episode is found in Exodus 33, where Moses says to the Lord:

> 'Show me your glory, I pray.' And [the Lord said], 'I will make all my goodness pass before you, and will proclaim before you the name, 'The Lord'; and I will be gracious to whom I will be gracious, and will show mercy on whom I will show mercy. But', he said, 'you cannot see my face; for no one shall see me and live'. And the Lord continued, 'See, there is a place by me where you shall stand on the rock; and while my glory passes by I will put you in a cleft of the rock, and I will cover you with my hand until I have passed by; then I will take away my hand, and you shall see my back; but my face shall not be seen'.[90]

We can link this with Elijah's experience of God on the mountain. Elijah is hiding in a cave, and the Lord says to him:

> 'Go out and stand on the mountain before the Lord, for the Lord is about to pass by.' Now there was a great wind, so strong that it was splitting mountains and breaking rocks in pieces before the Lord, but the Lord was not in the wind; and after the wind an earthquake, but the Lord was not in the earthquake; and after the earthquake a fire, but the Lord was not in the fire; and after the fire a sound of sheer silence. When Elijah heard it, he wrapped his face in his mantle and went out and stood at the entrance of the cave.[91]

To think about the fine-tuning of the universe, and from that intellectual perspective to look in one direction, backwards, and wonder why anything exists, is to see God's back, like Moses. And, to look in the other direction, forwards, and wonder why, when we mean what we say, the world is susceptible to our thinking and why we *keep on* making sense, as Rowan Williams emphasises, is to hear the sound of sheer silence, the edge of words, and go out and stand at the entrance of the cave, like Elijah. And there's a beauty in the 'fine-tuning' – an elegance and a harmonious balance. As people, to see that is to remember that 'God saw everything that he had made, and indeed, it was very good'.[92]

So good, in fact, we cannot help loving it. And, in the next chapter, we will look at the role of love in science.

Notes

1 Angus Ritchie, *From Morality to Metaphysics* (Oxford University Press, 2012), p. 43.
2 Ritchie, *From Morality to Metaphysics*, pp. 53–5, quotation on p. 53. See also pp. 143–4 for a formal demonstration.
3 Ritchie, *From Morality to Metaphysics*, p. 54.
4 Angus Ritchie, *From Goodness to God*, p. 29, www.theology-centre.org.uk/wp-content/uploads/2013/04/From-goodness-to-God-combined-FINAL.pdf
5 'Thus, in so far as aesthetic values provide reasons for action, these reasons would also count as "moral"', Ritchie, *From Metaphysics to Morality*, note on p. 26. See also Raymond Tallis, *Aping Mankind*, p. 63, on Wittgenstein in the *Tractatus Logico-Philosophicus*, where he says, 'ethics and aesthetics are one' (*Tractatus* 6.421), leading him to dicuss the similarity in brain activity between ethically and aesthetically engaged patterns of activity, with some reference to the writing of Robin Dunbar.
6 Ritchie, *From Goodness to God*, p. 14
7 Ritchie, *From Metaphysics to Morality*, p. 44.
8 Ritchie, *From Metaphysics to Morality*, pp. 18–19.
9 Ritchie, *From Metaphysics to Morality*, p. 19. And, as we've already noted three times, this makes science an objectively moral activity.
10 Ritchie, *From Metaphysics to Morality*, p. 20.
11 Ritchie, *From Morality to Metaphysics*, p. 16. There he demonstrates at greater length that, 'the problems which are alleged to afflict moral reasoning also affect other areas of knowledge where objectivism is widely accepted', such as science (pp. 21–2).
12 Ritchie, *From Metaphysics to Morality*, p. 38.
13 Tallis, *Aping Mankind*, pp. 100–11. For Tallis, intentionality and the ability to make other items appear discount the possibility of a material explanation for consciousness as they point in the opposite direction to causation. Intentionality 'points *from* effects (nerve impulses in the high levels of the visual pathways) *backwards* to their causes (the interference between the object and the light)', p. 105. See also pp. 243–62, 359–60. Thomas Nagel too focuses on the intentional aspect of consciousness; see *Mind and Cosmos*, pp. 46-69.
14 Ritchie, *From Metaphysics to Morality*, p. 65.
15 Ritchie, *From Metaphysics to Morality*, p. 66.
16 Ritchie, *From Metaphysics to Morality*, p. 71.
17 Ritchie, *From Metaphysics to Morality*, p. 74.

18 Ritchie, *From Metaphysics to Morality*, p. 74.
19 Ritchie, *From Metaphysics to Morality*, pp. 84–5.
20 Ritchie, *From Metaphysics to Morality*, pp. 22–3
21 Ritchie, *From Metaphysics to Morality*, p. 23.
22 Ritchie, *From Metaphysics to Morality*, p. 24.
23 Ritchie, *From Morality to Metaphysics*, pp. 1–2 and 29.
24 Experiences of euphoria or pleasure or calm induced by drugs have the same status as such machine-induced sensations. Arguably, pornography does too. In these senses, Nozick's machine is a real part of our world. The comparison of real-life and simulated 'experiences' is dicussed further in Chapter 5.
25 Ritchie, *From Metaphysics to Morality*, p. 32.
26 Ritchie, *From Metaphysics to Morality*, p. 33.
27 Ritchie, *From Metaphysics to Morality*, pp. 36–7. See also on this Nagel, *Mind and Cosmos*, pp. 98–11.
28 Ritchie, *From Metaphysics to Morality*, p. 123; take for example the moral demand felt by those who spend their time and money rescuing migrants from the overcrowded vessels of people traffickers on the sea between Africa and southern Europe.
29 Again, at the launch of *From Goodness to God*.
30 Ritchie, *From Metaphysics to Morality*, pp. 42, 44–5.
31 Ritchie, *From Metaphysics to Morality*, p. 44.
32 Ritchie, *From Metaphysics to Morality*, p. 146.
33 Dunbar, *The Trouble with Science*, pp. 96–113.
34 Dunbar, *The Trouble with Science*, p. 61: 'Despite the eulogies on its behalf, language is in fact a surprisingly poor means of communication about the natural world'. So, why does it work as well as it does? How can we, as Rowan Williams puts it, *keep on* making sense?
35 Williams, *The Edge of Words*, p. 191.
36 Williams, *The Edge of Words*, Chapter 1. See also Robert Gilbert, 'The Riot of the mind', *New Blackfriars Review*, *87*, 357–63 (2006).
37 Williams, *The Edge of Words*, p. 173.
38 Williams, *The Edge of Words,* p. 165.
39 Williams, *The Edge of Words* p. 168.
40 Williams, *The Edge of Words*, pp. 61–62, 64.
41 'An abundance that is always bound up in understanding', Williams, *The Edge of Words*, p. 32.
42 Williams, *The Edge of Words*, pp. 86–91. See also Williams, *Grace and Necessity*, pp. 163–6 – on how the same idea is illuminated by a theology of what artists do.
43 1 Corinthians 1:28.
44 Williams, *The Edge of Words*, p. 36.
45 'Evolutionary debunkers will have to specify why natural selection would lead us to adopt false beliefs in the religious domain, whereas it allows us to adopt true beliefs under many other conditions', de Cruz and de Smedt, *A Natural History of Natural Theology*, p. 188.
46 Williams, *The Edge of Words*, pp. 37–9, 41. Williams points out that morality is a helpful comparison here – morality *could* be otherwise (except we can't, or many of us can't, really conceive of that at all. I cannot conceive of a world in which being deliberately cruel to children was seen as morally acceptable).
47 Williams, *The Edge of Words*, pp. 44–5.
48 Williams, *The Edge of Words*, pp. 42–5.
49 Williams, *The Edge of Words*, pp. 54–6. See also Tallis, *Aping Mankind*, pp. 229–32.

50 See above, Chapter 2, n. 2. See also Chapter 6 and the discussion of coherence versus correspondence theories of truth. A dyadic view of reality is a version of a correspondence theory of truth, but many scientists clearly believe (if they could put it this way) in a coherence theory of truth, because they believe that what can be said is defined by the language game that you are playing. Is it the game of hypothesis–experiment–data–interpretation–conclusion or something else, something 'unscientific'?
51 Williams, *The Edge of Words*, pp. 66–72, quotation p. 72.
52 Williams, *The Edge of Words*, pp. 72–81.
53 Williams, *The Edge of Words*, p. 109.
54 Massey, *The Neural Imagination*, pp. 147–8: 'a crucial truth about the nature of language . . . is that this piece of instruction, the conferral of this major piece of knowledge – that meaning is created by the way words make contact with each other outside and beneath syntax . . . is a deeply moral act.'
55 Williams, *The Edge of Words*, p. 93.
56 Williams, *The Edge of Words*, Chapter 4. Williams takes as a particular case autism spectrum disorders to explore how our bodies can limit our language. Frances Young discusses these issues with great personal authority in her book *God's Presence*.
57 Gilbert, 'The riot of the mind'.
58 Williams, *The Edge of Words*, p. 81: The self is 'the action that here and now gathers events narrated from the past and possible courses of action in the future into one story that is unceasingly being revised from one utterance to the next.'
59 See Annie Dillard, *Pilgrim at Tinker Creek* (Canterbury Press, Norwich, 2011), p. 32, and Mark 8:24.
60 'We cannot think or speak intelligently about the "material" world without speaking/thinking about ourselves as speakers; we cannot talk about "matter" without presupposing "mind" . . . we badly need to free ourselves from the decadent Cartesianism of supposing the universe to be divided between impenetrably solid stuff and the immaterial content . . . of the noises we make', Williams, *The Edge of Words*, p. 107. See also Fergus Kerr, *Theology after Wittgenstein* (SPCK, 1997), and Herbert McCabe, *God Still Matters* (Continuum, 2002), Chapter 13, 'Sense and Sensibility'.
61 Williams, *The Edge of Words*, p. 112.
62 Williams, *The Edge of Words*, p. 123.
63 Williams, *The Edge of Words*, p. 102.
64 Williams, *The Edge of Words*, p. 103.
65 Williams, *The Edge of Words*, p. 117.
66 Williams, *The Edge of Words*, pp. 118–19.
67 Williams, *The Edge of Words*, pp. 123–4, 131. It involves play; see Chapter 4.
68 Williams, *The Edge of Words*, p. 130.
69 Williams, *The Edge of Words*, p. 124.
70 Williams, *The Edge of Words*, p. 197.
71 Williams, *The Edge of Words*, p. 170.
72 Williams, *The Edge of Words*, p. 171. And echoing, obviously, Thomas Aquinas.
73 Williams, *The Edge of Words*, p. 173.
74 John 1:1.
75 Bernard Carr and Martin Rees, 'The anthropic principle and the structure of the physical world', *Nature*, *278*, 605–12 (1979).
76 John Barrow, 'Cosmology, life and the anthropic principle', *Annals of the New York Academy of Sciences*, *950*, 139–53 (2001).
77 Barrow, 'Cosmology, life and the anthropic principle'.

78 See, for example: Plantinga, *Where the Conflict Really Lies* pp. 195–6; John Polkinghorne, *Beyond Science* (Canto/Cambridge University Press, 1998), pp. 81–2.
79 Robin Collins, 'The teleological argument', in *The Blackwell Companion to Natural Theology* (William Lane Craig and J.P. Moreland, eds, Blackwell, 2009), pp. 211–13.
80 Collins, 'The teleological argument', p. 215. Collins notes that, if one cites gravitational fine-tuning as set out here, then the force of the Big Bang cannot also be given as an independent fine-tuning argument.
81 Collins, 'The teleological argument', pp. 215–22; Polkinghorne, *Beyond Science*, pp. 81–2. As Collins notes, a slightly positive value of the cosmological constant accounts for the apparent acceleration of the universe's expansion, as estimated from the red-shifted light from distant supernovae. Collins notes that it is possible that 'the right set of laws–symmetries–mechanisms' might explain 'the fine-tuning of the effective cosmological constant' – such as superstring theory – but see the further discussion of this possibility within his account – for example, that there are 10^{500} solutions to superstring theory (pp. 262–75).
82 Plantinga, *Where the Conflict Really Lies*, p. 224.
83 Polkinghorne, *Beyond Science*, p. 88.
84 Paul Davis, *The Mind of God* (Penguin, 1993), pp. 220–48.
85 Davis, *The Mind of God*, p. 260.
86 Collins, 'The teleological argument', pp. 222–6.
87 Young, *God's Presence*, pp. 73–6.
88 And others seem to agree: 'The idea of God is the greatest, although possibly the most destructive, idea that mankind has ever entertained. The man-made notion that the sum total of things originated from, and is controlled by, a maker is a profound and distinctively human response to the amazing fact that the world makes sense. This response is more, not less, extraordinary for the fact that it has no foundation in truth and that, indeed, God is a logically impossible object', Tallis, *Aping Mankind*, p. 335.
89 Nagel, *The View from Nowhere*, p. 81: 'Belief isn't like action. One doesn't have to believe anything, and to believe nothing is not to believe something.'
90 Exodus 33:18–23.
91 1 Kings 19:11–13b.
92 Genesis 1:31a.

8 Loving beauty

The argument of this chapter will be that what underlies our capacity to understand the things we study is our capacity for loving attention to them. Terry Eagleton says:

> In the end, only love (of which faith is a particular form) can achieve the well-nigh impossible goal of seeing a situation as it really is.[1]

But, the love he means is far from mere romance. Indeed, it is what gives content to our thinking.

Appreciating the beauty of something involves being moved by it

As the Acknowledgements at the start reveal, the origins of this book stretch back to my schooldays, and the thinking I have tried to set out has developed over the 25 years since I was a sixth-form student. One of the reasons why I have wanted to write this argument up, though, is the way in which I have found my own honestly told experience of what it is like to be a practising scientist reflected in specific strands of theology whose historical roots I have accessed via the contemporary and recent writers I have followed. Reading Josef Pieper, for example, on *Faith, Hope, Love*,[2] or Rowan Williams's wonderful book of lectures *Grace and Necessity* has elicited a deep sense of resonance between my lived experience as a scientist and the vision of the world their theologies express.

Probably the most important single period for the development of my argument was when I was a graduate student at the University of Leicester, between the ages of 21 and 24. It was in many ways a very happy time: I was engaged with my local church in an enriching and rewarding way; I was engaged in the city in voluntary work I found challenging but inspiring; and I was intensely engaged in my PhD research on the bacterial protein toxin pneumolysin. Of course, I enjoyed friendships and my other activities, but I was *deeply* immersed in my studies and felt quite isolated. On a Friday evening, it was not uncommon for me to finish the week by going to the library to

look up and photocopy yet more papers for reading. And part of my work was completed in London, and to manage that I would go and sleep on the floors of friends from school who were working there. I really did throw myself into my work: I put my little heart into it; I gave myself over to it.

When I moved to Oxford, I felt a real and profound sense of loss for the church engagement I had had, for the voluntary work I had done, for how everything in my life had made sense while I lived in Leicester, for how all the bits of my life had fitted together. It took years to recover – and being appointed to the tutoring job I still hold at Magdalen College started to give me back the coherent living I had once enjoyed in Leicester. Being ordained some more years later was to some extent a culmination of this newly realised coherence, but of course also just the beginning of a renewed attempt to live in a way that makes sense, which for me is to live a life in which I am given over to what I do openly and honestly. I think the way to make most sense of this is to say that coherent living is, for me, a life that, as far as it can be, as far as I can manage, in every aspect of what I do, is loving, though of course I repeatedly and constantly fail.

In between, having lost my life in Leicester – an experience that, I felt, gave me a sense of what it means to be 'poor in spirit'[3] – I worked even harder. I threw myself with even greater passion into my lab work. I just *gave myself over* to it, and it just is true that in this, as in other ways in which I had disposed of myself for the sake of a task in hand or a goal I wanted to achieve, I had in mind the teachings of Jesus about the inversion by God's kingdom of the priorities of the world. I had in mind that we are told that, to gain your life, you have to be willing to lose it, and I had in mind Paul's teaching in 1 Corinthians that:

> God chose what is foolish in the world to shame the wise; God chose what is weak in the world to shame the strong; God chose what is low and despised in the world, things that are not, to reduce to nothing things that are.[4]

Because, to hand yourself over to what you study, to immerse yourself in what you study, to throw yourself into your research, is to risk loss of yourself, is to risk being thought a fool, and so is to risk being despised and shamed. And at times, in science, I have felt despised.

But that has been a source of joy, in the end. Because it has allowed me to understand that to really know something, to really understand something, you have to give yourself over to it; and that to the extent that you are willing to do this, the chances are increased that you will gain a new understanding. You risk yourself, but you gain a richer understanding of life. You put your little heart into your research, and you stand a better chance of properly deciphering how something works.

The subheadings of this chapter are not new. They are, more or less, the argument statements I used as the conclusion to a talk to some students at Merton College, Oxford, in 2008, organised by the then Assistant Chaplain,

Andrew Davison. As I say, they are the honest statements of my experience, and we start with the basic idea that when we see something beautiful we are moved by that experience, it engages what we have called before (following Poincaré) our sensibility. If you see or hear or read or experience something beautiful, it moves you. Maybe we are mildly affected, or more profoundly, it depends on the details, but the beauty we experience *can* make you cry or laugh or shout. So, if scientists see beauty, they are moved by it just as much as they might be by a film or a painting. In both cases, the scientist is, as we said in Chapter 1, *pleased*. She experiences pleasure.

So, there is a vulnerability in research: we lay ourselves open to being affected by what we study. The opposite would be to be bored by our studies. Scientists are *not* bored by their studies; they allow themselves to be affected in them and that is why they can, and do, say that a molecular structure or a theory or an equation is beautiful. If you look at something – or someone – and do not find it or them beautiful, in some sense, then you will never understand them. To come to an understanding of something or someone, you need to allow yourself to engage with them as they are, you need to appreciate them for themselves, you need to find them beautiful. To be bored by something is to display an arrogance towards it; for a scientist to display arrogance towards what they study is bound to be a source of failure and should horrify any researcher. It is not an arrogant eye but a loving eye that we turn on the world in our studies.[5]

Understanding truths about the world requires us to value it for itself

There is another side to this, however, which is that we need to recognise what we study as different from and independent of ourselves. Indeed, we need to value it for itself, be willing to let it be itself. This is the intention of controlled experimentation: we do not set out to impose our will on the objects of our study, we want them to be themselves and we want to avoid, as far as possible, being misled as to their properties. In fact, though we think they are beautiful or the data they give us are beautiful, at the same time we have to make ourselves see them as being ordinary, by poking them experimentally and measuring their response. Beautiful but ordinary: we recognise each other like this all the time; we know that someone we think beautiful is also ordinary, also flesh and blood, however much they mean to us. That is why we embrace them. We know that a painting is a rather ordinary artefact in some ways: planks, paint; that a landscape is quite ordinary: earth, plants, the sky as a backdrop. We know they are ordinary because we know they are fragile – we treasure the painting and take care of it. If something is fragile, we handle it with care, and the more fragile, the more extreme the care we take.

In fact, it is *because* someone is flesh and blood that we value them for their beauty so much: they are fragile and mortal, like us. It is *because* beautiful music, art and literature can be lost or destroyed that we value them to

the extent we do. Recognising the beauty and being moved by the beauty of something or of an experience are tied up with its transitory nature. So, equally, seeing the beauty in the world scientifically and seeing the beauty in our data require us to understand that they are ordinary, they are simply facts, even though they are facts we see as full of meaning. What we study is independent of us, and it deserves our respect and that we accept it for itself, not for what it means to us or for us.

Of course, science can be and often is about identifying ways in which the world can be instrumental for us, can give us what we want. But, to have the knowledge and understanding to make this possible, we have to first of all realise it is independent of our desires and seek to value it for itself. Only by valuing what we study for its internal coherence, its autonomy, can we get the wisdom about it that allows for its application.

There is theology behind this second move in the argument of this chapter, too, because I do take it that it is because of the life, death and resurrection of Jesus, as the culmination of the Judaeo-Christian development, that we have an understanding of the world as an independent reality anyway.[6] This move was non-trivial and it involved abandoning a view of the world as the domain of spirits and demons and gods and seeing it as ordinary, factual and regular. God in Jesus desacralises nature, he shows it to be ordinary, so that we understand sickness is not a punishment for sin, it is just sickness;[7] misfortune is not a punishment from God, it is just misfortune;[8] and, faithful to his own Jewish tradition,[9] human life is fragile and mortal and fundamentally embodied – to die is really to die, and to live again, if such a thing be possible, is for God alone to give and is to a life unimaginable to us now, a life of pure relationship.[10] Jesus's murder was a sacrifice that ends the power of sacrifice by showing up why people do the wrong they do: for fear, out of jealousy, for their own protection. Jesus shows by his death that people make victims of the innocent as a defence against disorder and conflict; but, in his resurrection, he shows that God has nothing to do with dark deeds like this but is wholly light, wholly good, wholly loving, wholly graceful, wholly free.

The realisation that the world is free, coherent and logical has deep origins in Judaism: the creation stories in Genesis tell us about God's creation of the world as free, as it*self*, as autonomous and rule-bound. God says, 'Let there be . . .': let there be things with the freedom to be themselves, to grow and multiply, to do wrong and right, to have knowledge; 'Let there be things that share my freedom . . .'. Through Jesus, 'God himself has given us the key to discover and inhabit with God the ordinary and good "secularity" of everything that is'.[11] Without it, there would be no science in the modern sense.[12]

Science requires a relationship to what we study

If science involves us understanding the independence of what we study, and respecting that independence, then it involves us being willing to come into relationship with it. To respect another person, someone other than myself, is

to be in relationship to them; to respect the world's factuality, its ordinariness, is to enter into relationship to it. You cannot understand what you do not know. We need to get to know what we are studying; we need to relate to it. This relating is, obviously, something that is occurring when we react with joy at the beauty of our data or the elegance of an experiment. We recognise something coherent in our data, we grapple successfully with the details of an experimental protocol. We get to know them for ourselves.

This relational attitude is something visceral. Anyone who has got to see the signal in the data in front of them, or worked out how to get something to work that they couldn't before, has felt the physical force of recognition, and it has made them profoundly glad. This can be partly about recognising a pattern where there was chaos, but can as well be about seeing a *new kind* of pattern for the first time. In other words, 'Eureka!' moments do happen, and they are moments of recognition and relationship. I have had a few myself – I think all scientists have. I have been convinced of one thing and suddenly I have realised I am wrong, everything has fallen into place, and there is a sudden and joyful recognition of what it all means. In one case I am thinking of, I can remember one specific moment, and where I was. I was in Mainz in Germany, in 2004; I was in my guest room in the local Catholic diocesan conference centre, which was being used as the accommodation for the meeting I was attending. I was reading a particular paper to prepare for a talk I was giving the next morning, which I hadn't yet prepared, though I knew I should have. I was drinking red wine (I was on a date with data, after all). I had tried unsuccessfully that evening to link my computer to the Internet using a silly array of adaptors (I was waiting for permission from a senior colleague to show images I had helped obtain, but I couldn't get the permission and made the argument I had wanted to in a different way). And then, reading through the paper in hand, it clicked, I saw what it all meant. It was a rather minor point in some ways, but it mattered to my field, and it mattered to an argument that had been going on for some years among several leading groups in it. In a moment of recognition, I suddenly knew my system significantly better: our relationship had deepened.

I gave my talk the next morning; I spent the next 10 years arguing my case, often being told I was rather obviously wrong, probably stupid, certainly ignorant. I kept trying to get grants to fund the work; I kept being unsuccessful. In 2014, suddenly, following work of my own but also that of several other scientists (some of whom had previously done their best to kill the argument off), it turned out I had been *exactly* correct. The relationship I entered to the data I had before me in 2004 stood the test of time; what I recognised through that relationship was truthful, and rich in implications for the system in question.

I just give this example to try and convince you that, as well as recognising beauty in science involving being moved, being affected by what we see; and as well as understanding the world being something that requires us to let it be itself; to know things scientifically is also to relate to them, to enter a relationship to them.

There is a final step to take in this chapter. To recognise beauty is to be moved, to understand is to allow something to be itself, and scientific understanding requires a relationship. But what kind of relationship? The kind that *involves* being moved, of course, and letting things *be themselves*, and *mutuality*. In other words, love.

When we do science we love the world

'As Wordsworth says, "where he [man] has no pleasure he has no knowledge" (preface to the Lyrical Ballads). It may be said that perception itself depends on love. "In order to see anything – a leaf or a blade of grass – you have, I think, to know the keenness of love" (John Cheever, *The Fourth Alarm*).'[13]

The original sequence in the argument I am making was as follows:

- Our appreciation of the aesthetic guides us to truths about the physical universe.
- Aesthetic understanding involves being affected by what is perceived.
- Aesthetic understanding involves appreciating things for themselves.
- Propagating aesthetic understanding is cultural, it involves language and demonstration.
- Understanding something in appreciating it involves giving oneself to it, immersing oneself in it.
- It involves loving it.

We have covered all the steps it takes except the last one. At the end of Chapter 1, I already said that, as far as I am concerned, scientists immerse themselves in their data. In Chapter 3, we looked at a series of examples of the ways in which scientists give themselves to their work. Obliquely, in this chapter, we have again been making these two points. To relate to another person is to give yourself to them in varying degrees; to relate to something you are doing properly you have to give yourself to it, you have to immerse yourself in it – as we say, you can't be in two minds. There is a sense in which all the previous steps in this sequence lead inexorably to the last: once you have said all the above, what are you talking about, but love?

Because, if beauty is a guide to scientific truth, then scientists need to adopt two different attitudes at once. They need to be willing to be personally affected by the beauty of the world, open to its subjective impact, *and* they need to value that beauty for itself, not for what it can do for us. If scientists are not open to the impact of the world's beauty, if they don't make themselves vulnerable, in a sense, before the world, then how can the world tell them what it's like? Metaphorically, how can the world get a word in edgeways? And, if scientists are constantly looking for an application of what they partly know, they will miss the chance to understand what they are studying more completely. Being a scientist relies on a four-dimensional point of view, in which the whole person in space and time comes to the scientific task and opens themselves to the

impression that the world makes on them, before responding in kind. But what is it, to be willing to be affected by something or someone, and to value it for itself, but implicitly (at the least) to love it? And that love gives us knowledge. 'By learning to see and appreciate beauty, we learn to reject self-interested pragmatism'.[14] In doing this, we are building on our basic characteristics as people – not some ghostly spiritual aspect of ourselves, but something very ordinary, just how we are. This is something we argued in Chapter 5 – it's just us, evolved and messy and complex and sometimes confused, who see the beauty of our world and love it. But, the capacities we have astonish us, and we feel in our hands, physically feel as we act on the world, the truthfulness of the knowledge this gives us. Maybe we should argue that, as well as being the linguistic animal and the ceremonial animal, human beings are the loving animal. What is it, to be human, but to love? Doesn't Christian faith assert that we are most ourselves when we love? 'Love' is the word that captures at once the attitude that values things for themselves and relates to them.

We mentioned earlier in this chapter how, if you are bored, you are failing to see the beauty around you. Boredom is to look at something – to gaze – without love.[15] The bewildering number of words for love in the world's 6,000 languages shows the richness with which we experience love. For example, in discussing the world's words for love, Josef Pieper notes the Russian words *lubovatsia*, to love with one's eyes, 'a form of loving that becomes a reality through seeing', and *blágost*, the love of God for men.[16] He continues:

> When we find something we see good, glorious, wonderful (a tree; the structure of a diatom seen under the microscope, one's partner for the whole of one's life, but also one's own existence in the world) – when we see something good, I say, when we love something lovable, we might become aware of our actually taking up and continuing that universal approval of creation by which all that has been created is 'loved by God' and is therefore good.[17]

When we give ourselves in study and analysis and in thought, we love. 'Only a thought that gives itself can devote itself to a gift for thought. But, for thought, what is it to give itself, if not to love?'[18]

In saying earlier that we need to respect what we study for its ordinariness, its simple physicality – just like we respect the people we love for their ordinariness and physicality – I was no less implicitly invoking the love of the ordinariness of the world that science opens up for us. When we love people – or things – this helps us to see them for what they really are, even though we are also acknowledging that to us they mean very much. It's the love of creation that helps us see the way it is structured. We are enabled by relating viscerally to the world with our ordinary and sometimes deluded mental arrangements, but *in love*, to understand the real, hard, physical, structural, objectively verifiable world there is. Our knowledge comes through our practice of self-gift in wisdom. In love with each other and in love with

the world, we acquire the ability to engage each other and it in knowledge and truth,[19] and then to make sense of it, via an aesthetic engagement. 'When one is actually in love, one is in what might be called a state of continuous metaphoric perception: nothing is merely what it is; everything is immediately transformed into something more significant.'[20]

This is not a new argument. It is something I have found to be true in my own life, but it is not a new position to adopt. The fundamental issue is a philosophical one and it is quite simple, in a way: I cannot love what I do not know, and yet also I cannot know what I do not love. The first part is common sense – how can you really love something or someone you have not taken the time or the care to get to know? The second part has been the focus of our meditation above – to really understand something is to love it, to know it for itself. To say, 'How wonderful that this exists!' – the cry of Josef Pieper, a follower of Thomas Aquinas, and through him of Aristotle.

For the argument is that of Aquinas, who was himself following Augustine of Hippo. Practical reason gives us knowledge and is an act of our intellect, but to act requires that we will or desire something – an end, even if that end is just the knowledge of something that we study. Knowledge and love, intellect and will – they are bound together in a circularity that Aquinas himself fought to understand.[21] His fundamental insight was 'that love has a certain priority on the level of exercise, but knowledge has priority on the level of specification, which is a structural and thus more fundamental priority'.[22] In other words, Aquinas affirms: 'that love depends on knowledge (because nothing is loved unless it is known) and that our moral knowledge depends on love (because our loves shape how we view things)'.[23] Our free will in science can be directly mapped on to this understanding of the relationship of knowledge (intellect) and love (will): our freedom is rooted in our capacity to reason, but our act of freedom is an expression of our will, our desire.[24] We can freely choose: but that freedom expresses the desires we have. This is as everyday a human experience as you could name, and Aquinas's precise point can be put more pithily: 'When I say to you "I love you" I do not merely issue a factual report on my mental state, I *make* love to you'.[25] We make love with our bodies, we do work with our bodies, we think with our bodies – human rationality is incarnate, and that is why we need to use analogy and intuition and 'sensuous particularity': 'we think as we do roughly because of the kind of bodies we have'.[26]

When a scientist acts – in simple terms, for example, they perform an experiment – then what they are doing is not obviously fundamentally different from the actions of craftsmen and their apprentices that Thomas Aquinas knew of in his own day. So, the same principles hold then as now: our actions in the lab might be theoretically grounded and have technical ability as their expression, but what is motivating the scientist is a set of virtues that lie at the heart of rationally acceptable human activity: sensible choices, a cool head, ambition combined with a kind of courage, and fair- and open-mindedness. Sensible choices do, I think, require that we want the right kinds of thing: true things, good things. So, just as knowledge and love – intellect and will – are bound

together in a circular embrace, our physical actions in the lab, as anywhere else, must – if they are to be truthful and truth-bearing – be caught in an equivalent circularity of choice and will, in other words, virtue and love.[27]

As we said, Aquinas's thought is inspired by that of Augustine of Hippo, a man 'fascinated by the ways in which will or desire runs ahead of reasoning and by the impossibilities of summoning all the resources of the mind for making clear decisions'.[28] Only delight can move the will . . .

Augustine sees that, whatever we do, we do for love. Love for someone – myself or another – is the basis of everything we do, and no less part of the actions that lead to understanding and to knowledge than part of anything else.[29] And, as love involves a vulnerability or openness to *an*other or *the* other – people that are not me, things that are not me – the actions with which we express our wills are grounded in what can be called 'a certain passive receptivity' – to goodness, to beauty and to truth.[30]

'Every human act, if it is truly a human act, is done from knowledge and with love', and 'these acts are always the product of some measure of knowing freedom'.[31]

Notes

1 Eagleton, *Reason, Faith and Revolution*, p. 121.
2 Josef Pieper, *Faith, Hope, Love* (Ignatius Press, 1997).
3 Matthew 5:3.
4 1 Corinthians 1:27–8.
5 The distinction of an arrogant eye and a loving eye is Sallie McFague's. See Elizabeth Johnson, *Ask the Beasts*, p. 44.
6 Pope Francis, *Laudato Si'*, p. 78: 'Judaeo-Christian thought demythologized nature. While continuing to admire its grandeur and immensity, it no longer saw nature as divine.' See also similar points in Chapters 5 and 6.
7 For example, John 9–10.
8 Luke 13:1–5.
9 Psalms 39:13; 78:39; 103:13–16, for example.
10 Jesus dies on the cross; the resurrection experiences are described in a way that makes it clear that this is a wholly new kind of life: Jesus can walk through walls and eat fish; he is unrecognised by people who knew him well and then recognised by an action he performs.
11 James Alison, *On Being Liked* (Darton, Longman & Todd, 2003), p. 60. Alison follows the thought of René Girard; also see his other books, *Living in the End Times*, *Knowing Jesus* (SPCK, 2nd edn, 1998) and *The Joy of Being Wrong*.
12 We made this point in Chapter 6; on the source of scientific thought lying in Christianity, see, again, Charles Taylor, *Sources of the Self*, pp. 13–16, 81–3, 211–47.
13 Massey, *The Neural Imagination*, p. 96.
14 Pope Francis, *Laudato Si'*, 215.
15 This idea is extensively discussed in Jean-Luc Marion, *God Without Being* (University of Chicago Press, 1991), Chapter 4, 'The reverse of vanity'. See also Harry G. Frankfurt, *The Reasons of Love* (Princeton University Press, 2004), p. 54.
16 Pieper, *Faith, Hope, Love*, pp. 161–2.
17 Pieper, *Faith, Hope, Love*, p. 275.

18 Marion, *God Without Being*, p. 49.
19 So Rowan Williams, 'Logic and spirit in Hegel', originally published 1998 in Phillip Bond (ed.) *Post-secular Philosophy: Between Philosophy and Theology* (Routledge, 1998), and republished in *Wrestling with Angels* (SCM, 2007). 'Our thinking, then, is ultimately radical loving: ecstasy, being-outside-ourselves', p. 42. See also Michael Sherwin, *By Knowledge and by Love* (Catholic University of America Press, 2005), pp. 64ff.
20 Massey, *The Neural Imagination*, p. 96.
21 Sherwin, *By Knowledge and by Love*, pp. 57, 111–20.
22 Sherwin, *By Knowledge and by Love*, p. 117.
23 Sherwin, *By Knowledge and by Love*, p. 120.
24 Sherwin, *By Knowledge and by Love*, pp. 34, 38, 52–3, 61–2, 71, 100–1; '(a) love depends upon cognition; (b) love is primarily the principle (not the terminus) of the agent's action; and (c) love as it exists in the will is the result of the agent's free choice', p. 71; 'The human act is like a work of art', p. 101.
25 Denys Turner, *On Aquinas* (Yale University Press, 2013), p. 239.
26 'as Thomas Aquinas noted', Terry Eagleton, *Culture and the Death of God* (Yale University Press, 2015), p. 203.
27 By sensible choices I mean prudence; by a cool head, temperance; by ambition/courage, fortitude; and by fair-mindedness, justice. See Sherwin, *By Knowledge and by Love*, pp. 107–11.
28 Williams, *On Augustine*, p. 4.
29 Sherwin. *By Knowledge and by Love*, pp. 87–92.
30 Sherwin, *By Knowledge and by Love*, p. 96.
31 Sherwin, *By Knowledge and by Love*, p. 239.

9 Conclusion

Truthful beauty

This book has sought to argue that the emotional human response to things of beauty is the source of our understanding them. The argument is not an eccentric obsession but is instead aligned with the oldest intellectual traditions we have. As Pope Francis comments in his encyclical *Laudato Si'*:

> Rather than a problem to be solved, the world is a joyful mystery to be contemplated with gladness and praise.[1]

Loving knowledge of the world requires a personal point of view

It is people who love, and people who gain scientific understanding. The knowledge we get about our world – the loving knowledge we obtain through our engagement in science – is something requiring a first-person perspective. If there is one conclusion that should be obvious from the argument made in this book it is this one, because it is people who see beauty, it is people who make sense of data, it is people, individual persons, who see the pattern that explains a phenomenon in terms of the regularities and laws that express the freedom and autonomy of creation. And we should simply acknowledge that, in the event that a computer or some other kind of machine or man-made entity acquired the capacity to do such things, we would have to confer on it the status we confer on each other and recognise another form of personhood than the one associated with the biological species *Homo sapiens*. The same would go for intelligent life elsewhere in the universe.

The role of the personal in scientific discovery is a further link to be made between what we do when we research and what we do when we pray. Like religion, scientific endeavour is the product of a 'community of minds' – a society – because, like religion, scientific understanding is '*argued* into place'.[2] This requires language, and language of the form that is useful for an argument is distinctively the possession of persons – human or otherwise. In this sense, neither science nor religion can be understood as themselves products of a biological process. The successful, coherent prosecution of scientific endeavour depends on some basic principles of honesty and decency that are

inherently human, and however true it is that they are phenomena associated with an evolutionarily derived biological species, they are not the product of evolution as such, but of personhood in human society. Alongside love and mercy, decency and honesty are human characteristics and cannot be naturalised or separated from their dependence on conscious human awareness, on deliberate action, on living people.[3] We can naturalise neither religion nor science, but must accept that they are *characteristics of human beings in society*, and nothing less.[4]

So, to repeat a point made in Chapter 2, we humans have only one way of seeing the world, the one that belongs distinctively to us as people. We aren't scientists and then priests, any more than we are scientists and then husbands or wives or children. We are the same people in everything we do – however flawed that makes us. We integrate experience, we make judgements on the sense data we receive, we analyse and we infer relationship and order; we make decisions – somebody has to decide, and, in any given situation, it could be me or someone else (or some of us together), but it cannot be less than one of us.[5] Just as we make something of ourselves, we make something of reality.[6] This is doubtless true when we make art, but it is no less the case when we do science; it is *not* a neurological epiphenomenon when we come up with the right interpretation or a correct theory: it is *us* doing it.

There is something empathetic about perception[7] and therefore about the way in which scientists come to understanding. We appreciate the beauty of the world and are moved by it – we take the knowledge into ourselves and build an internal representation that structures a move to new understanding. In this process, we have some fellow-feeling for what we are studying, we have some empathy. Perhaps empathy evolved as a way for us to understand the world better – by having feelings for the world around us, we would be better able to build interior relationships to it and representations of it, to understand it, to navigate it. Clearly this would be of evolutionary advantage – we could plan better – but this would put feelings of empathy and concern in control. It might mean that finding the world beautiful (because it really is) was a good way to find out the world makes sense, is susceptible to reason.

Our desires and the recognition of beauty they reflect draw us to study the world, and then we draw the world into ourselves[8] and, as our feelings engage, we find that a new sense takes shape of the way in which the world is working, freely and coherently. We are astonished that we have such a capacity for understanding.

'I express myself in expressing the world; in my effort to decipher the sacredness of the world, I explore my own.'[9]

The personal point of view is irreducible

'The human brain does not think. It is no more than what we could not think without. A tennis racquet isn't what plays tennis even if you cannot play tennis without one.'[10]

Coupled to the assertion that a personal perspective is required for us to acquire loving knowledge of the world is the claim that that perspective is authentic, or irreducible. It isn't my left brain, or my right brain, or my cerebellum, or my pineal gland, it's me that thinks and relates to the world and makes sense of it. We have already said as much in Chapter 5, but the tendency and temptation towards what Rowan Williams calls a 'decadent Cartesianism'[11] is persistent: that is, a tendency to isolate 'thought' from other aspects of our personality in the broadest sense, and particularly from our physicality *in general*. We each have a body and a history, and belong to a community, and to *think* requires our *knowing application of ourselves*, all of ourselves. It is not just a 'mental' affair – after all, we can have a gut feeling for something.

One of the reasons we tend to try and isolate what it is to know we are thinking/be self-conscious, or what we think with, or how knowing thought/self-consciousness works, is I think because we view our mental activity as somehow free in ways our bodies are not. Our bodies are lumpen and isolated – our thoughts can range freely. Thought can seem theoretical, but our bodies are engaged in practical things. Yet, our undivided, *personal* freedom involves the theoretical and the practical at the same time: freedom is something we work towards, something we make in community, something that is about our aim, and about not feeling restrained. 'Practical reason is the medium through which we experience freedom . . . is what makes freedom possible',[12] what Herbert McCabe called, following Jane Austen, *sensibility*.[13] This reminds us again how knowledge and love are dependent on one another, with neither being somehow primary and the other secondary, neither more real and the other more ghostlike. Our freedom is about choices we make, and the choices we make shape the freedom of the people we become, consciously and unconsciously.

A lot of what we do is unconscious, and one of the challenges for those who identify self-consciousness with (subsets of) brain activity is that brain activity appears similar in all parts of the brain, and the specificity of what we are engaged in is not reflected in specific patterns of activity.[14] To return to an example of a kind we have already mentioned, if you are reading, then the 'reading' bits of your brain become more active – but what is the difference between reading a shopping list, *Middlemarch* or a poem by W.H. Auden or George Herbert? There is a significant difference between all of these texts, but it is not found in brain activity. The functioning of the brain to generate consciousness is mainly about awareness of the world, is fundamentally decentred and decentring – consciousness is not mainly an internal mechanism, inward-looking, but an external alertness to an environment that we can name and change. Self-consciousness, knowing we are thinking, being conscious of our thoughts is, I suggest, a relatively uninteresting aspect of the phenomenon. What is more interesting is the unself-conscious awareness that we experience when we are doing something that really matters to us, whether it's making a loaf of bread, making the bed or making love. The fundamental importance of a decentred awareness for us to function as human beings, in science as in

love, will ultimately be the focus of the final part of this chapter. But it leaves our mental activity irreducibly distributed, complex *and* simple, unified *and* divided. For Raymond Tallis, this is a mystery greater even than that of the Holy Trinity beloved of theologians.[15]

Part of our making sense of self-consciousness comes from our memories, which too present a challenge for a dissecting attitude to human personality. We know the difference between past and future, between what we have done and what we plan to do – but our brains do not. The only reality is *now*; there is no nostalgia or hope in the physical world, no awareness of what has been or expectation of what will be, there is no sense of possibility, and there are no tenses. Our brains show the same pattern of activity when we are engaged in something – watching a television show, for example – and recalling having done it.[16] But the situations are fundamentally different. Tallis quotes William James: 'a succession of feelings is not a feeling of succession'.[17]

To understand human personality, including human consciousness (of different kinds), we need to understand the holistic, undivided nature of our selves, with head and heart, mind and body entwined and in gear with one another. We must acknowledge the dishonesty, arrogance, solipsism and pride of our attempting to separate the objective and subjective in some fundamental way, or the physical and the mental. This is decadent Cartesianism indeed, when our rational abilities are as much the fruit of 'the embodied reality of wise, everyday living' as they are a product of the wiring of our brains.[18] All the sense we make, we make together as a product of our subjective and objective perspectives, as we bump against, embrace and help each other. 'The frail transcendence of the individual human being is woven into a dense fabric of togetherness, of human being: a world that is outside nature.'[19]

Can we make sense of this?

In the last couple of chapters, I have sought to show how our reflections in this book on the relationship between aesthetic judgement and scientific discovery indicate that, not only is there something fundamentally personal about what we are doing in the lab or the field, but that this involves a loving attitude to what we study. We heard in Chapter 8 how Josef Pieper explicitly links scientific wonder with love and the persistent cry, 'How wonderful that this exists!' In doing this, it is obvious, the scientist echoes the words of the writer of Genesis 1, where we are persistently told that God sees that creation is good – in other words, it is lovely. It seems to me that a valid way to summarise the scientist's attitude is therefore that scientists are 'loving the beautiful for its goodness' when they study what they do. They are engaged in a double affirmation, a simultaneous judgement of the soul: this is beautiful, and this is good: it makes sense, it is harmonious, it hangs together, it balances, it fits, it is beautiful, it is good.

There is a problem here that should be obvious, and that echoes a similar problem that Alvin Plantinga, among others, has made a cornerstone of his

evolutionary argument against naturalism.[20] The problem is one that we have identified repeatedly in our argument, and it is that loving beautiful things and finding them good is a subjective act, whereas science is an objective product. How can we justify this move from subjectivity to objectivity?

The short answer is that we can't, at least not in scientific terms. There are three (or four) ways we could react. The fourth is that we could say that there just isn't a problem here, there is still, we could say, something *really different* going on when we do science compared with all the epiphenomena that go with it and that are associated with being a human being (epiphenomena such as having affairs with colleagues, stabbing people in the back, developing a monstrous ego, becoming fundamentally selfish, and finding our work pleasing and our results beautiful). This is an option, but I want to argue that finding things beautiful is different from the other behavioural adaptations that go with being a scientist. One difference is that finding our work beautiful appears to be a universal experience among scientists, whereas many scientists do not have affairs with colleagues, stab people in the back, develop a monstrous ego or become particularly selfish. Some scientists are and remain lovely people. A second difference is that finding things beautiful, loving the beautiful for its goodness, is obviously what one might call a positive attitude, whereas the other things I mentioned are arguably negative. The perpetrator might not think them negative, but their victims do.

Another way to argue that the apparent tie-up between human aesthetic judgement and scientific activity is a non-problem is to say that this is just what we might expect. After all, we are evolved creatures, aren't we? And, indeed, we are – as I have asserted many times – but this still does not provide the kind of explanation that we might ask for and that philosophers might demand. It doesn't provide an explanation because the argument it is making is circular – we evolved, and so evolution must be able to explain all our capabilities – and also because it ignores that blatant disjunction between what we find beautiful, as scientists, now, and what we could have evolved to find beautiful because it helped us reproduce or find food or navigate across an ocean. Yes, like everything else about human beings, our capacity to find things gorgeous evolved, of course it did, but that cannot explain why we find *particular* things beautiful. We spent some time considering this point in Chapter 5.

The three other options begin with the simplest and perhaps most likely to be adopted: we can shrug. This isn't a question we can answer, or this is just one of those things we can't explain, or it doesn't really matter, I mean, it's nice, and I like studying this stuff, but I wouldn't read anything more into it. Cautious, wise even, thoughtful, gentle, good-humoured: a sensible approach.

The second option is that we could demand an explanation but be clear that it cannot be theistic, because God does not or even cannot exist – the idea of God is a logical impossibility or a moral outrage. This is a principled approach, and it is no less to be respected than the shrug – both are respectable answers. This is the approach of Thomas Nagel to the questions he is most concerned with: how can we know factual things about the world? How can we know

moral truths? How can we be conscious? His own answer is that the universe itself is teleological, is working towards a goal, and we have been formed under the influence of that goal-directed movement.[21] Raymond Tallis also takes this kind of a stance and looks for solutions, not in an Aristotelian teleology as Nagel does, but in an affirmation of the uniqueness of human beings and their society. His argument is beautiful in itself.

But, I want here to consider a third option, a theistic option of a particular kind. Plantinga and Ralph Walker[22] (for example) provide theistic answers to their questions about factual knowledge of the universe. Angus Ritchie provides a theistic answer to his question about our knowledge of moral value. I want to suggest a theistic answer to the question of why the pursuit of the beautiful in a scientific mode draws us to discover the truth: why loving the beautiful for its goodness gives us a window on objectivity. My argument is grounded on the idea that we are made in the image of God.

The beauty of the world and the image of God

The first chapter of the Book of Genesis asserts that we were not the first to find the world beautiful or good. It also states that God's creation of humanity, male and female, is the creation of something in his image and after his likeness.[23] For Christianity, the image of God that is humanity gains its fulfilment in the life of Jesus Christ. This was an early belief of the Church, far earlier than the year 100 – early enough that St Paul could, during the 50s AD, quote an extraordinary hymn in praise of Christ in exactly these terms.[24] What do we mean by the image of God, and how does that relate to the argument made in this book?

I want to consider the assertion that we are made in the image of God with respect, first, to our capacity to self-reflect and our intelligence; second, with respect to the trinitarian nature of human beings that echoes God's Holy Trinity; third, with respect to human knowledge of good and evil; fourth, in the respect that we have received our being from God and are journeying towards him as our end; and finally – because this *is* our end – relationally and grounded in love.

Intelligence in the image of God

The Hebrew Scriptures, through their depiction of God's ordering of the world, and the wisdom components of them as a particular strand of thinking, suggest an understanding of God that would find resonance with or relationship to human intelligence. From a Christian perspective, this understanding might emphasise Jesus as the incarnation of God's Wisdom and God's Word: God's Logos, the structuring and ordering principle of creation.[25] For this understanding of humanity as in God's image, our capacity to understand the world scientifically is grounded in its foundation by an intelligence not totally without relationship to our own: that 'things exist with intelligible form

because intelligence is what actively structures them'.[26] When we then use language about the world, and founded on that language make sense of it to each other, we are building our sense-making out of the sense written into the order of existence: a sense or intelligence not totally without relationship to our own. 'For the bare fact is that the material world speaks. It is . . . material agents who speak, and this speech is not . . . a chance decorative addition to mechanical process, but an activity that is implicated in the entire complex of finite agency'.[27]

Coupled with this understanding of humanity, where the way in which language structures our thinking gives us a way of understanding something of the logic in and with which God created the world, is our capacity to self-reflect. Human beings are reflexive: they can point to themselves and think about the ordering of their thoughts. As we have said, they are self-conscious. For Raymond Tallis, the capacity to point to ourselves – the capacity to physically self-indicate – grounds our capacity to know we are conscious and thereby to differentiate ourselves from others. This seems to me to be a perfectly plausible and rather attractive hypothesis: that the key advance that made us know we are conscious was an 'upright position that liberated the hand so that it could turn our animal – primate – consciousness upon itself'. The human hand, with its opposable thumbs, made 'the hominid ancestor' of humanity 'uniquely aware of its own actively engaged body'.[28] It might be that self-knowledge, the reflexive seat of intelligence, is a key sense in which we are made in the image of God. For Jews and for Christians, the capacity to point to oneself in some sense defines God. YHWH says to Moses, 'I am that I am' (or even 'I will be what I will be'), and Jesus's most striking claim to divinity is perhaps, in the Gospel of John, his use of 'I Am', in the Greek Old Testament '*Ego Eimi*',[29] the divine self-reference, as a reference to himself.

The idea that God's logic, given to us, gives us access to knowledge for ourselves is, of course, a venerable and long-standing one, argued among others by Aquinas and, in the twentieth century, by the Roman Catholic theologian Hans Urs von Balthasar. Balthasar made logic one of the keywords of his theology, with such a divine logic at the heart of the ordering of creation and fundamentally of the act of creation itself. As 'things, when understood, become more fully themselves',[30] it is implied that to know things fully *is* to create them, that God's knowledge is generative; and then, the sharing of the capacity for knowledge with us gives us the ability to understand what God has done. We see logic, intelligence and knowledge imaging God in us in the applications of science. Because we understand, we can change the world in itself and make new things in it and of it. As mentioned in Chapters 1 and 2, a current scientific goal is the construction of *synthetic* biology. Our capacity to create – not from nothing, like God, but from the something he has given us – is a kind of imaging in us of God's own power.

However, there is a difference in the way we use words, and construct logic, and the way in which God must. Both for us humans and for God, 'true knowledge is never without an element of love' (and, as God's love is perfect,

so is his knowledge), but love is not logical, it is free.[31] Nevertheless, our knowledge – like our freedom and our love – is expressed in language that, as we have discussed (Chapter 7), is fundamentally capable of deceit, and hence our logic cannot itself or alone bring us as close as we might get to understanding the way in which we image God. Love, however, might.[32]

Lover, Loved, Love

As Rowan Williams says in discussing Augustine of Hippo's understanding of God in terms of human personality, human beings remember, they understand, and they have a will, they love – to do these things is to possess what we call a mind. Thinking of human personality in this way helps us understand what it means to describe God as Father, Son and Holy Spirit. So, our minds image God, not because of some kind of logical structure, but because of a common set of relationships or movements, relationships and movements in our minds that constitute our personality and that make us who we are.[33]

Our understanding of God as a Holy Trinity of Father, Son and Holy Spirit (Lover, Loved and Love, or, remembering, understanding and love) is another way in which we can try and grasp what it means to say that human beings are made in God's image. Human personality, like human language, is triadic, has a trinitarian form. The Orthodox theologian John Zizioulas wrote a book entitled *Being as Communion*[34] in which he discusses the fundamentally relational structure of personhood. Human beings are most themselves, can only become themselves, through communion with each other – and they move towards communion with God. 'The human person grows more, matures more and is sanctified more to the extent that he or she enters into relationships, going out from themselves to live in communion with others and with all creatures.'[35] Raymond Tallis would agree: it is our communion with each other, our fundamental relationality, that makes us *people*. God is, as Trinitarian theology asserts, a communion of persons, a constantly active set of interrelationships: Lover, Loved and Love. In every act of God, all three 'persons' are present and active, and humans image this being. Confusion about the Trinity derives from using the word 'person' of Father, Son or Holy Spirit in a way too similar to our use of it for another human being; rather like confusion about the purpose and meaning of Genesis Chapters 1 and 2 deriving from a category error in which we treat them like a scientific text. All we as humans can do is respond to what God has shown us of himself, and for Christians that is most emphatically demonstrated in the crucifixion of Jesus Christ. It is because of the relationships involved in what happens on the cross that we understand God as relational, and as a Holy Trinity of relations. On the cross, 'there is a son crying out to a Father whom he has lost . . . and so there is implied a Father who suffers the loss of a son, with a Spirit of abandonment between them'.[36] Seeking to express what has happened, all we can do is say that in God there is constantly 'the movement of a forsaken son towards a father, and a desolate

father to a lost son'.[37] And moving between them, a spirit of mutual self-abandonment. We then image God because, 'for all our limitations, gestures of generosity, solidarity and care cannot but well up within us, since we were made for love'.[38]

So, we end this section realising, again, that, although our minds work in a triadic way, like our language does, it is our capacity to love that really defines our likeness to God.

The knowledge of good and evil

In Genesis Chapter 3, Adam and Eve fall, they eat the fruit of the tree of the knowledge and good and evil, and they fall. Why, according to the serpent, did God forbid them to do this? Because 'God knows that when you eat of it your eyes will be opened, and you will be like God, knowing good and evil'.[39] Is this, then, what it is to be in the image of God, to know right from wrong, to have a morality?

There is a sense in which, yes, our knowledge of right and wrong images the God who underwrites the existence of right and wrong in the first place (see Chapter 7). God creates us free, with the freedom to make choices, and those choices can be for good or evil, and can be creative or destructive. This is an analogy of freedom, freedom in us that images the total freedom of God.[40] God places in our hands, we have the power with our minds, to act freely, with all the risk that that entails and all the choice in terms of morality. But, is the image itself this capacity? In other words, does the image of God in humankind guide us towards choices that are for the good, the beautiful and the true?

The evidence is pretty damning that it does not. If humans beings have a divine image in them, it does not seem to be inherent to our capacity to choose, as the destructiveness, cruelty, thoughtlessness and indifference of people towards one another rather shows. The direction of our choices seems to need another guide or basis, something else that helps us to follow a way of virtue, and this does seem to be our ability to be more concerned for the good of others than for ourselves, to look outwards from ourselves with concern.[41] Holiness, the expression of the image of God in us, is not something we possess or achieve, but an action of self-abandonment for the good of others. This is something we need to learn – it is about *habitus*, a praxis of goodness – and that we need to apply rationally and with objective intent. It is 'wise, everyday living' that leads us to understand and to be good.[42]

What wise, everyday living leads us to is a progressive abandonment of ourselves as the expression of our freedom. Love is what freedom was meant to be,[43] and to realise – as Annie Dillard puts it – that you must not need life[44] is to experience life in its fullness. It is to overcome the strong man that is our 'selves' in the full realisation *of* ourselves.[45]

So, the sense in which our morality images God is found in our love for one another, which trains our moral sense towards understanding.

Becoming more in God's image day by day

God has made us, and we are journeying back towards God; he has formed us and given us freedom to grow into his likeness. This is another meaning of our imaging God: that by following the example of Christ we are given the ability to develop that image by our own choices. So, we image God in some sense now, but are called to develop the image in ourselves by our choices that lead to greater wisdom and understanding. This is a belief of Christianity – we are called to embrace the life of Christ, to make it the pattern for our life, to grow into the full stature of Christ.[46] As we journey towards God, we acquire greater understanding and ability; becoming more Christ-like, we become more ourselves as well.[47] But, underpinning such a view of humankind as in the image of God is our *desire* for greater perfection, for a closer resemblance to Christ himself. Underpinning such a view is our will, or in other words, again, love. Such love may be 'the form of the beloved (God) existing in the will',[48] but it is the love itself that gives us a likeness to God, not our ability (knowledge) which gives us charity. 'The goal and ultimate perfection of the human soul is by knowledge and by love to transcend the entire created order and to attain the first principle, who is God.'[49]

Relational desire: The image of God is the form of love

Part of Raymond Tallis's argument in *Aping Mankind* focuses on the way in which our deliberate use of our consciousness to study the nature of reality results in a disappearance of consciousness itself. We have what he calls a 'disappearance of appearance' as we move towards more fundamental (and therefore more abstract) descriptions of the nature of things – as we hunt for Thomas Nagel's view from nowhere, we find ourselves heading towards nothing. For Tallis, this is of interest because it shows that the point of view we have, the appearances we perceive, are not fundamental to reality at all but imposed by us on it – things, of themselves, have no appearances, they only *appear* to us.

> Consciousness is, at the basic level, appearances or appearances-to, but neither nerve impulses nor the material world have appearances. So there is absolutely no basis for the assumption . . . that the intrinsically appearance-less material world will flower into appearance to a bit of that world (the brain) as a result of the particular material properties of that bit of the world.[50]

So, as we search for a fundamental understanding of reality and, by necessity towards the disappearance of appearance, we leave aside consciousness – there is no consciousness at the quantum level, and consciousness cannot, he argues, be explained by a system from which it is excluded. In a sense, the point is also simply made by the fact you cannot analyse rationally the basis of your rationality. In language I once used: if human personality is like the internal

experience of a riot, if the mind is a riotous phenomenon,[51] you cannot get a perspective on what makes the mind work the way it does because you cannot get 'outside' the mind to see what its appearance is.

For our purposes here, Tallis's argument is of particular relevance because it highlights the way in which we can, and do, 'lose consciousness' when we study the world. When I am engrossed in my work, I do not notice the passage of time, I do not have a sense of self-reference. As we have said, our study of the world involves our love of it – and, when we are in love, that is all we are doing, we are not being particularly conscious of ourselves, but instead are focused on the one we love. Indeed, we are *most ourselves* when we *forget about ourselves*: human beings who are intensely present, engaged in the moment, are being most them*selves*. We are most alive when we don't know it: a musician is most themself when caught up in their music-making, a scientist is most themself when absorbed in their research, a friend is most themself when focused on the one they care about. You are most yourself when you forget what you are doing and just get on with it. This is something Jesus picked up on: to gain your life, you must be willing to lose it, pouring yourself into the task in hand. A shepherd is most themself when they go searching for the one sheep that is lost.

Jesus used the example of a shepherd searching for a single lost sheep as a way of talking about what he called the kingdom of God or kingdom of heaven. I want to suggest – as has been trailed above – that we image God most profoundly in the forgetfulness of our concern, in the unselfconsciousness of our desire, in the absence of what we call mind.[52] To be in the image of God means to be transfixed with wonder. And, as we forget more about ourselves, our science becomes all the more excellent. Our love of others and our love of creation is what images God in us: the way we go out from ourselves, and lose our minds. But given that love is – as we say – essential to the acquisition of truthful knowledge, we have what some people would think a paradox. On the one hand, in loving we are closest to God; on the other, love lets us see the basic, massy individuality (the ordinariness) of what we love because it gives us knowledge. In loving, we love with God; but, in loving, we love without what popular imagination associates with religion; in loving, we love without awareness of anything else than the loved thing, even without awareness of God, and in doing that we come the closest we can to God – as someone has said, to God without being.[53] This forgetfulness of ourselves is God's great gift to us of his image.[54] We can love because God loved us first;[55] our echoing of God's love for creation in our own love of it reveals his image in us. In our scientific discussions, we lose ourselves in our words – we give ourselves over to exchange. The radically unfinished and unfinishable nature of language and desire directs us towards a Word that justifies words and a Love that grounds our will.[56] This turning to God helps us justify the patent sense we can make of the world and uncovers the divine image in us.[57]

The more we forget ourselves, the more we become ourselves; and the more we become ourselves, the better we image God. This is risky – in another

reflection on the way full humanity is realised by a lack of self-reference, Jesus said we must take up our cross and follow him – running the risk of losing everything. And, indeed:

> the intolerable truth [is] that the God of Christianity is friend, lover and fellow accused, not judge, patriarch and superego. He is counsel for the defence, not for the prosecution. . . . For Christian faith, the death of God is not a question of his disappearance. On the contrary, it is one of the places where he is most fully present.[58]

We are called on to befriend God, and so grow our likeness to him.[59] We are also called on to befriend each other: being human is communal, as Raymond Tallis would agree, and it is in giving ourselves to each other that we will realise our full being and become the people we should be. It's so ironic: arguments about self-consciousness and selfhood are stuck when they are focused on the contents of the human skull, but gain meaning and sense when we realise that men, women and children *realise* themselves, *make* themselves alive, when they engage in other-consciousness (such consciousness isn't something we possess: it's a process we deliberately take part in) by abandoning the fantasy of autonomy and the individual and embracing a common way of life, as Christians say, 'in Christ'.[60] Other-consciousness, not self-consciousness, is the awareness that matters most.

In her book *Pilgrim at Tinker Creek*, Annie Dillard writes of the need for us to lose ourselves to see reality, and to abandon self-consciousness to fulfil our human nature. In one governing experience she is transfixed by a tree full of light and comes to realise that it's not that she saw something special, but that something special was shown to her – the door to see it, as she puts it, is opened *from eternity*.[61] When we see the world for what it is, and make sense of it, that too is a door being opened to us from eternity. Our 'possession', our self-proclaimed 'ownership' of self-consciousness is something that separates us both from God and our fellow creatures, and is what Dillard calls 'a bitter birthday present from evolution, cutting us off at both ends'. In fact, self-consciousness disables us and removes our ability really to see things.[62] Aquinas said that God is pure act (an absence of mind if ever there was one) – and we are called to try and become more purely acting ourselves.

> There is always an enormous temptation in all of life to diddle around making itsy-bitsy friends and meals and journeys for itsy-bitsy years on end. It is so self-conscious, so apparently moral, simply to step aside from the gaps where the creeks and winds pour down, saying, I never merited this grace, quite rightly, and then to sulk along the rest of your days on the edge of rage. I won't have it. The world is wilder than that in all directions, more dangerous and bitter, more extravagant and bright. We are making hay when we should be making whoopee; we are raising tomatoes when we should be raising Cain, or Lazarus.[63]

In this book, I have sought from a very personal perspective to share an argument that has been taking shape in my mind for 25 years, since I was at school. It has been profoundly influenced by my scientific work and interest, alongside my religious commitment and my desire to understand why Christians believe what we do that I have been fortunate to be able to explore in wider reading. But, the argument is far, far older than me and in a way reaches back to the beginning of science, because from the beginning scientists have invoked the aesthetic, an appreciation of beauty, as a tool for understanding the way things really are. Pope Francis quotes Thomas Aquinas, who was writing on the eighth book of Aristotle's *Physics*:

> Nature is nothing other than a certain kind of art, namely God's art, impressed upon things, whereby those things are moved to a determinate end. It is as if a shipbuilder were able to give timbers the wherewithal to move themselves to take the form of a ship.[64]

When we see the beauty of the world, we see God's art for itself and, when we understand that beauty for what it is via a process of self-denial in the loving attention of the researcher, focused on a corner of reality we have noticed, we grow more into the image of God, which justifies our understanding. It is the simplest explanation for the capacity of human feeling to open up for us the objective understanding of reality: that reality was created with kindred feeling and with resounding joy.

Notes

1 Pope Francis, *Laudato Si'*, p. 12.
2 Tallis, *Aping Mankind*, p. 332.
3 Tallis, *Aping Mankind*, p. 334.
4 'To naturalize religion is to naturalize even those parts of humanity that are most remote from the natural world. It is the supreme expression of a devastating reductionism that disgusts even an atheist like me', Tallis, *Aping Mankind*, p. 336. The same goes for science. See also Pope Francis, *Laudato Si'*, p. 81.
5 Massey, *The Neural Imagination*, p. 19.
6 Turner, *On Aquinas*, p. 89.
7 Turner, *On Aquinas*, pp. 57–8.
8 Williams, *On Augustine*, p. 157.
9 Pope Francis, *Laudato Si'*, p. 86, quoting Paul Ricouer.
10 Turner, *On Aquinas*, p. 83.
11 Williams, *The Edge of Words*, p. 107.
12 Sherwin, *By Knowledge and by Love*, pp. 213–17.
13 McCabe, *God Still Matters*, pp. 139–51. See also Tallis, *Aping Mankind*, pp. 265–75 – at any moment, humans need to 'am' themselves, taking responsibility and initiative, to realise self-consciousness.
14 Tallis, *Aping Mankind*, pp. 100–2.
15 Tallis, *Aping Mankind*, pp. 112–23.
16 Tallis, *Aping Mankind*, pp. 124–9, 132–3.
17 Tallis, *Aping Mankind*, p. 130.

18 Young, *God's Presence*, p. 187.
19 Tallis, *Aping Mankind*, p. 238; see also p. 157 and Massey, *The Neural Imagination*, pp. 98–9, and Williams, *The Edge of Words*, pp. 118–19, particularly with respect to the fundamental role of metaphor in the getting of 'objective' knowledge.
20 Plantinga, *Where the Conflict Really Lies*, see Chapter 7.
21 Nagel, *Mind and Cosmos* (and on the need for an atheistic explanation, pp. 25–6), and, earlier, *The View from Nowhere*, see Chapter 6.
22 Walker, *The Coherence Theory of Truth*, pp. 222–5.
23 Genesis 1:26.
24 Colossians 1:15–20.
25 John 1:1–14. See, for example, Young, *God's Presence*, pp. 158–66.
26 Williams, *The Edge of Words*, p. 120.
27 Williams, *The Edge of Words*, p. 123.
28 Tallis, *Aping Mankind*, p. 215. Tallis points out (n. 27, p. 226) that the hominid remains nicknamed Lucy indicate an upright posture and so that this postural innovation predated the human brain by about 3 million years.
29 Exodus 3:13–15.
30 Aidan Nichols, *A Key to Balthasar* (Darton, Longman & Todd, 2011), p. 94. See pp. 90–5.
31 Nichols, *A Key to Balthasar*, p. 95, while Balthasar viewed logic itself as inherently triadic (p. 101).
32 Nichols, *A Key to Balthasar*, pp. 97–8. See also Williams, *The Edge of Words*, pp. 93–4.
33 Williams, *On Augustine*, pp. 135–7.
34 St Vladimir's Seminary Press, 1985.
35 Pope Francis, *Laudato Si'*, 240.
36 Paul Fiddes, *The Creative Suffering of God* (Oxford University Press, 1992), p. 123.
37 Fiddes, *The Creative Suffering of God*, p. 141.
38 Pope Francis, *Laudato Si'*, 58.
39 Genesis 3:5.
40 Nichols, *A Key to Balthasar*, p. 66.
41 Young, *God's Presence*, p. 181.
42 Young, *God's Presence*, pp. 186–7.
43 Nicholas, *A Key to Balthasar*, p. 69
44 Dillard, *A Pilgrim at Tinker Creek*, p. 275.
45 Mark 3:27; Radcliffe, *Take the Plunge*, p. 172.
46 Ephesians 4:13.
47 Sherwin, *By Knowledge and by Love*, pp. 25–7.
48 Sherwin, *By Knowledge and by Love*, p. 196.
49 Sherwin, *By Knowledge and by Love*, p. 203, quoting Thomas Aquinas, *Summa contra gentiles* II 87.6. See also pp. 234–9.
50 Tallis, *Aping Mankind*, pp. 142–5.
51 Gilbert, 'Riot of the mind', *New Blackfriars Review*.
52 Marilynne Robinson, *Absence of Mind* (Yale, 2010).
53 The title of Jean-Luc Marion's book, cited elsewhere.
54 Turner, *On Aquinas*, p. 207; Sherwin, *By Knowledge and by Love*, pp. 54–9, 79–81.
55 1 John 4:7–11.
56 Williams, *On Augustine*, pp. 54–67. See p. 195: 'The image of God in human beings is thus the human being turned towards God, having God as object.' The more we forget ourselves, the more we become ourselves.

57 Young, *God's Presence*, pp. 138–9, 173–5.
58 Eagleton, *Culture and the Death of God*, p. 160.
59 Sherwin, *By Knowledge and by Love*, pp. 147–8 and ff. Thomas Aquinas says: 'Charity is a certain friendship of the human person toward God' (*ST* II-II 23.1).
60 Young, *God's Presence*, pp. 179–83.
61 Dillard, *Pilgrim at Tinker Creek*, p. 82.
62 Dillard, *Pilgrim at Tinker Creek*, pp. 80–2.
63 Dillard, *Pilgrim at Tinker Creek*, p. 274.
64 Pope Francis, *Laudato Si'*, 80.

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