'Nothing by mere authority'

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> *And certainly … any custom, however long established and widespread, must stand second to truth, and practice that is contrary to truth must be abolished* (Pope Gregory VII, ca 1020-1085, the 11th century's greatest reform pope).

Even if we no longer find ourselves at the centre of the universe, we remain nevertheless a most singular species. This brief outline of the story of the head-on clash between science and religion over the past thousand years will, I think, bear witness to this. The title 'Nothing by mere authority', motto of the Royal Society of London, is at the heart of the exploration. We open and close with quotations from two revered religious figures of their respective eras: Pope Gregory VII and the Dalai Lama. Each, from the very different perspective of their time, is saying much the same thing (though probably thinking something quite dissimilar). In the centuries separating them the world changed more than one might possibly have imagined. And it is science that has propelled that change.

We focus on 20 nodes in the history of this astonishing pursuit we call science. Each represents a seminal leap in the understanding of our world and universe. More nodes could be added, but they would not alter the essential story told by these towering beacons punctuating our journey through the second millennium. Epicentral to our theme stands Charles Robert Darwin and his *Origin of species* (1859). His book elucidating evolution forms a watershed between two states of the collective human mind: before Darwin the leading scientists still bowed before God and church; after Darwin they soon abandoned such deference. Each of the 20 nodes opens with the nature of the scientific breakthrough and concludes with an expression of the religious sentiment of the time, mostly quoting the words of the scientists themselves. The aim is to capture a true sense of the intertwining histories of science and religion.

These pages are dedicated to Darwin, with this conference volume appearing in the bicentenary year (2009) of his birth and 150 years after the publication of his *Origin of species*.

1000: Arabic science and philosophy

Alhazen (Ibn Al-Haytham) (ca 965-1038): Arabian; the greatest of medieval physicists

For the first couple of centuries into the second millennium science and philosophy shone brightest in the Muslim world. It was they who carried the baton that was passed on by the Greeks and Romans. Born in Basra (in present-day Iraq) and died in Cairo, Alhazen emerged as the greatest physicist of the Middle Ages. His especial interest was optics, which in 16th century Latin translation had an important influence on Kepler (1571-1630), until whose time it was not superseded. His most influential

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contemporary, **Avicenna** (Abu-Ali Al-Husain) (980-1037), was a Persian physician with no less than 100 books attributed to him, the most important of which were on medicine and based on the Greek physicians Hippocrates (460-370 BCE) and Galen (ca 130-ca 200 CE). These were translated into Latin in the 12th century and became Europe's leading textbooks in the field until Harvey (1578-1657) discovered blood circulation in 1628. **Averroes** (Abu-Al-Walid Muhammad Ibn Ahmad Ibn Rushd) (1126-1198), who was born in Spain and died in Morocco, "was at once the peak and the end of Arabic philosophy, for the gathering woes of Muslim disunity were coming to a head" (Asimov 1964). His great influence rests on his commentaries on Aristotle, which were read and amplified in Christian Europe through Latin translations, reaching a climax in Thomas Aquinas (see below).

As Bertrand Russell captured so starkly in his *History of Western philosophy* (1945): "The year 1000 may be conveniently taken as marking the end of the lowest depth to which the civilization of Western Europe sank … No one could have guessed that Western Europe would later become dominant both in power and in culture." Visualise the scene at the basilica of St Peter's in Rome at midnight as the turn of the millennium approached. Pope Sylvester II (r. 999-1003) presided, celebrating midnight mass. The trembling worshippers "in sackcloth and ashes, having spent the last weeks and months doing penance and mortifying the flesh", lay prostrate on the marble floor, their arms spread out in the shape of a cross. Many "had given away all their possessions to the poor − lands, homes, household goods − in order to assure for themselves forgiveness for their trespasses at the Last Judgement and a good place in heaven near the footstool of the Almighty". As the church bells across the papal city began to toll the hour of midnight, the nobility, priests and peasants of Christendom awaited the end of the world (Erdoes 1989). It did not come. In its place came the 2nd millennium that was to see the extraordinary exponential ascendancy of science.

Should one try to paint a picture of Europe through the first half of this 2nd millennium, it would depict the monolithic Catholic Church and the monarchy (mostly absolute) playing out a perpetual power struggle between them. A succession of popes (Sylvester II, Gregory VII, Urban II, Innocent III, Boniface VIII, Alexander VI), abbots (Hugh, Suger) and saints-in-waiting (Bernard, Becket, Dominic, Francis, Aquinas, Joan of Arc) strode like colossi across the European cultural landscape. Romanesque and Gothic cathedrals, churches, abbeys and monasteries sprang up everywhere in extraordinary profusion and with them evolved Western art and music − mostly dedicated expressions of Christianity. The Roman Catholic Church filtered through to every nook and cranny of the European mind. Anticipation of heaven or hell hovered everywhere for everyone. Nature was long forgotten.

1202: Arabic numerals

Leonardo Fibonacci (ca 1170-1230): Italian mathematician; introduced Arabic numerals into Europe

Science is to a large degree driven by measurement and numbers. The profound historical significance, therefore, of introducing the Arabic system of numerals (adopted in turn from the Hindus) into Europe can be readily appreciated. It was Fibonacci's *Liber Abaci* (Book of the abacus), published in 1202, that transferred the simple and effective run of numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 0 to Europe. It displaced the cumbersome notation using letters of the alphabet that had previously been adopted from the Greeks and Romans. The Italian was indeed the major contributor in the field of number theory prior to the 17th century. The Fibonacci Series (0, 1, 1, 2, 3, 5, 8, 12, 20, etc), expressed so ubiquitously throughout the natural world (in the spiral of a nautilus shell or the scales of a pinecone), was his. Fibonacci lived in Pisa, a major mercantile centre with close commercial ties with Muhammadan North Africa.

He was to travel widely along the Mediterranean belt of the continent and thus had ample opportunity to absorb Arabic mathematics.

Consideration of two enduringly famous Italian saints, **St Francis of Assisi** (ca 1182-1226) and **St Thomas Aquinas** (1225-1274) offers a flavour of the omnipotent power and reach of the Catholic Church in medieval Europe. Aside from their devotion to God and Catholicism, they were in many senses opposites. St Francis believed, and taught his friars, that the rules and practices of his order were divinely inspired – any deviation from them was naturally an offence against God. The Franciscan decrees included: the practice of complete poverty; the denial of property, dwelling or church; the eschewal of books and learning; begging for bread and dependence on chance hospitality; chastity; devotion to preaching, missionary zeal and good works. St Francis travelled widely, sent his brothers to distant lands and enjoyed enormous success in spreading his Franciscan brotherhood. His response to any deviation from his cherished rules was unwavering: "It is by your learning you will come to confusion. Whether you will or not, you shall taste regret and I am certain that God will punish you"; and further, "Let the brothers take great care not to receive churches, habitations, and all that man build for them."

St Thomas enjoyed at least equal success. To this day his philosophic system remains the basis of Catholic teaching. His towering intellect was devoted to achieving a synthesis of Faith (Catholic theology) and Reason (Aristotelian philosophy and science). In this he was at odds with St Francis, who had no use for reason. After studying under **Albertus Magnus** (1193-1280) – the German scholar who brought the new learning based on Arabic translations north to Paris in the 1240s – Aquinas taught in various institutions across France and Italy. It was his series of commentaries on **Aristotle** (ca 384-322 BC), whose encyclopaedic output ranged across all fields, that initially brought Aquinas fame. His triumph in spreading Aristotelian thought, translated into a medieval worldview, was dazzling. In the last decade of his life he wrote the overarching work, *Summa Theologiae* (1265-74), which included his five proofs of God's existence. These focussed on God as the fountainhead of movement, cause, physicality, degree and design.

1454: The printing press

Johann Gutenberg (1398-1468): German inventor; his press was the mother of all revolutions

Little is known of Gutenberg's youth and he died in debt, an apparent failure; but his development of an efficient printing process in 1454 was arguably the single most influential event in Western history. It was his re-invention of moveable type, using the Western alphabet, that did it. Simple, like the wheel, but shatteringly effective! By the year 1500 up to nine million printed copies of 30 000 different works were in circulation. Printing made books cheap, which made literacy worthwhile. No longer were reading and writing the exclusive preserve of mendicant monk and artless aristocrat.

Victor Hugo (1802-85), the leading French Romantic writer, described the overwhelming reach of the printing press as well as anyone. In his novel *The hunchback of Notre Dame* (1831), of all places, he wrote, "The invention of the printing press is the greatest event in history. It was the mother of revolutions … Thought itself was everywhere being set free … Prior to the press, the Reformation would have been only a schism, the press turned it into a revolution … Gutenberg was the precursor of Luther … until Gutenberg, architecture was the chief, the universal form of writing. It was the Middle Ages which wrote the final page in the book of granite … The human mind discovered a means of perpetuating itself which was not only more lasting and resistant than architecture but also simpler and easier. Architecture was dethroned … The book was to kill the building."

The printing press did in fact spell the end of medieval Europe; it rang the death knell on the Gothic cathedrals. It was indeed the mother of all revolutions! First came the Age of Exploration (Columbus 1492); then a new architectural age (Alberti 1485); the Humanist revolution (Erasmus 1509); political science (Machiavelli 1513); the Reformation (Luther 1517); and the Scientific Revolution (Copernicus & Vesalius 1543). Then followed the Industrial Revolution (Watt 1769), the medical revolution (Pasteur 1867) and the electronic revolution (Faraday 1831 and Maxwell 1873).

The church (and the monarchy) quaked.

1543: The scientific revolution

Nicolas Copernicus (1473-1543): Polish astronomer; shifted the Earth from the centre of the universe

A remarkable coincidence marks the birth of the scientific revolution in 1543. Two works, not just one, of the most profound significance appeared in that same year: *De Revolutionibus Orbium Coelestium* (*On the revolution of the celestial spheres*) by Copernicus, the Polish astronomer; and *De Corporis Humani Fabrica* (*On the structure of the human body*) by **Andreas Vesalius** (1514-1564), the Flemish anatomist. All the more extraordinary is that Copernicus was 70 years of age and on his deathbed when his volume appeared, whilst Vesalius was just 29 and near the start of his career. In *Revolutionibus* Copernicus introduced his heliocentric universe, dislodging the earth from the centre of the cosmos − a heretical theory bound to agitate and traumatise the church. In his *Fabrica* Vesalius produced the first accurate (and beautifully illustrated) book on human anatomy, based on human, not animal, cadavers and dissection, thus beginning a tradition of first-hand observation.

Martin Luther (1483-1546), a very close contemporary of Copernicus, stood firmly guarding the portals of religion. It is ironical that on the one hand he initiated the revolt against the Catholic Church, yet on the other he robustly opposed the scientific revolution. “The fool will turn the whole of astronomy upside down,” Luther said of Copernicus. He repeatedly lashed out at reason (Dawkins 2006), which he rightly saw as the archenemy of religion: “Reason is the greatest enemy that faith has; it never comes to the aid of spiritual things, but more frequently than not struggles against the divine Word, treating with contempt all that emanates from God.” In other words, “Whoever wants to be a Christian should tear the eyes out of his reason.” Or again, “Reason should be destroyed in all Christians.”

Two Greek scientists of the first two centuries of the Common Era had held the centre ground of Christian church dogma till 1543. The first was **Claudius Ptolemy** (ca 75-? CE), astronomer, mathematician and geographer. His book, the *Almagest* as it became known through the Arabs after the fall of the Roman Empire, became the basis for the study of all astronomy till Copernicus in the Renaissance. The Ptolemaic system held that the earth was at the centre of the universe and that the planets, the moon and sun included, revolved around it. The second of these pervasive authorities was the physician **Galen** (ca 131-200 CE). His anatomy, based on the dissection not of humans, but of dogs, goats, pigs, monkeys, “became the ultimate medical authority for Europeans until the time of Vesalius in anatomy and Harvey in physiology” (Asimov 1964). Lest anyone think the church could be shifted too readily from its chosen dogma, there was the fate of **Giordano Bruno** (1548-1600) to consider. The Italian philosopher had travelled widely, lecturing on his views of the universe and expressing scorn of traditional beliefs. In 1592 he was arrested, tried by the Inquisition and charged with heresy. In 1600 he was burned alive at the stake.

1609: The telescope

Galileo Galilei (1564-1642): Italian physicist; initiated telescopic astronomy

When Galileo turned his telescope skywards in 1609 the heavens (previously seen only with the naked eye) changed. That year saw the second great step in the scientific revolution and, as in 1543, two seminal works appeared concurrently. Firstly there were Galileo's telescopic observations of the planets, moon, sun and stars; and secondly **Johannes Kepler's** (1571-1630) mathematical calculations showing the elliptical motion of the planets. With his telescope (able to magnify to a power of 32), Galileo found mountains on the moon, spots on the sun, satellites circling Jupiter and phases characterising Venus; also that the planets appeared as small globes, whilst even the brightest stars remained mere spots. Employing the power of mathematics, Kepler dispelled the notion that the planets moved in flawless circles. The heavens were clearly not as the ancient Greeks Aristotle and Ptolemy had described them, and whose perfection had become firmly embedded as church law. The application of the scientific method (experimentation, observation, calculation) took a major leap forward. It was Galileo's masterpiece, *Dialogue of the two world systems* (1632) – completed at age 68 and taking the form of a debate between disciples of Aristotle, Ptolemy and Copernicus – that posed the untenable threat to Rome.

The Galileo-**pope Urban VIII** (1568-1644) saga is the ultimate embodiment of the head-on collision between science and the church. The lives of these two giant figures in European history were closely intertwined. They were virtually exact contemporaries, Galileo being born four years before Urban and dying two years ahead of him. Prior to the *Dialogue* (supporting Copernicus, toppling Ptolemy), Galileo and Urban (then Maffeo Barberini) had been long-time friends, colleagues and keen mutual admirers. The book was an instant success scientifically, but an instant disaster for its author. Galileo was rapidly silenced by the church for his heretical support of Copernicus. But what was so irreverent about the *Dialogue*? The Catholic Church's view of the universe was that of Ptolemy (2nd century CE): the heavens were perfect, order prevailed, all heavenly bodies were smooth, regular and moved in circles; earth occupied the centre of this universe and stood still, with the sun revolving around it. This was the divine order of things. The Copernican system (1543) with Earth dethroned and revolving around the sun was declared a heresy; Bruno was burned at the stake (1600) for espousing it; Galileo's *Dialogue* (1632) was banned and he was forced to recant (by then an old man of 69), then kept under house arrest for his last ten years.

Galileo was a deeply religious man. Despite his trial and conviction, he rejected neither church nor religion, but only the attempt of its authorities to stifle investigation of scientific matters. He has become a symbol of revolt against dogmatism and authoritarian attempts to smother freedom of thought. A calendar of events relating to the offending *Dialogue* offers a poignant sense of the evolving science-religion conflict over the past four centuries: 1623, cardinal Maffeo Barberini becomes **pope Urban VIII**; 1632, Galileo publishes his *Dialogue*; 1633, Galileo stands trial for heresy by the Inquisition and the *Dialogue* is prohibited; 1835, Galileo's *Dialogue* is dropped from the *Index of prohibited books*; 1966, *Index of prohibited books* is abolished after Vatican II; 1979, **pope John Paul II** calls for theologians, scholars and historians to re-examine Galileo's case; 1982, John Paul II sets up the Galileo Commission (with four formal study groups) to reinvestigate the Galileo affair; 1992, John Paul II publicly endorses Galileo's *Dialogue*, noting how "intelligibility, attested to by the marvellous discoveries of science and technology, leads us, in the last analysis, to that transcendent and primordial thought imprinted on all things" (Sobel 1999). It had taken the church 359 years to officially apologise for condemning Galileo's *Dialogue* …

1620: The scientific method

Sir Francis Bacon (1561-1626): English philosopher; his writings promoted the scientific method

Whereas Galileo was the creator of the scientific method in practice (experimentation, empirical observation, inductive method, laws and generalisations from observed facts), Francis Bacon, his close contemporary across in London, is given credit for laying its philosophical basis. Bacon, after studying law at Cambridge (where he developed a marked distaste for Aristotle's philosophy), became a prominent courtier under queen Elizabeth I and subsequently king James I. He wrote a number of elegant scholarly works in which he proposed the formation of a society of scientists pushing at the boundaries of knowledge through experiment, whilst eschewing traditional theory. Most important amongst these were the three books, *Advancement of learning*' (1605), *Novum Organum* (1620), and the *New Atlantis* (1626, unfinished at his death). In the *New Organon* (as it is in English) he takes issue with Aristotle's *Organon*, in which the Greek philosopher promoted the method of logic, of reasoning by deduction. Bacon proposed instead the new method of inductive reasoning. The laws of science should be induced, established as generalisations from a mass of specific observations.

In Bacon's scientific method there was no room for mysticism. The role of science was to establish the laws of nature. Isaac Asimov (1964), in his masterly biographical encyclopaedia of the scientists, says of Bacon: "[in the *Advancement of learning*] he argued against mysticism and characterized the dead hand of tradition as the true devil threatening mankind. There was no use, he said, in studying magic and trying to work through spirits. Science should concern itself with the actual world that was apparent to the senses, for its true purpose was not that of bolstering religious faith, but of improving the human condition."

1660: The Royal Society of London

Sir Christopher Wren (1632-1723): English architect; major figure at birth of the Royal Society

With its motto 'Nothing by mere authority', the Royal Society has played a critical role in the rise of science and the relative demise of the church. It was formally founded on 28 November 1660 at Gresham College, Oxford (where it continued to hold its meetings until 1703) − the year of the restoration of the British monarchy. The meeting that evening had begun with a lecture on astronomy by Christopher Wren. The Royal Society of London for the Promotion of Natural Knowledge received its charter from Charles II in 1662. It was John Evelyn, the gentleman diarist, who gave the society its motto *Nullius in Verba* (Nothing by mere authority), derived from Horace (65-68 BCE, popular Roman lyric poet and satirist). It has been suggested that Evelyn, a royalist, may have persuaded the king to back the Society; but my guess is that Wren might have been equally instrumental. The king and he had been childhood friends before the Cromwellian revolution, and after the fire of London (1666) he became surveyor general of the Royal Works. The fellows who initiated the Royal Society were deeply influenced by the vision of Sir Francis Bacon. The French soon followed with the *Academie Royale des Sciences*, formally founded in 1666 under the name of Louis XIV.

The Royal Society could not have adopted a more appropriate motto. The overriding authorities in the West till this time were, of course, God, king and country. God, in the form of the church and its penetrating reach, whether Catholic or Protestant, was still perhaps the dominant one amongst these. Regarding science and philosophy, the works of classical Greece and Rome, chiefly through Aristotle and Aquinas, were still the bedrock of church dogma. The arts, most notably painting, sculpture and architecture, were universally inspired by Christianity and the church. The skyline of London before the great fire in 1666 was that of Gothic religious architecture; after the fire it was that of Baroque religious architecture. Travel down the Thames river, whether before or after the fire, and the church took centre stage. The great fire had destroyed no less than 86 parish churches in the centre of London

as well as the old Gothic St Paul's cathedral. Consider Christopher Wren once again. He was steeped in the church at the highest levels. His father was the dean of Windsor, a position his paternal uncle, who held a series of bishoprics, had previously occupied. Wren rebuilt 51 of the parish churches plus the new St Paul's. It is he who created the Baroque skyline of London. His spires were varied and original, numbering amongst them St Martin, St Stephen, St Bride and St Mary-le-Bow. From 1661 Charles II had appointed him assistant to the royal architect and from 1669 he was named royal architect, a post he held for over 45 years. He also became surveyor to Westminster Abbey.

1674: Discovery of *animalcules*

Anton van Leeuwenhoek (1632-1723): Dutch microscopist; discovered Protozoa, spermatozoa, bacteria

For close on 50 years, from 1673 until near his death, Van Leeuwenhoek wrote voluminous letters to the Royal Society on his microscopic findings. There are 375 of these letters (plus a further 27 that he sent to the French Academy of Science). In these communications he described a whole new world of diversity unseen by the naked eye − just as the telescope had expanded our view of the macrocosm so dramatically. He was neither the earliest microscopist (Malpighi, an Italian physician, began his microscopic studies in the 1650s), nor were his instruments the most complex (Hooke used a compound microscope and his *Micrographica*, with exquisite illustrations, appeared in 1665). But his tiny single-lens microscopes, with lenses he ground himself to such perfection that he could magnify up to nearly 200 times, allowed him to see what no one else could in his century. With these instruments he made a succession of profound discoveries. First came his observations of microbes (in 1674), the single-celled animals he called 'very little animalcules' (later to be named Protozoa). This was a realm no less significant than that of the elephant and the whale. He was also the first to discover spermatozoa (in 1677) and bacteria (in 1683). It was 200 years before the great medical significance of the latter was to be discovered by Pasteur.

In a devoted tribute to Leeuwenhoek, his fellow protozoologist and bacteriologist, Dobell (1932), offers translations from many of the original letters. Here is a small glimpse into the microscopist's sense of empathy with God. In the closing lines of a letter dated 13 May 1680, acknowledging his unanimous election as fellow of the Royal Society, Leeuwenhoek writes, "Wherewith commending you, most noble Gentlemen, one and all, to the merciful protection of Almighty God, I remain, Gentlemen, Your most humble servant." On 19 March 1694, he wrote, "my efforts are ever striving towards no other end than, as far as in me lieth, to set the Truth before my eyes, to embrace it, and to lay out to good account the small Talent that I've received: in order to draw the World away from its Old-Heathenish superstition, to go over to the Truth, and to cleave unto it." In a letter dated 17 May 1707 he writes, "As to my health, thanks be to God, as long as I sit still I am without pain …" Shortly after his death the minister of Leeuwenhoek's church, the Rev. Mr Peter Gribius (a well-versed classical scholar who had visited Oxford and Cambridge before becoming minister of the New Church in Delft) wrote to the Royal Society, "In our present scientific age, Antony van Leeywenhoek considered that what is true in natural philosophy can be most fruitfully investigated by the evidences of the senses." For both Leeuwenhoek, a simple religious man, and his minister there was no conflict between religion and truth as revealed in nature.

1687: *Principia mathematica*

Isaac Newton (1642-1727): English physicist; elucidated the laws of universal gravitation

In 1687 Newton published his *Philosophiae Naturalis Principia Mathematica* (commonly referred to by only the last two words). It is generally considered to be the greatest scientific work ever published, and its author to have been the greatest intellect that ever lived. In it Newton proposed his supremely elegant universal theory of gravitation. The apple falling to earth, the moon revolving around the earth or the planets about the sun, all obey the famous 'inverse square' law: all move according to the same laws of gravitation. Newton's work heralded the Enlightenment of the 18th century; also known as the Age of Reason. In 1703 he was elected president of the Royal Society, and such was his eminence that he was re-elected to the post each subsequent year until his death. The epitaph on Newton's tomb in Westminster Abbey reads: "Let mortals rejoice that there has existed such and so great an Ornament to the Human Race."

For some fifty years, from around the 1670s until his death, Newton devoted a considerable part of his time and attention to a study of the scriptures (Ackroyd 2006). He was a deeply religious man: for him science and theology were equal avenues to revealing God, to a true understanding of the workings of the universe. His biblical studies were no less rigorous and thorough than were his scientific studies. Aside from having more than thirty versions of the Bible, he gathered about him a huge library of biblical literature. He studied Hebrew in order to delve into the original texts of the prophets. At his death he left an unfinished 850-page manuscript attesting his labours. It was of necessity a secret pursuit. His conclusions were at odds with orthodox belief in the holy trinity. They would amount to heresy against the Church of England that would have cost him his professorial chair at Cambridge. In his notebooks Newton declared that "the father is God of the Son", that we should confine our worship to "the only invisible God", but venerate the "one mediator between God & man the man Christ Jesus", and at the peril of our souls "we must not pray to two Gods". His intensive, obsessive studies took him along various paths: seeking to prove the literal authenticity of the prophets; interpretation of their words through dreams and symbols in the Old Testament; and quarrying their texts for hidden prophecies of future historical events.

In a letter to one Richard Bentley in 1692 Newton stated that God had created every particle of matter "with an innate gravity towards the rest", but since the divine being had created an infinite universe, some of this matter "would convert into one mass & some into another so as to make an infinite number of great masses scattered at great distances from one another throughout all that infinite space". He added that "the cause of gravity is what I do not pretend to know", it required "mediation of something else which is not material". That mediation, Newton harboured no doubt, was divine plan, the work of God the creator (Ackroyd 2006).

Voltaire (1694-1778), who became the greatest spokesman of Newton the scientist ("Before Kepler, all men were blind. Kepler had one eye, Newton had two"), was a deist. In this he was in line with the thinking of the 18th century Enlightenment, where God set in motion the cosmos with its exquisitely tuned physical laws, then stepped back, playing no further role, unconcerned with the sins and tribulations of humankind. In his torrent of potent prose Voltaire wrote, for instance: "Those who can make you believe absurdities can make you commit atrocities" (Dawkins 2006).

1759: The binomial system

Carolus Linnaeus (1707-1778): Swedish botanist; father of modern biological classification

Between 1735 and 1759 Linnaeus wrote a series of works that shifted the way humans respond to the world around them. These, beginning with his *Systema Naturae* (1735), included *Flora Suecica* (*Swedish Flora*, 1745), *Philosophia Botanica*

(1751) and *Species Plantarum* (1753). It was his tenth edition of *Systema Naturae* (1758-1759) that marks the starting point of modern taxonomy and nomenclature.

With these momentous works Linnaeus gave humanity – from scientist to poet, composer to layperson – a system of naming and classifying plants and animals that has allowed us to connect with the world around us and to communicate about what we see. Without words, without names, our capacity to know and love the natural diversity around us is severely handicapped. Before these works of Linnaeus the arts were inspired very largely by religious awe; after Linnaeus, they were largely inspired by a love of nature. Before his works, we have the Baroque world of Bach and Handel; after his works the Romantic world of Beethoven and Schubert. Before *Systema Naturae* mountains were obstructions in the way of travel, after *Systema Naturae* they became places inspiring poetic wonder and terrains for testing body and soul.

Jean-Jacques Rousseau (1712-1778), among the greatest philosophers of the Enlightenment, the father of Romanticism, was one of Linnaeus's earliest converts. He travelled Europe with Linnaeus's works in his bag, much as today we might travel with a book on trees and another on birds to enhance our journeys. He loved and revered Linnaeus and wrote to tell him so. It was Rousseau who acted as the primary conduit opening the floodgates of Romanticism in the arts. Consider his famous phrase. "Man was born free and he is everywhere in chains" – the opening line of *The social contract* (1762). Rousseau certainly went a long way towards loosening some of those chains. **Johann Wolfgang von Goethe** (1749-1832), literary giant at the birth of Romantic German literature, was another. He, too, carried the works of Linnaeus with him on his excursions around Europe and wrote of the reverence he felt.

Linnaeus's father was a Lutheran pastor who was an avid botanist in his spare time. Though his father encouraged him to follow in his footsteps as a preacher, Carolus became passionate about the botanical side instead – and that passion changed our world, as we have seen. In an article celebrating the tercentenary of the birth of Linnaeus, David Quammen (*National Geographic*, June 2007) writes, "There was a deeper purpose, for Linnaeus, to his enterprise. Find the 'natural method' of arranging plants into groups, and you would have discovered God's own secret logic of biological creation, just as Isaac Newton had discovered God's physical mathematics." Aside from laying the basis for the classification of nature, the great Swede was a lot more than a prolific botanist: "He was something more modern …. Here's what makes him a hero for our time", Quammen concluded: "He treasured the diversity of nature for its own sake, not just for its theological edification."

1787: The foundation of modern chemistry

Antoine Laurent Lavoisier (1743-1794): French chemist; father of modern chemistry

Out of chaos, Lavoisier created order. It was the year 1787, the centenary of Newton's *Principia* (1687). In his *Methods of chemical nomenclature* (1787), followed soon after by his *Elementary treatise on chemistry* (1789), he laid the foundations of modern chemistry. In the first, Lavoisier introduced his system of nomenclature that gave each substance a name based on its included elements, doing for chemistry what Linnaeus had done for biology. In the second work, his chemical textbook synthesising all that had been learnt to that date, he firmly established the indispensable role of measurement – and in this he did for chemistry what Galileo had done for physics. His more particular discoveries included resolving the composition of air as consisting of two gases, one supporting combustion (oxygen), the other not (nitrogen). Lavoisier named the former oxygen, and the latter azote (renamed nitrogen by the chemist Chaptal a generation later). It was he, also, who named the inflammable gas in water, hydrogen; who correctly explained combustion

as the combining of a substance with air (thus debunking the phlogiston theory); and who established the conservation of mass in chemical reactions.

As an alternative to probing the religious views of Lavoisier, it might be revealing to consider how an exact contemporary, **Thomas Jefferson** (1743-1826), viewed the matter. Jefferson was, of course, one of the founding fathers of America (it was he who wrote the Declaration of Independence in 1776), was two-term president from 1800-1809, and was the most polymathic of the 44 presidents from Washington to Obama. He was a gentleman-scientist of note, well versed in the chemical advances of his day; he studied and classified fossils when this field was in its infancy; took a keen interest in agriculture, conducting his own experiments into varieties of grain; and was a considerable architect. During his spell as ambassador to France he had been more than welcome at Lavoisier's laboratory. In 1786, in a letter from Paris to his nephew Peter Carr, he wrote: "Shake off all the fears of servile prejudices, under which weak minds are servilely crouched. Fix reason firmly in her seat, and call on her tribunal for every act, every opinion. Question with boldness even the existence of a god; because if there be one, he must more approve the homage of reason, than that of blindfolded fear … but those facts which contradict the laws of nature, must be examined with more care, and under a variety of faces" (Peterson 1975). Here is another Jeffersonian reflection (Dawkins 2006): "To talk of immaterial existences is to talk of nothings. To say that the human soul, angels, god, are immaterial, is to say they are nothings, or that there is no god, no angels, no soul. I cannot reason otherwise … without plunging into the fathomless abyss of dreams and phantasms. I am satisfied, and sufficiently occupied with the things which are, without tormenting or troubling myself with those which may indeed be, but of which I have no evidence." And here, again quoted by Dawkins (2006) (with relish!), is an extraordinarily ironical piece of outright criticism (considering attitudes in the present-day US): "Christianity is the most perverted system that ever shone on man."

1859: *Origin of species*

Charles Robert Darwin (1809-1882): English naturalist; discovered evolution through natural selection

Darwin represents the real turning point in our exploration of the interdependent histories of science and religion. In 1859, with the publication of his *Origin of species*, the graphs representing the empirical (scientific) versus the transcendental (religious) views of life crossed.

It began with his five-year (1831-1836) Beagle voyage around the world and, most famously, the Galapagos finches. In 1838 he read Malthus's *Essay on the principle of population* and had his flash of insight that **natural selection** was the mechanism for adaptation; the "continual pressure for selection ... works with the facts of **variation** and **inheritance** to create new species as circumstances changed" (Keynes, a great-great-grandson of Darwin, 2001). In January 1844 he wrote a letter to his botanist friend Joseph Hooker about his theory of evolution, and in July of that same year a note to his wife Emma: "I have just finished the sketch of my species theory" (Keynes 2001). The *Origin of species* finally appeared in 1859, a full 21 years after his 1838 insight and fifteen years after his species-theory letters. He wanted to have answers to every possible criticism that he knew would be hurled at him, notably by the church. The *descent of man* (1871), in which humankind explicitly took its place in the family tree of nature, was Darwin's coup de grace. He was an insatiable observer. From primitive humans in Tierra del Fuego, to chimpanzees and orang-utans in the London zoo, to his own children, to barnacles and orchids and climbers – all were grist to his theory of evolution. Today Darwin invariably comes near the top of any list of the most influential persons in history; but his own compatriots back in the 19th century found it difficult to honour him. Queen Victoria never did knight him, for instance. He did, however, enjoy the ultimate honour of

being buried in Westminster Abbey, just a few metres from the tomb of Sir Isaac Newton.

As a young man of nineteen in 1828, Darwin (having already given up on completing a medical degree in Edinburgh) was sent to Cambridge by his father to study for a bachelor's degree in theology. The aim was for him to settle comfortably as a country parson within the ample embrace of the Anglican Church. By 1831 he had his BA, but then his Beagle voyage intervened and his purpose in life took a dramatic turn. Darwin's personal drift from trainee pastor to unbeliever was slow but absolute. Here, in his words, are some selected steps in that evolution. In his almanac/notebook in 1838 (at 29), he wrote, "Let man visit Ourang-outan in domestication [in the London zoo], hear its expressive whine; see its intelligence when spoken [to], as if it understood every word said; see its affection to those it knew; see its passion and rage, sulkiness and very actions of despair; let him look at savage … and then let him dare to boast of his proud pre-eminence" (Keynes 2001) And he summed up: "Man in his arrogance thinks himself a great work, worthy the interposition of a deity. More humble and I believe true to consider him created from animals." Some years later, in 1845 (at 36) in his *Autobiography* (1929), he relates being "very unwilling to give up my belief … [I had] daydreams of old letters between distinguished Romans and manuscripts being discovered at Pompeii or elsewhere which confirmed in the most striking manner all that was written in the gospels". By 1849 (at 40), again in his *Autobiography*, he could write, "disbelief crept over me at a very slow rate, but was at last complete. The rate was so slow that I felt no distress, and I have never since doubted for even a second that my conclusion was correct". Emma, Darwin's wife, remained deeply religious throughout her life, and fretted that she and Charles would be separated in the life hereafter because of his loss of belief.

1867: *The germ theory of disease*

Louis Pasteur (1822-1895): French chemist and microbiologist; discovered the germ theory of disease

Just eight years after Darwin's *Origin* came Pasteur's *Germ theory of disease*, the most seminal of all medical discoveries. His varied and profound contributions place Pasteur amongst the top elite of scientists and make him the most influential figure in the long history of medicine. From his studies of a range of fermentation processes he could show that different micro-organisms were the cause (germ theory of fermentation). This work in the late 1850s to early 1860s marks the starting point of the science of bacteriology and gave us the process known as pasteurisation. Inter alia it saved the beer, wine and silk industries in France and elsewhere. It was this that led him to develop and demonstrate his historical theory that different species of germs were the cause of various human and animal diseases. He went on to stress that antiseptic surgical procedures should be introduced to prevent germs gaining entry to the body – an advance that his colleague and friend, Joseph Lister, put into practice.

Pasteur went on to develop modern vaccine therapy and successfully used it against chicken cholera (1880), anthrax (1881) and the dreaded rabies (1885). He showed that persons vaccinated with serially cultured, weakened forms of these diseases became immunised against the virulent strains. Life expectancy, through much of the world, roughly doubled between 1850 and 1950. Pasteur's discoveries, of such fundamental nature, were undoubtedly the greatest contributory factor in this alarming development. It meant the virtual negation of Darwinian survival of the fittest, the end of natural selection, and of evolution in regard to humankind.

If Pasteur was the greatest chemist in the mid to late 19th century, then **Michael Faraday** (1791-1867) and **James Clerk Maxwell** (1831-1879) were the greatest physicists. All three were devout Christians. All were unswayed in their beliefs by Darwin's *Origin of species*. Pasteur's firm religious convictions coloured his scientific

zeal and judgment. The old doctrine of the spontaneous generation of life from dead matter (non-life) had flared up again in 1858. Since the creation of life was a matter for God alone, Pasteur had designed his fermentation experiments with a view to disproving the theory once and for all (this he achieved). The reverse side was that he was led by his belief to reject Darwinian evolution by natural selection.

Faraday, the supreme experimental physicist (electric motor, laws of electrolysis), belonged to the Sandemanian sect (now all but extinct), became an elder in 1860 and died seven years later still a member. The Sandemanians had markedly conservative leanings: they espoused a literal interpretation of the Bible; ritually washed the feet of new inductees; and drew lots to interpret divine will. Maxwell, the equally supreme theoretical physicist (electromagnetic spectrum of radiation), knew the Bible in depth and devoted much time to the intellectual examination of his Christian faith. He expressed this pursuit in fine metaphorical prose in a letter to his close friend Campbell: "Now my great plan, which was conceived of old … is to let nothing be wilfully left unexamined. Nothing is to be holy ground consecrated to Stationary Faith, whether positive or negative. All fallow land is to be ploughed up and a regular system of rotation followed … Never hide anything, be it weed or no, nor seem to wish it hidden … Again I assert the Right of Trespass on any plot of Holy Ground" (mit.edu website). His faith remained firmly intact.

1895: The second scientific revolution

Wilhelm Konrad Roentgen (1845-1923): German physicist; unleashed the second scientific revolution

Towards the end of the 19th century some leading scientists felt that our knowledge of the world of physics and of physical laws had been more or less sewn up. There were surely some finishing touches to be added, but the bigger picture was settled. Then came Roentgen's chance discovery of X-rays in 1895. The second scientific revolution was unleashed. In almost breathless succession followed a series of fundamental discoveries. Henri Becquerel was first with radioactivity (1896), Sir Joseph Thomson followed with the first subatomic particle, which he called the electron (1897), then entered Marie and Pierre Curie with their discovery of radium (1898), Max Planck with the quantum theory (1900), Einstein with his theory of relativity (1905), Ernest Rutherford with the nuclear theory of the atom (1911), Niels Bohr with his improved model of the atom combining the Rutherford atom and Planck's quantum theory to explain radiation (1913), and Rutherford again, first with his discovery of the proton (1914), then achieving the alchemist's dream (the transmutation of elements) through changing nitrogen into oxygen by dislodging a proton from its nucleus (1917). It went on and on and still goes on. It is historically appropriate that Roentgen was to be awarded the first Nobel prize for physics (1901). His X-rays, a highly penetrative form of radiation, had truly opened Pandora's box – as St Francis of Assisi would undoubtedly have claimed.

Of all these breakthroughs we might dwell a moment on the quantum theory. **Max Planck** (1858-1947), a solid, conservative German physicist, proposed his radically new hypothesis that radiant energy is emitted in 'quanta' (his word), an elementary unit that he gave the symbol *h* (since referred to as Planck's constant). This *h* has found its way everywhere in the world of physics; it has become one of the two or three most fundamental constants. It features in Einstein's theories of radiation and relativity, in Bohr's theory of the atomic structure, in Heisenberg's uncertainty principle; it is seen in a plethora of scientific formulae. Quantum mechanics has become perhaps the most important development in physics of the 20th and early 21st centuries, topping even Einstein's theory of relativity. And it has taken us into the strangest territory. Richard Feynman was to write of it, "If you think you understand quantum theory … you don't understand quantum theory" (Dawkins 2006)

The first generation of physicists at the helm of this new scientific revolution held a spectrum of positions relating to religion. Whilst Sir Joseph Thomson, for instance, was a devout Anglican and Heisenberg remained a committed Lutheran, Roentgen and Rutherford appear to have had no religious persuasions. Max Planck maintained his Christian faith throughout life. He found science and religion perfectly compatible: they had the same goal in the "recognition of an omnipotent intellect ruling the universe. No matter where and how far we look, nowhere do we find contradiction between religion and science" (adherents.com website). He did however regret the church's insistence on unquestioning belief. To him "the faith in miracles must yield, step by step, before the steady and firm advance of the facts of science, and its total defeat is undoubtedly a matter of time". Marie Curie, on the other hand, espoused no faith, having given up her Roman Catholic background. Before reaching twenty, after the deaths of her mother (when she was eleven) and of her elder sister, she had shifted to anticlerical atheism. She married Pierre Curie in a civil ceremony as "Pierre belonged to no religion and I did not practise any" (womenshistory.about.com. & adherents.com websites).

1900: The subconscious and unconscious mind

Sigmund Freud (1856-1939): Austrian psychiatrist; discovered the subconscious mind

Appearing in the opening year (1900) of the new century, in the same year as Planck's outlandish quantum theory, was Freud's book on *The interpretation of dreams*. Like Copernicus (with his heliocentric universe) and Darwin (with his theory of evolution), so Freud's tapping into our often irrational subconscious and unconscious minds shifted humanity further from its cherished position at the centre of the universe. His *Interpretation of dreams* is generally recognised as the most original of a host of original works that opened up the world of psychoanalysis flush with Freudian concepts and terms: the Oedipus complex, libido, the id, the ego, the superego, the death wish, repressed sexuality. Dreams are a window onto our unconscious mind; and it has become largely accepted, following Freud, that unconscious mental processes play an enormous and decisive role in human behaviour.

Freud – whose great-grandfather and grandfather were rabbis – was riveted by Michelangelo's "Moses" (ca 1513-1515) from the moment he first saw it in 1901. He visited Rome seven times and each time made numerous pilgrimages to the "Moses". The obsessed psychiatrist saw it variously as a 'love child', a father figure, or an image with which he identified. His close friend and colleague, Ernest Jones (1953), put it succinctly: "'The three great men in whom Freud seems to have taken the most interest, and with whom he perhaps partly identified himself were Leonardo da Vinci, Moses and Shakespeare … The leader who kindled his imagination above all others was inevitably Moses, the great man who did more than anyone to build the Jewish nation … One cannot avoid the pretty obvious conclusion that ... Freud had identified himself with Moses" (Jones 1953). Indeed, two of Freud's principal works have a clear focus on Moses, the Hebrew prophet who led the enslaved Israelites out of Egypt to the Promised Land and gave them the divinely revealed Ten Commandments: *The Moses of Michelangelo* (1914) and *Moses and monotheism* (1939). Interestingly, despite his ancestry and his sense of identification with Moses, Freud was an atheist who wrote pessimistically in these two works about the role of religion in civilisation.

1905: *Annus mirabilis*

Albert Einstein (1879-1955): German physicist; formulated the theory of relativity

Five years into the new century and a decade into the second scientific revolution came Einstein's *Annus mirabilis*. At the stunningly young age of 26 Einstein stood on the shoulders of Galileo and Newton (and of Roentgen, Planck and many others) and peered out at a new and strange universe. In 1905 he published not one but five papers (all in the German *Yearbook of Physics*), three of seminal significance that could legitimately have earned him the Nobel Prize. One dealt with the photoelectric effect (applying quantum theory), a second was on Brownian motion (molecules in random motion in a fluid), and − most profound of all − his *Special theory of relativity* (that all motion is relative). The well ordered Newtonian universe, having reigned supreme for over two centuries, was replaced by the relativistic Einsteinian universe. Time now passed at a variable rate depending on the observer's velocity of motion; space and time became locked together as space-time. And, nestling in the relativity paper, appeared the most famous of all scientific formulae: $E=mc^2$. Energy equals mass times the speed of light squared; and that means that there is stupendous energy locked up in the atom. (We have all come to learn the extreme danger and extreme value of that fact.) In 1915 (at the age of 36) followed Einstein's *General theory of relativity* (Asimov 1964), adding still further dimensions to the perplexing drama of the universe. Then, for close on four decades from 1918 to 1955, he devoted his genius to grappling with the still elusive unified field theory (combining gravitation and the quantum). With his shock of white hair, Einstein has become the iconic image of science.

Because of his mega-stardom Einstein's views on everything outside of science were eagerly sought. He has written widely on religion and the relationship between science and religious belief, and he left little doubt as to his own position. To provide but a small flavour (selected from Einstein 1954): "The man who is thoroughly convinced of the universal operation of the law of causation cannot for a moment entertain the idea of a being who interferes in the course of events. He had no use for the religion of fear and equally little for social or moral religion. A god who rewards and punishes is inconceivable to him … It is easy therefore to see why the churches have always fought science and persecuted its devotees." "You will hardly find one amongst the profounder sort of scientific minds without a religious feeling of his own. But it is different from the religiosity of the naïve man. For the latter, God is a being from whose care one hopes to benefit and whose punishment one fears; a sublimation of a feeling similar to that of a child for its father, a being to whom one stands, so to speak, in a personal relation, however deeply it may be tinged with awe … But the scientist is possessed by the sense of universal causation … There is nothing divine about morality; it is a purely human affair. His religious feeling takes the form of a rapturous amazement at the harmony of natural law … This feeling is the guiding principle of his life and work."

1953: The double helix

James Dewey Watson (b. 1928): American biologist; co-discovered the structure of DNA

The year 1953 was huge in the annals of British history. It was the year Mount Everest, the highest peak on earth, was finally scaled (by Hillary and Tenzing on 29 May). It was the year Elizabeth II was crowned queen of the United Kingdom (in Westminster Abbey on 2 June). And it was the year an article by Crick and Watson appeared in the pages of *Nature* (25 April). The paper was a thing of remarkable brevity, just 900 words, but it unlocked our knowledge of nature no less than did Darwin's book nearly 100 years earlier. It began with the words: "We wish to suggest a structure for the salt of deoxyribose nucleic acid (DNA). This structure has novel features which are of considerable biological interest." The first sentence was somewhat understated, the second immensely prophetic.

Their paper unlocked the genetic code – it opened up the world of molecular biology as Roentgen's X-rays had opened up the world of atomic physics. The DNA molecule, with its four bases (adenine, guanine, thiamine, cytosine), is the key to 3.6 billion years of life on our planet. It explains genetic inheritance. It explains Darwinian evolution. It explains mutation and variation within a species. It underpins the diversity of life on earth. It enables us to classify this diversity of life and to draw up the phylogenetic tree of its myriad branches. We can now map the entire human genome, and that of any other organism. It opens up endless possibilities in the field of medicine.

In an interview in 1996 in the gardens of Clare College, Cambridge, Richard Dawkins (2006) questioned James Watson on his religious viewpoint. Dawkins was making a BBC television documentary on Gregor Mendel, founder of the study of genetics. Their conversation went like this:

> Dawkins: [Do you know] many religious scientists today?
> Watson: Virtually none. Occasionally I meet them, and I'm a bit embarrassed [laughs] because, you know, I can't believe anyone accepts truth by revelation.
> Dawkins: Unlike you and Crick, some people see no conflict between science and religion, because they claim science is about how things work and religion is about what it is all for.
> Watson: Well I don't think we're for anything. We're just products of evolution. You can say, 'gee, your life must be pretty bleak if you don't think there's a purpose.' But I'm anticipating having a good lunch.
> Dawkins (in an aside to his readers): We did have a good lunch too.

Francis Crick (1916-2004), Watson's DNA colleague, was at least equally emphatic in his response to religion. Dawkins (2006) writes, "Watson's co-founder of the whole molecular genetics revolution, resigned his fellowship at Churchill College, Cambridge, because of the college's decision to build a chapel (at the behest of a benefactor)."

1970s: The infinite universe

Stephen Hawking (1942-…): English cosmologist; leading figure in elucidating the origin of the universe

Scientific exploration has shifted significantly since the days of Galileo, Newton and even Einstein. With the exploding human population and the rapid rise in the number of professional scientists, cooperative international projects requiring mega-funding are becoming the norm. Go back to **Sir William Herschel** (1738-1822), the Hanover-born British astronomer. With the enthusiastic backing of king George III (who loved astronomy and made Herschel's career), he had the universe to a remarkable degree to himself. His discoveries might have earned him three Nobel prizes in our day: in 1781 he discovered Uranus, the first new planet found in historical times; around 1800 he debunked the heliocentric theory (seeing our sun in its true perspective, as just one of innumerable suns); and he was the first to recognise galaxies (swirling clusters of stars) and saw a universe full of such galaxies.

Such was the nature of science a little before Darwin. Selecting an individual to represent cosmology in the past half century is a lot more tricky than for previous centuries. In view of his iconic status (a variation on the theme of Einstein), though, Hawking would probably be most people's popular choice. His scientific territory has been that of black holes and singularities, of the origin of the universe and the nature of time. He too, like Einstein, has been in search of the universal theory – still elusive – combining gravitation and quantum mechanics into one grand synthesis.

Hawking, like both Watson and Einstein before him, professes no belief in any God. In 1981 the legendary theoretical physicist, confined apparently helplessly to his wheelchair, attended a conference organised by the Jesuits at the Vatican. The Catholic Church, having reacted so shamefully to the scientific contributions of Copernicus and Galileo, now sought advice from the experts on cosmology. In his bestseller, *A brief history of time*' (1988), Hawking wrote in his familiar style laced with sly British humour: "At the end of the conference the participants were granted an audience with the pope [**John Paul II**]. He told us that it was all right to study the evolution of the universe after the big bang, but we should not inquire into the big bang itself because that was the moment of Creation and therefore the work of God. I was glad then that he did not know the subject of the talk I had just given at the conference − the possibility that space-time was finite but had no boundary, which means that it had no beginning, no moment of Creation. I had no desire to share the fate of Galileo, with whom I feel a strong sense of identity, partly because of the coincidence of having been born exactly 300 years after his death!"

1992: *The diversity of life*

Edward O. Wilson (b. 1929): American biologist; gave true meaning to the word biodiversity

In his autobiography, *Naturalist* (1994) Edward O. Wilson wrote the unforgettable opening lines to his chapter entitled "The molecular wars": "Without a trace of irony I can say I have been blessed with brilliant enemies …. They redoubled my energies and drove me in new directions … James Dewey Watson, the codiscoverer of the structure of DNA, served as one such adverse hero for me." Watson and Wilson, young men only a year apart in age, ended up in the 1950s and 1960s working in the same corridor at Harvard University. From here, hardly speaking to one another, they pushed forward their respective revolutions in biological science, Watson on the molecular level, and Wilson out there in the mostly visible world of teeming life.

Wilson is the world's number one myrmecophiliac (lover of ants), the world's leading ant expert; yet his contributions in the field of biology extend far more widely. His books synthesising and popularising his science include *On human nature* (1978), pushing evolutionary psychology; *Biophilia* (1984), the word he coined for our love of nature; *The diversity of life* (1992), documenting biodiversity; *Naturalist* (1994), his autobiography; *Consilience* (1998), lobbying holism; and *The future of life* (2002), warning against extinction. Each of these volumes is a work of literary art and each a major contribution to knowledge and the understanding of our natural world. In *The diversity of life* (1992), he writes: "In the realm of physical measurement, evolutionary biology is far behind the rest of the natural sciences. Certain numbers are crucial to our ordinary understanding of the universe. What is the mean diameter of the earth? It is 12,742 kilometers (7,913 miles). How many stars are there in the Milky Way, an ordinary spiral galaxy? Approximately 10^{11}, 100 billion. How many genes are there in a small virus? There are 10 (in ϴX174 phage). What is the mass of an electron? It is 9.1×10^{-28} grams. And how many species of organisms are there on earth? We don't know, not even to the nearest order of magnitude. The number could be close to 10 million or as high as 100 million." In this remarkable concentration of words, Wilson catches his moment in the history of science masterfully. Since Copernicus we have come a considerable distance in unravelling the universe from its quarks to its quasars, but we still walk half blind through the prodigious diversity of life about us. Our myrmecophiliac, more than anyone, has opened us to a new view of the living world. It is Wilson who has given the word 'biodiversity' gravitas, and sent it out from Harvard to become, one could justifiably argue, the most important single word in our 21st century vocabulary.

In his *Consilience; the unity of knowledge* (1998), Wilson devotes a brilliantly argued chapter to "Ethics and religion". Of his personal perspective, he writes: "I will

of course try to be plain about my own position: I am an empiricist. On religion I lean toward deism but consider its proof largely a problem in astrophysics. The existence of a cosmological God who created the universe (as envisioned by deism) is possible, and may eventually be settled, perhaps by forms of material evidence not yet imagined. Or the matter may be beyond human reach. In contrast, and of far greater importance to humanity, the existence of a biological God, one who directs organic evolution and intervenes in human affairs (as envisioned by theism) is increasingly contravened by biology and the brain sciences." In other words (which summarises our walk through the second millennium pretty closely), "Science has taken us very far from the personal God who once presided over Western Civilisation." And further along, "Science … will test relentlessly every assumption about the human condition and in time uncover the bedrock of the moral and religious sentiments … The eventual result of the competition between the two world views [transcendentalist and empiricist], I believe, will be the secularisation of the human epic and of religion itself."

2008: The International Year of Planet Earth (IYPE)

So let us consider the present. We are in the middle of the Sixth Extinction of **biodiversity** and we appear to be melting the icecaps at a rate even more alarming than we thought. We seem hardly less arrogant about our elite status in the universe than we ever were; we appear no wiser than we ever were; science and religion appear still in many quarters to be on a head-on collision course. The year 2008 (more broadly 2007-2009), was declared the International Year of Planet Earth by UNESCO. It is about the effective transfer of the rapidly increasing knowledge in the earth sciences to the decision makers (political, business, whoever) globally – to the greater benefit of all everywhere.

And this is my special interest in a conference such as this: how are the devotees of science and the devotees of religion to find common ground, to work flawlessly together to solve the greatest problems of current time: the escalating **Sixth Extinction** of biodiversity and **global warming**. For if we don't, life on earth is doomed (or, more correctly, perhaps 90% of all multicellular species probably are). Consider the **penguins**: there are seventeen species of these comical, quizzical, naively human-tolerant creatures. Let us melt the icecaps, let us melt the Antarctic, and they are gone, every one of them – outside of zoos that is. And where is our sense of spirituality then? The penguins – and the rest of life – are dependent on us and we are failing them, God or no God!

Richard Dawkins in his unsparingly powerful polemic, *The God delusion* (2006), presents striking statistics on levels of religious belief between scientists and non-scientists. He opens with the 'elite' scientists elected to the US National Academy of Sciences, where it is found that only about seven percent believe in a personal God. Of compelling significance is the finding that "this overwhelming preponderance of atheists is almost the exact opposite of the profile of the American population at large". It turns out that over 90 percent of Americans are believers in some sort of supernatural being. Dawkins continues his survey, now looking at the next rung of US scientists, those not elected to the National Academy: "As with the more distinguished sample, religious believers are in a minority, but a less dramatic minority of about 40 per cent." He sums up: "it is completely as I would expect that American scientists are less religious than the American public generally, and that the most distinguished scientists are the least religious of all." A survey of religiosity versus atheism amongst the members of the Royal Society of London (the British equivalent of the National Academy) came up with similar results: "The overwhelming majority of FRS, like the overwhelming majority of US Academicians, are atheists." Research surveys in the general US population have also been conducted on the correlation between religiosity and levels of education, intelligence (IQ), interest in science and political liberalism: all are 'negatively correlated', and in the last group,

‘strongly’ so. “None of this is surprising,” comments Dawkins, “nor is the fact that there is a positive correlation between religiosity and parent’s religiosity. Sociologists studying British children have found that only about one in twelve break away from their parents’ religious beliefs.”

Glimpsing the future

“Ontogeny recapitulates phylogeny” – the embryological development of each individual follows the long history of the evolution of life. The shift in Darwin, the individual, from belief to atheism, parallels the changing balance between religion and science from 1000 to 2000 CE. The drift of scientists away from the church has been gradual but emphatic! The overall decrease in religious faith with increasing scientific knowledge through the past millennium correlates well with the finding in the extant population that levels of faith and scientific creativity (or knowledge) are inversely proportional.

All things are interdependent and evolve all the time. Change is inevitable. Dramatic change is inevitable. So it has been with the clash between science and religion; and so it will certainly continue. The unknown is how this interaction will evolve into the future, and how fast. Life on earth is in serious peril. Humanity is in serious peril, as are the 50 million or so other species sharing our planet. We have to invent a new future: and working along the lines of Edward Wilson’s concept of consilience – aiming at a holistic, seamless synthesis of all knowledge – will surely be our most promising option. For the past thousand years in the West (and globally) we have known near nothing of consilience. We have known unending warfare between humans and their fellow humans, and between humans and nature. And it is perhaps worse today than yesterday. The science-religion collision has been, and is, an integral part of that warfare, more destructive than constructive.

Surely the most widely loved and esteemed religious figure in our era is the Dalai Lama – and he has endured against tremendous odds for some considerable time. Deepak Chopra (2008) reflected on his meetings with the Tibetan leader (*Time*,): “The most inspiring thing he ever told me was to ignore all organised faiths and keep to the road of higher consciousness.” The Dalai Lama had added, “Without relying on religion, we look to common sense, common experience and the findings of science for understanding.”

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