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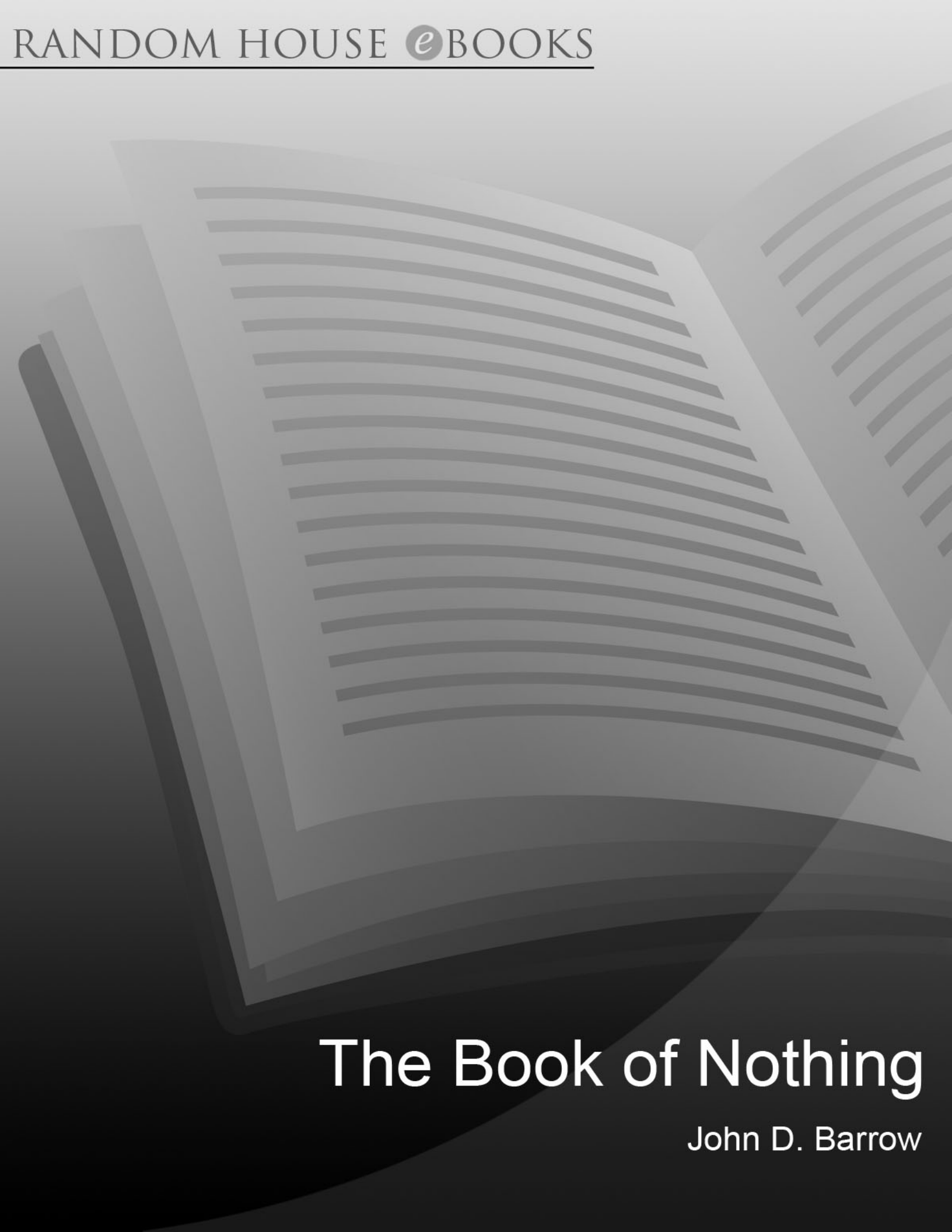

The Book of Nothing

John D. Barrow

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About the Author

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ALSO BY JOHN D. BARROW

Theories of Everything

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The Origin of the Universe

Between Inner Space and Outer Space

The Universe that Discovered Itself

In memory of Dennis Sciama

The Book of Nothing

John D. Barrow

VINTAGE BOOKS
London

Preface

> “Deciding on a book’s beginning is as complex as determining the origins of the universe.”
>
> Robert McCrum

‘Because it’s not there’ might be reason enough to write a book about Nothing, especially if the author has already written one about Everything. But, fortunately, there are better reasons than that. If one looks at the special problems that were the mainsprings of progress along the oldest and most persistent lines of human inquiry, then one finds Nothing, suitably disguised as something, never far from the centre of things.

Nothing, in its various guises, has been a subject of enduring fascination for millennia. Philosophers struggled to grasp it, while mystics dreamed they could imagine it; scientists strove to create it; astronomers searched in vain to locate it; logicians were repelled by it, yet theologians yearned to conjure everything from it; and mathematicians succeeded. Meanwhile, writers and jesters were happy to stir up as much ado about Nothing as ever they possibly could. Along all these pathways to the truth Nothing has emerged as an unexpectedly pivotal something, upon which so many of our central questions are delicately poised.

Here, we are going to draw together some of the ways in which our conceptions of Nothing influenced the growth of knowledge. We will see how the ancient Western addiction to logic and analytic philosophy prevented progress towards a fruitful picture of Nothing as something that could be part of an explanation for the things that are seen. By contrast, Eastern philosophies provided habits of thought in which the

idea of Nothing-as-something was simple to grasp and not only negative in its ramifications. From this first simple step, there followed a giant leap for mankind: the development of universal counting systems that could evolve onwards and upwards to the esoteric realms of modern mathematics.

In science, we will see something of the quest to make a real vacuum, in the midst of a thousand years of tortuous argument about its possibility, desirability and place. These ideas shaped the future direction of many parts of physics and engineering while, at the same time, realigning the philosophical and theological debates about the possibility and desirability of the vacuum – the physical Nothing. For the theologians, these debates were, in part, the continuation of a crucial argument about the need for the Universe to have been created out of both a physical and a spiritual Nothing. But for the critical philosophers, they were merely particular examples of ill-posed questions about the ultimate nature of things that were gradually falling into disrepute.

At first, such questions about the meaning of Nothing seemed hard, then they appeared unanswerable, and then they appeared meaningless: questions about Nothing weren’t questions about anything. Yet, for the scientists, producing a vacuum appeared to be a physical possibility. You could experiment with the vacuum and use it to make machines: an acid test of its reality. Soon this vacuum seemed unacceptable. A picture emerged of a Universe filled with a ubiquitous ethereal fluid. There was no empty space. Everything moved through it; everything felt it. It was the sea in which all things swam, ensuring that no nook or cranny of the Universe could ever be empty.

This spooky ether was persistent. It took an Einstein to remove it from the Universe. But what remained when everything that could be removed was removed was more than he expected. The combined insights of relativity and the quantum have opened up striking new possibilities that

have presented us with the greatest unsolved problems of modern astronomy. Gradually, over the last twenty years, the vacuum has turned out to be more unusual, more fluid, less empty, and less intangible than even Einstein could have imagined. Its presence is felt on the very smallest and largest dimensions over which the forces of Nature act. Only when the vacuum's subtle quantum influence was discovered could we see how the diverse forces of Nature might unite in the seething microworld inhabited by the most elementary parts of matter.

The astronomical world is no less subservient to the properties of the vacuum. Modern cosmology has built its central picture of the Universe's past, present and future on the vacuum's extraordinary properties. Only time will tell whether this construction is built on shifting sand. But we may not have to wait very long. A series of remarkable astronomical observations now seem to be revealing the cosmic vacuum by its effects on the expansion of the Universe. We look to other experiments to tell us whether, as we suspect, the vacuum performed some energetic gymnastics nearly fifteen billion years ago, setting the Universe upon the special course that led it to be what it is today and what it will eventually become.

I hope that this story will convince you that there is a good deal more to Nothing than meets the eye. A right conception of its nature, its properties, and its propensity to change, both suddenly and slowly, is essential if we are to understand how we got to be here and came to think as we do.

The glyphs accompanying the chapter numbers throughout this book, from zero to nine, are reproductions of the beautiful Mayan head-variant numerals. They represent a spectrum of celebrated gods and goddesses and were widely used by the Mayans more than fifteen hundred years ago for recording dates and spans of time.

I would like to thank Rachel Bean, Malcolm Boshier, Mariusz Dąbrowski, Owen Gingerich, Jörg Hensgen, Ed Hinds, Subhash Kak, Andrei Linde, Robert Logan, João Magueijo, Martin Rees, Paul Samet, Paul Shellard, Will Sulkin, Max Tegmark and Alex Vilenkin for their help and discussions at various times. This book is dedicated to the memory of Dennis Sciama without whose early guidance neither this, nor any of my other writing over the last twenty-five years, would have been possible.

This book has survived one move of house and three moves of office in the course of its writing. In the face of all these changes of vacuum state, I would also like to thank my wife Elizabeth for ensuring that something invariably prevailed over nothing, and our children, David, Roger and Louise, for their unfailing scepticism about the whole project.

J.D.B.
Cambridge, May 2000

chapter nought

Nothingology – Flying to Nowhere

“As I was going up the stair,
I met a man who wasn’t there.
He wasn’t there again today,
I wish, I wish he’d stay away.”

Hughes Mearns

MYSTERIES OF NON-EXISTENCE

“You ain’t seen nothing yet.”

Al Jolson[1]

‘NOTHING’, IT HAS been said, ‘is an awe-inspiring yet essentially undigested concept, highly esteemed by writers of a mystical or existentialist tendency, but by most others regarded with anxiety, nausea, and panic.’[2] Nobody seems to know how to handle it and perplexingly diverse conceptions of it exist in different subjects.[3] Just take a look at the entry for ‘nothing’ in any good dictionary and you will find a host of perplexing synonyms: nil, none, nowt,[4] nulliform,[5] nullity – there is a nothing for every occasion. There are noughts of all sorts to zero-in on, from zero points to zero hours, ciphers to nulliverses.[6] There are concepts that are vacuous, places that are evacuated, and voids of all

shapes and sizes. On the more human side, there are nihilists,[7] nihilianists,[8] nihilarians,[9] nihilagents,[10] nothingarians,[11] nullifideans,[12] nullibists,[13] nonentities and nobodies. Every walk of life seems to have its own personification of nothing. Even the financial pages of my newspaper tell me that 'zeros'[14] are an increasingly attractive source of income.

Some zeros seem positively obscure, almost circumlocutory. Tennis can't bring itself to use so blunt a thing as the word 'nil' or 'nothing' or 'zero' to record no score. Instead, it retains the antique term 'love', which has reached us rather unromantically from *l'oeuf*, the French for an egg which represented the round 0 shape of the zero symbol.[15] Likewise, we still find the use of the term 'love' meaning 'nothing' as when saying you are playing for love (rather than money), hence the distinction of being a true 'amateur', or the statement that one would not do something 'for love or money', by which we mean that we could not do it under any circumstances. Other games have evolved anglicised versions of this anyone-for-tennis pseudonym for zero: 'goose egg' is used by American ten-pin bowlers to signal a frame with no pin knocked down. In England there is a clear tradition for different sports to stick with their own measure of no score, 'nil' in soccer, 'nought' in cricket, but 'ow' in athletics timings, just like a telephone number, or even James Bond's serial number. But sit down at your typewriter and 0 isn't O any more.

'Zilch' became a common expression for zero during the Second World War and infiltrated 'English' English by the channel of US military personnel stationed in Britain. Its original slang application was to anyone whose name was not known. Another similar alliterative alternative was 'zip'. A popular comic strip portrays an owl lecturing to an alligator and an infant rabbit on a new type of mathematics, called 'Aftermath', in which zero is the only number permitted; all problems have the same solution – zero – and

consequently the discipline consists of discovering new problems with that inevitable answer.[16]

Another curiosity of language is the use of the term ‘cipher’ to describe someone who is a nonentity (‘a cipher in his own household’, as an ineffectual husband and father was once described). Although a cipher is now used to describe a code or encryption involving symbols, it was originally the zero symbol of arithmetic. Here is an amusing puzzle which plays on the double meaning of cipher as a code and a zero:

“U 0 a 0, but I 0 thee
O 0 no 0, but O 0 me.
O let not my 0 a mere 0 go,
But 0 my 0 I 0 thee so.”

which deciphers to read

“You sigh for a cipher, but I sigh for thee
O sigh for no cipher, but O sigh for me.
O let not my sigh for a mere cipher go,
But sigh for my sigh, for I sigh for thee so.”

The source of the insulting usage of cipher is simple: the zero symbol of arithmetic is one which has no effect when added or subtracted to anything. One Americanisation of this is characteristically racier and derives from modern technical jargon. A null operation is technospeak for an action that has no consequence. Your computer cycles through millions of them while it sits waiting for you to make the next keystroke. It is a neutral internal computer operation that performs no calculation or data manipulation. Correspondingly, to say that someone ‘is a zero, a real null op’ needs no further elucidation. Of course, with the coming of negative numbers new jokes are possible, like that of the individual whose personality was so negative that when he

walked into a party, the guests would look around and ask each other ‘who left?’ or the scientist whose return to the country was said to have added to the brain drain. The adjective ‘napoo’, meaning finished or empty, is a contraction of the French *il n’y a plus*, for ‘there is nothing left’.

Not all nominal associations with ‘nothing’ were derogatory. Sometimes they had a special purpose. When some of the French Huguenots fled to Scotland to escape persecution by Louis XIV they sought to keep their names secret by using the surname Nimmo, derived from the Latin *ne mot*, meaning no one or no name.

Our system of writing numbers enables us to build up expressions for numbers of unlimited size simply by adding more and more noughts to the right-hand end of any number: 112300000000000 . . . During the hyperinflationary period of the early 1920s, the German currency collapsed in value so that hundreds of billions of marks were needed to stamp a letter. The economist John K. Galbraith writes[17] of the psychological shock induced by these huge numbers with their strings of zeros:

> “‘Zero stroke’ or ‘cipher stroke’ is the name created by German physicians for a prevalent nervous malady brought about by the present fantastic currency figures. Scores of cases of the ‘stroke’ are reported among men and women of all classes, who have been prostrated by their efforts to figure in thousands of millions. Many of these persons apparently are normal, except for a desire to write endless rows of ciphers.”

Pockets of hyperinflation persist around the globe; indeed there are more zeros around today than at any other time in history. The introduction of binary arithmetic for computer calculation, together with the profusion of computer codes for the control of just about everything, has filled machines with 0s and 1s. Once you had a ten per cent chance of happening upon a zero, now it’s evens. But there are huge numbers that are now almost commonplace. Everyone

knows there are billions and billions of stars, and national debts conjure up similar astronomical numbers. Yet we have found a way to hide the zeros: 10^9 doesn't look as bad as 1,000,000,000.

The sheer number of synonyms for 'nothing' is in itself evidence of the subtlety of the idea that the words try to capture. Greek, Judaeo-Christian, Indian and Oriental traditions all confronted the idea in different ways which produced different historical threads. We will find that the concept of nothingness that developed in each arena merely to fill some sort of gap then took on a life of its own and found itself describing a something that had great importance. The most topical example is the physicists' concept of nothing – the vacuum. It began as empty space – the void, survived Augustine's dilution to 'almost nothing',[18] turned into a stagnant ether through which all the motions in the Universe swam, vanished in Einstein's hands, then re-emerged in the twentieth-century quantum picture of how Nature works. This perspective has revealed that the vacuum is a complex structure that can change its character in sudden or gradual ways. Those changes can have cosmic effects and may well have been responsible for endowing the Universe with many of its characteristic features. They may have made life a possibility in the Universe and one day they may bring it to an end.

When we read of the difficulties that the ancients had in coming to terms with the concept of nothing, or the numeral for zero, it is difficult to put oneself in their shoes. The idea now seems commonplace. But mathematicians and philosophers had to undergo an extraordinary feat of mental gymnastics to accommodate this everyday notion. Artists took rather longer to explore the concepts of Nothing that emerged. But, in modern times, it is the artist who continues to explore the paradoxes of Nothing in ways that are calculated to shock, surprise or amuse.

NOTHING VENTURED

> “Now, is art about drawing or is it about colouring in?”
>
> Ali G

> “Nothing is closer to the supreme commonplace of our commonplace age than its preoccupation with Nothing . . . Actually, Nothing lends itself very poorly indeed to fantastic adornment.”
>
> Robert M. Adams[19]

In the 1950s artists began to explore the limiting process of going from polychrome to monochrome to nullichrome. The American abstract artist Ad Reinhardt produced canvases coloured entirely red or blue, before graduating to a series of five-foot square all-black productions that toured the leading galleries in America, London and Paris in 1963. Not surprisingly, some critics condemned him as a charlatan[20] but others admired his art noir: ‘an ultimate statement of esthetic purity’, according to American art commentator Hilton Kramer.[21] Reinhardt went on to run separate exhibitions of his all-red, all-blue and all-black canvases and writes extensively about the *raison d’être* for his work.[22] It is a challenge to purists to decide whether Reinhardt’s all-black canvases capture the representation of Nothing more completely than the all-white canvases of Robert Rauschenberg. Personally, I prefer the spectacular splash of colours in Jasper Johns’ *The Number Zero.*[23]

The visual zero did not need to be explicitly represented by paint or obliquely signalled by its absence. The artists of the Renaissance discovered the visual zero for themselves in the fifteenth century and it became the centrepiece of a new representation of the world that allowed an infinite number of manifestations. The ‘vanishing point’ is a device to create a realistic picture of a three-dimensional scene on a flat surface. The painter fools the eye of the viewer by

imagining lines which connect the objects being represented to the viewer's eye. The canvas is just a screen that intervenes between the real scene and the eye. Where the imaginary lines intersect that screen, the artist places his marks. Lines running parallel to the screen are represented by parallel lines which recede to the line of the distant horizon, but those seen as perpendicular to the screen are represented by a cone of lines that converge towards a single point – the vanishing point – which creates the perspective of the spectator.

Musicians have also followed the piper down the road to nothing-town. John Cage's musical composition *4′ 33″* – enthusiastically encored in some halls – consists of 4 minutes and 33 seconds of unbroken silence, rendered by a skilled pianist wearing evening dress and seated motionless on the piano stool in front of an operational Steinway. Cage explains that his idea is to create the musical analogue of absolute zero of temperature[24] where all thermal motion stops. A nice idea, but would you pay anything other than nothing to see it? Martin Gardner tells us that 'I have not heard *4′ 33″* performed but friends who have tell me that it is Cage's finest composition'.[25]

Writers have embraced the theme with equal enthusiasm. Elbert Hubbard's elegantly bound *Essay on Silence* contains only blank pages, as does a chapter in the autobiography of the English footballer Len Shackleton which bears the title 'What the average director knows about football'. An empty volume, entitled *The Nothing Book*, was published in 1974 and appeared in several editions and even withstood a breach of copyright action by the author of another book of blank pages.

Another style of writing uses Nothing as a fulcrum around which to spin opposites that cancel. Gogol's *Dead Souls* begins with a description of a gentleman with no characteristics arriving at a town known only as N.:

> “The gentleman in their carriage was not handsome but neither was he particularly bad-looking; he was neither too fat nor too thin; he could not be said to be too old, but he was not too young either.”

A classic example of this adversarial descriptive style, in which attributes and counter-attributes cancel out to zero, is to be found on a woman’s tomb in Northumberland. The family inscribed the words

> “She was temperate, chaste, and charitable, but she was proud, peevish, and passionate. She was an affectionate wife and tender mother but her husband and child seldom saw her countenance without a disgusting frown . . .”[26]

Not to be forgotten, of course, are those commercial geniuses who are able to make more out of nothing than most of us can earn from anything. ‘Polo, the mint with the hole’ is one of the best-known British advertising pitches for a sweet that evolved independently as a ‘Lifesaver’ in the United States. More than forty years of successful marketing have promoted the hole in the mint rather than the mint itself. Nobody seems to notice that they are buying a toroidal confection that contains a good chunk of empty space, but then he wouldn’t.

NOTHING GAINED

> “Nothing is real.”
>
> The Beatles, “Strawberry Fields Forever”

So much for these snippets of nothing. They show us nothing more than that there is a considerable depth and breadth to the contemplation of Nothing. In the chapters to come, we shall explore some of these unexpected paths. We shall see that, far from being a quirky sideshow, Nothing is never far from the central plots in the history of ideas. In every field we shall explore, we shall find that there is a

central issue which involves a right conception of Nothing, and an appropriate representation of it. Philosophical overviews of key ideas in the history of human thought have always made much of concepts like infinity,[27] but little of Nothing. Theology was greatly entwined with the complexities of Nothing, to decide whether we were created out of it and whether we risked heading back into its Godless oblivion. Religious practices could readily make contact with the reality of Nothingness through death. Death as personal annihilation is an ancient and available variety of Nothing, with traditional functions in artistic representation. It is a terminus, a distancing, suggesting an ultimate perspective or perhaps a last judgement; and its cold reality can be used to spook the complacent acceptance of a here-and-now to which listeners are inevitably committed.

One of our aims is to right this neglect of nothing and show a little of the curious way in which Nothing in all its guises has proved to be a key concept in many human inquiries, whose right conception has opened up new ways of thinking about the world. We will begin our nullophilia by investigating the history of the concept and symbol for the mathematicians' zero. Here, nothing turns out to be quite as one expected. The logic of the Greeks prevents them having the idea at all and it is to the Indian cultures that we must look to find thinkers who are comfortable with the idea that Nothing might be something. Next, we shall follow what happened after the Greeks caught up. Their battle with zero focused upon its manifestation as a physical zero, the zero of empty space, the vacuum and the void. The struggle to make sense of these concepts, to incorporate them into a cosmological framework that impinged upon everyday experiences with real materials, formed the starting point for an argument that would continue unabated, becoming ever more sophisticated, for nearly two thousand years. Medieval science and theology grappled constantly with the

idea of the vacuum, trying to decide questions about its physical reality, its logical possibility and its theological desirability.

Part of the problem with zero, as with the complementary concept of infinity, was the way in which it seemed to invite paradox and confusing self-reference. This was why so many careful thinkers had given it such a wide berth. But what was heresy to the logician was a godsend to the writer. Countless authors avoided trouble with Nothing by turning over its paradoxes and puns, again and again, in new guises, to entertain and perplex. Whereas the philosopher might face the brunt of theological criticism for daring to take such a sacrilegious concept seriously, the humorist trying to tell his readers that ‘Nothing really matters’ could have his cake and eat it, just as easily as Freddie Mercury. If others disapproved of Nothing, then the writer’s puns and paradoxes just provided more ammunition to undermine the coherence of Nothing as a sensible concept. But when it came back into fashion amongst serious thinkers, then were not his word games profound explorations of the bottomless philosophical concept that Nothingness presented?

Hand-in-hand with the searches for the meaning of Nothing and the void in the Middle Ages, there grew up a serious experimental philosophy of the vacuum. Playing with words to decide whether or not a vacuum could truly exist was not enough. There was another route to knowledge. See if you could make a vacuum. Gradually, theological disputes about the reality of a vacuum became bound up with a host of simple experiments designed to decide whether or not it was possible to evacuate a region of space completely. This line of inquiry eventually stimulated scientists like Torricelli, Galileo, Pascal and Boyle to use pumps to remove air from glass containers and demonstrate the reality of the pressure and weight of the air above our heads. The vacuum had become part of experimental science. It was also very useful.

Still, physicists doubted whether a true vacuum was possible. The Universe was imagined to contain an ocean of ethereal material through which we moved but upon which we could exert no discernible effect. The science of the eighteenth and nineteenth centuries grappled with this elusive fluid and sought to use its imagined presence to explain the newly appreciated natural forces of electricity and magnetism. It would only be banished by Einstein's incisive genius and Albert Michelson's experimental skill. Together they removed the need and the evidence for a cosmic ether. By 1905 a cosmic vacuum had become possible again.

Things soon changed. Einstein's creation of a new and spectacular theory of gravity allowed us to describe a space that is empty of mass and energy with complete mathematical precision. Empty universes could exist.

Yet something had been missed out in the world of the very small. The quantum revolution showed us why the old picture of a vacuum as an empty box was untenable. Henceforth, the vacuum was simply the state that remained when everything that could be removed from the box was removed. That state was by no means empty. It was merely the lowest energy state available. Any small disturbances or attempts to intervene would raise its energy.

Gradually, this exotic new picture of quantum nothingness succumbed to experimental exploration. The multiplication of artificial voids by scientists at the end of the nineteenth century had paved the way for all sorts of useful and now familiar developments in the form of vacuum tubes, light bulbs and X-rays. Now the 'empty' space itself started to be probed. Physicists discovered that their defensive definition of the vacuum as what was left when everything that could be removed had been removed was not as silly as it sounds. There *was* always something left: a vacuum energy that permeated every fibre of the Universe. This ubiquitous, irremovable vacuum energy was detected and shown to

have a tangible physical presence. Only relatively recently has its true importance in the cosmic scheme of things begun to be appreciated. We shall see that the world may possess many different vacuum states. A change from one to another may be possible under certain circumstances, with spectacular results. Remarkably, it appears that such a transition is very difficult to avoid during the first moments of our Universe's expansion. More remarkable still, such a transition could have a host of nice consequences, showing us why the Universe possesses many unusual properties which would otherwise be a complete mystery to us.

Finally, we shall run up against two cosmological mysteries about Nothing. The first is ancient: the problem of creation out of nothing – did the Universe have a beginning? If so, out of what did it emerge? What are the religious origins of such an idea and what is its scientific status today? The second is modern. It draws together all the modern manifestations of the vacuum, the description of gravity and the inevitability of energy in a quantum vacuum. Einstein showed us that the Universe might contain a mysterious form of vacuum energy. Until very recently, astronomical observations could only show that if this energy is present, as an all-pervading cosmic influence, then its intensity must be fantastically small if it is not to come to dominate everything else in the Universe. Physicists have no idea how its influence could remain so small. The obvious conclusion is that it isn't there at all. There must be some simple law of Nature that we have yet to find that restores the vacuum and sets this vacuum energy equal to zero. Alas, such a hope may be forlorn. Last year, two teams of astronomers used Earth's most powerful telescopes together with the incomparable optical power of the Hubble Space Telescope to gather persuasive evidence for the reality of the cosmic vacuum energy. Its effects are dramatic. It is accelerating the expansion of the Universe. And if its presence is real, it will set the future course of the

Universe, and determine its end. What better place to begin?

chapter one

Zero – The Whole Story

> “Is it not mysterious that we can know more about things which do not exist than about things which do exist?”
>
> Alfréd Renyi[1]

> “Round numbers are always false.”
>
> Samuel Johnson[2]

THE ORIGIN OF ZERO

> “The great mystery of zero is that it escaped even the Greeks.”
>
> Robert Logan[3]

WHEN WE LOOK back at the system of counting that we learned first at school it seems that the zero is the easiest bit. We used it to record what happens when nothing is left, as with a sum like 6 minus 6, and anything that gets multiplied by zero gets reduced to zero, as with $5 \times 0 = 0$. But we also used it when writing numbers to signal that there is an empty entry, as when we write one-hundred and one as 101.

These are such simple things – much simpler than long division, Pythagoras’ Theorem, or algebra – that it would be easy to assume that zero must have been one of the first

pieces of arithmetic to be developed by everyone with a counting system, while the more difficult ideas like geometry and algebra were only hit upon by the most sophisticated cultures. But this would be quite wrong. The ancient Greeks, who developed the logic and geometry that form the basis for all of modern mathematics, never introduced the zero symbol. They were deeply suspicious of the whole idea. Only three civilisations used the zero, each of them far from the cultures that would evolve into the so-called Western world, and each viewed its role and meaning in very different ways. So why was it so difficult for the zero symbol to emerge in the West? And what did the difficulty have to do with Nothing?

As the end of the year 1999 approached, the newspapers devoted more and more copy to the impending doom that was to be wrought by the Millennium Bug. The reason for this collective loss of sleep, money and confidence was the symbol ‘zero’, or two of them to be more precise. When the computer programs that control our transport and banking systems were first written, computers were frugal with memory space – it was much more expensive than it is today.[4] Anything that could save space was a money-saving bonus. So when it came to dating everything that the computer did, instead of storing, say, 1965, the computer would just store the last two digits, 65. Nobody thought as far ahead as the year 2000 when computers would be faced with making sense of the truncated ‘date’ 00. But if there is one thing that computers really don’t like, it’s ambiguity. What does 00 mean to the computer? To us it’s obviously short for year 2000. But the computer doesn’t know it isn’t short for 1900, or 1800 for that matter. Suddenly, you might be told that your credit card with its 00 expiry year is 99 years out of date. Born in 1905? Maybe the computer would soon be mailing out your new elementary-school application forms. Still, things didn’t turn out as badly as the pessimists predicted.[5]

Counting is one of those arts, like reading, into which we are thrust during our first days at school. Humanity learned the same lessons, but took thousands of years to do it. Yet whereas human languages exist by the thousand, their distinctiveness often enthusiastically promoted as a vibrant symbol of national identity and influence, counting has come to be a true human universal. After the plethora of our languages and scripts for writing them down, a present-day tourist from a neighbouring star would probably be pleasantly surprised by the complete uniformity of our systems of reckoning. The number system looks the same everywhere: ten numerals – 1, 2, 3, 4, 5, 6, 7, 8, 9 and 0 – and a simple system that allows you to represent any quantity you wish: a universal language of symbols. The words that describe them may differ from language to language but the symbols stay the same. Numbers are humanity's greatest shared experience.

The most obvious defining feature of our system of counting is its use of a base of ten. We count in tens. Ten ones make ten; ten tens make one hundred; and so on. This choice of base was made by many cultures and its source is clearly to be found close at hand with our ten fingers, the first counters. Sometimes one finds this base is mixed in with uses of 20 as a base (fingers plus toes) in more advanced cultures, whilst less advanced counting systems might make use of a base of two or five.[6] The exceptions are so rare as to be worth mentioning. In America one finds an Indian counting system based on a base of eight. At first this seems very odd, until you realise that they were also finger counters – it is just that they counted the eight gaps between the fingers instead of the ten fingers.

You don't have to be a historian of mathematics to realise that there have been other systems of numbers in use at different times in the past. We can still detect traces of systems of counting that differ in some respects from the decimal pattern. We measure time in sets of 60, with 60

seconds in a minute, 60 minutes in an hour, and this convention is carried over to the measurement of angles, as on a protractor or a navigator's compass. Elsewhere, there are relics of counting in twenties:[7] 'three-score years and ten' is the expected human lifetime, whilst in French the number words for 80 and 90 are *quatre-vingts* and *quatre-vingtdix*, that is four-twenties and four-twenties and ten. In the commercial world we often order by the gross or the dozen, witness to a system with a base of twelve somewhere in the past.

The ten numerals 0, 1, . . ., 9 are used everywhere, but one other system for writing numbers is still in evidence around us. Roman numerals are often to be found on occasions where we want to emphasise something dynastic, like Henry VIII, or traditional, like the numbers on the clock face in the town square. Yet Roman numerals are rather different from those we use for arithmetic. There is no zero sign. And the information stored in the symbols is different as well. Write 111 and we interpret it as one hundred plus one ten plus one: one-hundred and eleven. Yet to Julius Caesar the marks 111 would mean one and one and one: three. These two missing ingredients, the zero sign and a positional significance when reading the value of a symbol, are features that lie at the heart of the development of efficient human counting systems.

EGYPT – IN NEED OF NOTHING

> "Joseph gathered corn as the sand of the sea, very much, until he left numbering; for it was without number."
>
> Genesis 41

The oldest developed counting systems are those used in ancient Egypt and by the Sumerians in Southern Babylonia, in what is now Iraq, as early as 3000 BC. The earliest