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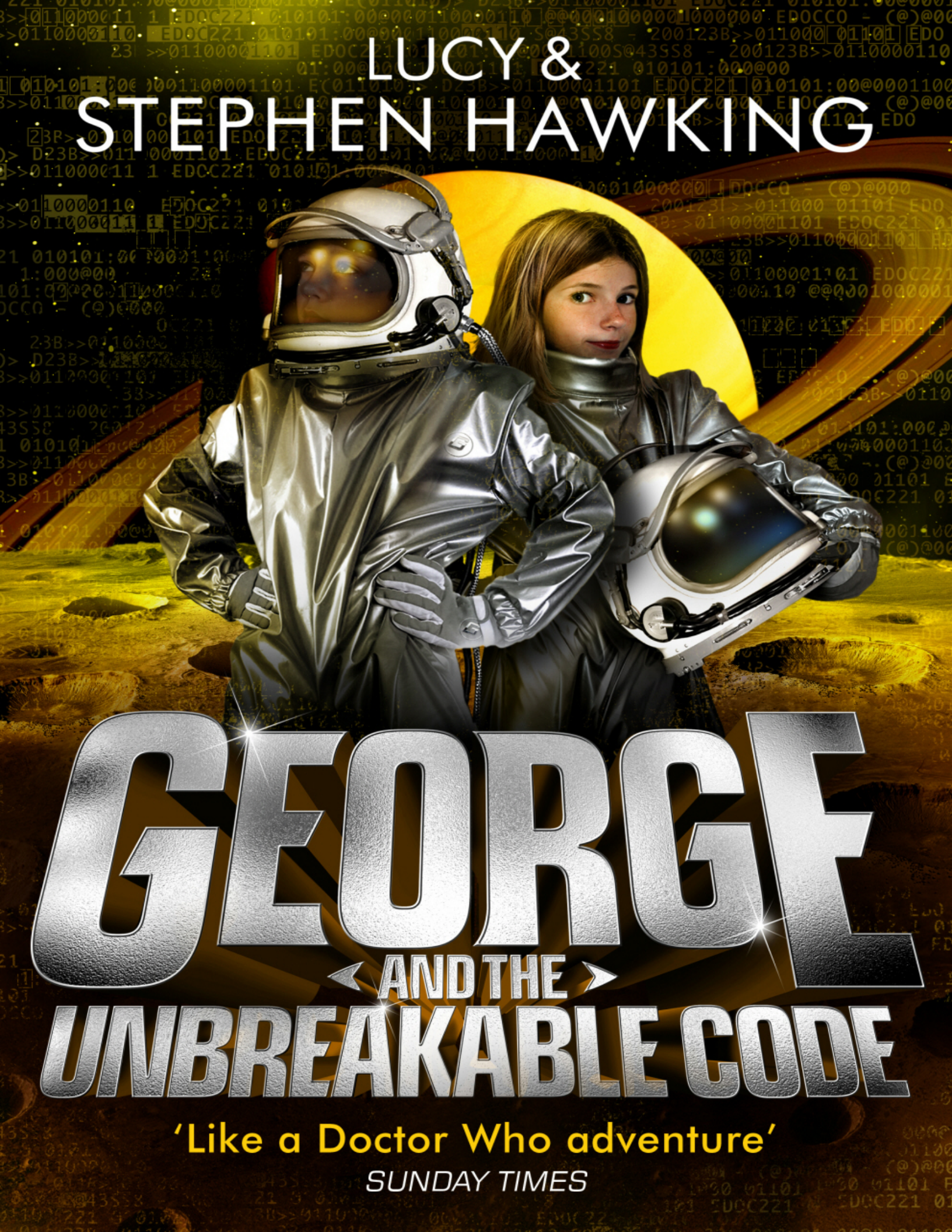

GEORGE AND THE UNBREAKABLE CODE

'Like a Doctor Who adventure'
SUNDAY TIMES

Contents

About the Book

George and his best friend Annie haven’t had any space adventures for a while and they’re missing the excitement. But not for long . . .

Seriously strange things start happening:

Banks are handing out free money; supermarkets can’t charge for their food; and aircraft are refusing to fly. It looks like the world’s biggest and best computers have all been hacked.

George and Annie must travel further into space than ever before in order to find out what – or who – is behind it.

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LUCY &
STEPHEN HAWKING

GEORGE AND THE UNBREAKABLE CODE

Illustrated by Garry Parsons

RHCP DIGITAL

To all those who have looked up at the night sky and wondered . . .

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Life in the Universe
by Professor Stephen Hawking
Director of the Institute for Theoretical Cosmology, University of Cambridge

With special thanks for the additional material to:
Dr Stuart Rankin
High Performance Computing Service, University of Cambridge

ON ANOTHER PLANET, the treehouse would have been the ideal spot for star-gazing. On a planet with no parents, for example, it would have been perfect. The treehouse – halfway up the big apple tree in the middle of the vegetable patch – was the right height, location and angle for a boy like George to spend all night staring up at the stars. But his mum and dad had other ideas, involving chores, homework, sleeping in beds, eating supper or spending 'family time' with his little twin sisters, none of which were of any interest to George.

All George wanted to do was take a picture of Saturn. Just one teeny photo of his favourite planet – the enormous frozen gas giant with its beautiful icy, dusty rings. But at this time of year, when the sun set so late, Saturn didn't appear in the night sky until nearly midnight. Which was so far past George's bedtime, there was no hope of his parents leaving him out in the treehouse until then.

Sitting with his legs dangling over the edge of the platform, George sighed and tried to calculate how many hours and days it would be before he was old enough to be free . . .

‘’S up?’ His train of thought was broken as a slight figure dressed in long baggy camo shorts, a hoodie and a baseball cap bounded onto the treehouse platform.

‘YOLO!’ George cheered up instantly. ‘Annie?’

Annie was his best friend, and had been ever since she and her mum and dad had moved to Foxbridge a couple of years ago. She lived next door, but that wasn’t the only reason why they were mates. George just liked her: Annie, the daughter of a scientist, was fun and clever and cool and brave. Nothing was beyond her – no adventure could be shunned, no theory go untested and no assumption stay unchallenged.

‘What are you doing?’ she asked.

‘Nothing,’ George muttered. ‘Just waiting.’

‘Waiting for what?’

‘For something to happen.’ He sounded miserable.

‘Me too,’ said Annie. ‘D’you think the Universe has forgotten about us now we’re not allowed to go on space

adventures any more?'

George sighed. 'D'you think we'll ever get to fly in space again?'

'Not right now,' said Annie. 'Perhaps we've had all our fun already; now that we're eleven, we've got to be really serious all the time.'

George stood up, feeling the wooden planks rock slightly under his feet. He was *almost* sure that the tree-house was safe and that there was very little chance they could both go crashing down to the hard ground below. He'd built it with his dad, Terence, out of stuff they'd scavenged from the local tip. And once, when they were busy constructing the 'house' part where he and Annie now sat, his dad had plunged his foot through a rotten plank. Fortunately he hadn't fallen through entirely, but it had taken all George's strength to pull him back up again, while below, on the ground, his twin sisters, Juno and Hera, shrieked with laughter.

The good thing about the mini-accident was that the treehouse was judged dangerous enough by George's parents for his toddler sisters to be banned from coming up the rope ladder. Which made George very happy. It meant that the treehouse was *his* kingdom, protected from the chaos of the rest of his house. Under strict instructions to pull up the rope ladder to stop eager small people from shinning up to join their beloved brother, George was very careful about security. He never left the ladder down. Which meant . . .

'Hey!' He suddenly realized that Annie shouldn't have been able to appear out of nowhere like that. 'How did you get up here?'

Annie grinned. 'I was bitten by a spider when I was just a baby,' she intoned dramatically. 'Which gave me special magic powers that I am only just coming to understand.'

George pointed over to the knotted rope that he had just spotted lassoed onto the end of the thickest branch. 'Is that

your work?’

‘It is,’ admitted Annie in her normal voice. ‘I just wanted to see if I could do it.’

‘I would have let the ladder down for you,’ George told her.

‘Last time I asked you to do that,’ she complained, ‘you made me guess about a thousand million different passwords and I still had to give you half my Kit Kat.’

‘That wasn’t a Kit Kat!’ George reminded her. ‘It was a piece of “chocolate”’ – he used his fingers to make comma marks around the word – ‘you’d tried to create under lab conditions, done up in a Kit Kat wrapper to see if I could tell the difference.’

‘If a mouse can grow an ear on its back,’ protested Annie, ‘then why can’t I grow a Kit Kat? It’s got to be possible to make self-replicating chocolate molecules that just keep on doubling.’

Annie was a budding experimental chemist. She often used the kitchen as her own personal laboratory space, which drove her mother, Susan, crazy. Her mum would reach into the fridge to get a carton of apple juice, and encounter crystalline protein growth instead.

'FYI,' said George. 'Your Kit Kat tasted like a dinosaur's toe—'

'It did not!' interrupted Annie. 'My home-grown chocolate was delicious. I don't know what you mean. And when have you ever chewed a dinosaur's toe anyway?'

'Toenail,' finished George. 'Seriously gross. Like it had been fossilized for a trillion years.'

'ROFL,' replied Annie sarcastically. ''Cos you're, like, *so* gour-may.'

'You don't even know what gourmet means,' George retorted.

'Do so.'

'What is it, then?' George was pretty sure he'd won this one.

'It's like when you have some gours,' explained Annie, 'and it's the month of May. It makes you go all *gour-may*.' She just made it to the end of the sentence before bursting out laughing – so hard that she fell off the beanbag.

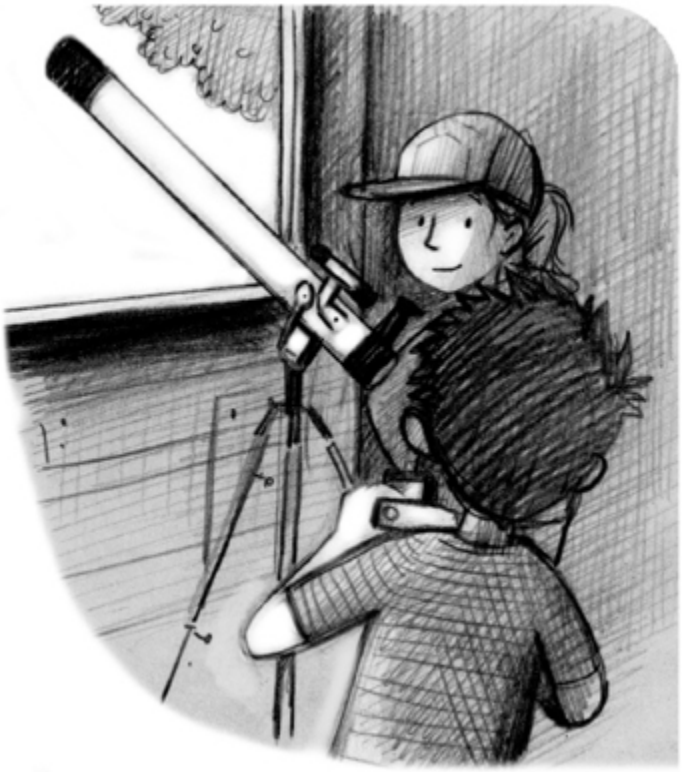
'You're an idiot,' said George good-naturedly.

'With an IQ of 152.' Annie picked herself up off the floor. She'd had her IQ tested the week before and she wasn't about to let anyone forget the results. Suddenly she spotted the line-up of George's possessions. 'What's all this?'

'I'm getting my things ready.' George pointed at the equipment, which had been rescued from the tiny hands of his twin sisters and borne up to the treehouse for safety. There was a 60mm white telescope with black bands at each end, and a camera which he was attempting to rig up to the telescope so that it could take a picture. The telescope had been a present from his grandmother, Mabel, but amazingly, the camera had come from the tip. 'So I can

get photos of Saturn when it gets dark. If my *boring* mum and dad don't make me go in. It's my half-term project.'

'Cool!' Annie squinted into the viewfinder of the telescope. 'Ew!' she exclaimed immediately. 'It's got something sticky on it!'



'What!' shouted George.

He looked at the telescope more carefully. Sure enough, around the viewfinder was some kind of gluey pink substance.

‘That’s *enough*!’ His temper suddenly exploded. He started to climb down the rope ladder.

‘Where are you going?’ Annie scrambled after him. ‘It’s no biggie! We can clean it off!’

But George had steamed ahead, back into his house, his face red with fury. He barged into the kitchen, where his father was attempting to give Juno and Hera their tea.

‘And *one* for Dadda!’ Terence was saying to Hera, who opened her mouth, accepted the green goo and promptly spat it back at him. Hera then shrieked with laughter and banged her spoon maniacally on the tray of her high chair, which made all the other bits and bobs of food jump around like Mexican beans. Juno, who tended to copy her twin, joined in, banging her spoon and making a disgusting wet farting noise with her lips.

Terence turned to look at George, an expression of mixed suffering and joy on his face; green slime dripped off his beard and down his home-made shirt.

George took a deep breath to start on his angry tirade about small people who messed up other people’s stuff, but Annie managed to squeeze past him just in time.

‘Hola, Mr G!’ she sang cheerily to Terence. ‘Hello, baby girls!’

The girls banged their spoons and gargled eagerly at this new distraction from dinner time.

‘Just wanted to ask if George could come over to mine!’ chirped Annie. She reached out a hand to tickle Hera under her soft sticky chin, which made the little girl dissolve into helpless giggles.

‘What about my telescope?’ George muttered crossly behind her.

‘We. Will. Sort. It,’ she said firmly back to him in a low voice. ‘So lucky to have baby sisters,’ she cooed over the twins. ‘I wish I had lovely ickle baby sisters. I’m just a one and only lonely child . . .’ She pulled an exaggeratedly sad face.

‘Hmph.’ George would have liked nothing better than to live in Annie’s quiet, geeky, techno-obsessed household, with her scholarly father and her increasingly career-minded mother. Where there were no babies, no noise, no organic vegetables and no mess – except, perhaps, when Annie had been conducting one of her more ‘interesting’ experiments in the kitchen.

‘Er, yes, you can go – but make sure you’re back in time to do your chores,’ said Terence, trying to sound like he was in charge.

‘Great!’ shouted Annie enthusiastically, pushing George back out of the door.

George knew that when Annie was in bossy mode, he just had to go with the flow. So he followed, which wasn’t so hard: he didn’t feel like hanging around at home in a bad mood when a visit to Annie’s house was on offer.

‘Bye, Mr G and baby Gs!’ bellowed Annie as they ran off. ‘Have a wonderful time!’

‘Don’t forget, George, you need to fill in your reward chart by completing your weekly tasks!’ Terence called weakly after the departing figure of his oldest child. ‘You’ve still got three fifths of the pie-chart left!’

But George was gone, swept away by Annie to the exciting domain of Next Door – the home of all things techno, cutting edge, scientific, electronic and amazing in George’s eyes.

THEY REACHED ANNIE'S house by means of a hole in the fence between the two gardens. The hole had been made when Freddy the pig – another present from George's enterprising Granny Mabel – broke through from the Greenbys' back garden in a bold bid for freedom. Following Freddy's hoof prints that afternoon had led George to meet Annie and her family for the first time – her dad, mega-scientist and super-boffin Eric; her mum, musician Susan; and their super-computer, Cosmos, who was so powerful and intelligent, he could draw doorways through which you could walk to any part of the known Universe you wanted to visit (provided you were wearing a spacesuit, that is). Since that day, George had surfed the Solar System on a comet, walked on the surface of Mars, and had a showdown with an evil scientist in a distant solar system. It was fair to say that his life had never been quite the same since.

'Hey!' said Annie as they ran. 'You shouldn't be mean to your sisters.'

'What?' George wasn't thinking about his baby sisters any more. 'What are you talking about? I wasn't mean!'

‘Only ’cos I stopped you,’ accused Annie. ‘You were going to say something horrible.’

‘I was angry!’ George replied indignantly. ‘They’re not supposed to touch my stuff or go up to the treehouse!’

‘You’re lucky to have a brother or a sister at all,’ said Annie piously. ‘I haven’t got anything.’

‘Yes you have!’ George burst out. ‘You’ve got so much stuff! You’ve got Cosmos the computer, you’ve practically got your own science lab, you’ve got an Xbox, you’ve got a smartphone, a laptop, an iPod, an iPad, an i-everything; you’ve got that mechanical dog; you’ve got a scooter with a motor on it . . . I dunno . . . You’ve got the lot.’

‘It’s not the same,’ said Annie quietly, ‘as having a real-life brother or sister.’

‘If you actually had one,’ said George dubiously, ‘or even two, I bet you wouldn’t want it. Them.’

The two friends hurried through the door into the kitchen.

‘Huzzah!’ Annie skidded across the floor towards the huge fridge, reaching out to grab the handle.

Even the Bellises’ fridge didn’t look like a normal fridge – more like the sort of thing you might find in a laboratory: massive and made of steel, with cavernous drawers and separate compartments for isolating elements from each other. It was, of course, a professional machine, as far removed from a normal fridge as a spaceship is from a paper aeroplane. That was one of the things George loved about Annie’s house: it was full of unexpected gadgets and scientific oddities which Eric had bought or acquired or been given in the course of his many years of work. George looked at the fridge enviously; it glowed with a strange blue light. The most technologically advanced item in his whole house probably contained less processing power than Annie’s refrigerator.

George was just musing on that depressing fact when he realized that there were voices coming from the sitting room.

‘Annie! George!’ Annie’s dad, Eric, stuck his head round the kitchen door. He was smiling broadly, his eyes sparkling behind his thick glasses, his tie loosened and his shirt sleeves rolled up. He came in carrying two crystal glasses.

‘I’ve come to get a fill-up,’ he explained, reaching for a dusty old bottle and pulling the cork out with a loud *thop*. He poured out a sticky brown fluid and turned to go back to the sitting room.

‘Come and say hello to my guest.’ His face was creased into long laughter lines. ‘I think she has something that might interest you.’

George and Annie immediately forgot their brief argument and followed Eric into the sitting room, which was packed from floor to ceiling with rows and rows of books. It was a beautiful room, full of interesting objects like Eric’s old brass telescope. The cutting-edge technology that ruled the rest of the house was less overwhelming here; it was cosy and inviting rather than cool and futuristic. On the squashy sofa, which Eric had owned since his student days, sat a very ancient lady.

‘Annie, George,’ said Eric, handing the old lady her glass of sherry. ‘This is Beryl Wilde.’

Beryl accepted the drink gratefully and started slurping it straight away. ‘How d’you do!’ She waved a cheery hand at them.

‘Beryl is one of the greatest mathematicians of our times,’ said Eric seriously.

Beryl burst out laughing. ‘Oh! Don’t be absurd!’

‘It’s true!’ he insisted. ‘Without Beryl’s mathematical genius, millions more people would have died.’

‘What people?’ asked George.

Annie had whipped out her smartphone and was trying to pull up a Wikipedia entry for Beryl Wilde.

‘How do you spell your last name?’ she asked.

‘You won’t find it,’ said Beryl, guessing what Annie was trying to do, her pale blue eyes twinkling. ‘I’m completely covered by the Official Secrets Act. Still, even after all these years. You won’t find me anywhere.’

Eric gestured to an object on the coffee table in front of the sofa. ‘This,’ he said dramatically as he pointed to what looked like an old-fashioned typewriter, ‘is an Enigma machine – one of the ones used during the Second World

War to encode messages. It meant that messages could be sent that were impossible for interceptors to understand. But Beryl was one of the mathematicians who broke the Enigma code. Which meant that the war ended much sooner than it might have done, and fewer people on both sides lost their lives.'

'OMG!' said Annie, looking up from her phone. 'So you could read the secret messages without the other people realizing you knew what they were planning? Like, if someone read all my emails now . . .? Except, obviously,' she added, 'I'm not fighting a war with anyone. Except Karla Pinchnose, who made everyone laugh at me when I spelled something wrong on the smartboard . . .'

'Exactly.' Beryl nodded. 'We could intercept their messages and decrypt the content so we knew what they were planning to do. That gave us a huge advantage.'

NUMBER SYSTEMS

Decimal

Our everyday numbering system – the *decimal* system – is based on a factor of 10. We number from 1 to 9, and then go to a new column for the number of '10's.

36 = 3 × 10, plus 6 × 1
48 = 4 × 10, plus 8 × 1
148 = 1 × 100, plus 4 × 10, plus 8 × 1
And so on.

Binary

With early computer systems, a *binary* numbering system was used. This is because binary is based on a factor of 2, so the only digits used are 0 and 1.

10 = 1 × 2, plus 0 × 1 i.e. the number 2 in the decimal system
11 = 1 × 2, plus 1 × 1, i.e. the number 3
111 = 1 × 4, plus 1 × 2, plus 1 × 1 i.e. the number 7

The 0/1 choice could be linked to switches in the computer circuits so that 0 = 'off' and 1 = 'on' and code written in binary could then make the circuits turn themselves on and off as needed to make calculations.

Hexadecimal

Nowadays, computers are much more sophisticated and codes are often written using a *hexadecimal* numbering system, based on a factor of 16. This counts figures from 0 to 9 but then also uses A for ten, B for eleven and so on up to F for fifteen.

C therefore represents 12 in the decimal system
10 is the hexadecimal way of writing the number 16
11 = seventeen
1F = 1 × 16, plus F × 1 (15) = 31
20 = 2 × 16 = 32
F7 = F × 16 (15 × 16 = 240), plus 7 × 1 = 247
100 = 256

CODE BREAKING

Code breaking usually means the unscrambling or decryption of messages, without having access to the secret key which the person who sent the message used. Another name for this is *cryptanalysis*, and a particular method of encryption is also called a *cypher*.

Before computers

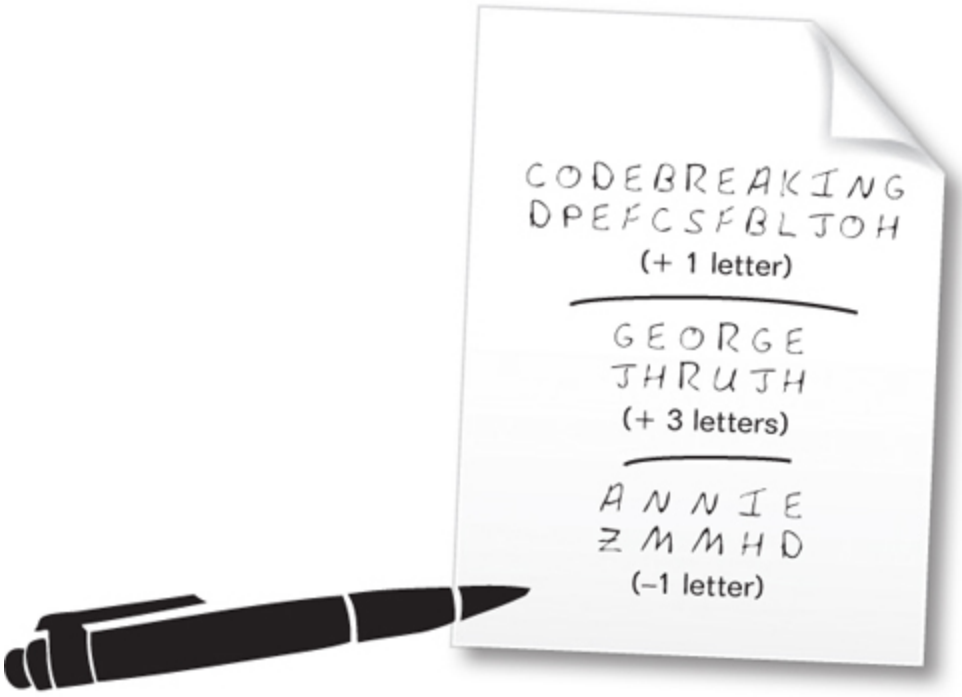
Until the arrival of digital computers, encryption worked on letters, or on numbers representing letters. For example, each letter appearing in a message might be replaced with another letter. In a simple code, A would be replaced by E, B replaced by F and so on through the alphabet. Or the alphabet would be scrambled in some way.

To solve this sort of cypher, a good approach is to count how often each letter appears in the encrypted text (this is called *frequency analysis*) and then guess some of the substitutions. For instance the letter ‘e’ appears in a great many words, and if the letter ‘s’ is in the coded message, then this might mean that ‘s’ = ‘e’. This can be enough to correctly guess the remaining substitutions since the original message has to make sense.

More complicated cyphers might use a different scrambling of the alphabet for each letter of the message – and there are a very large number of possible scramblings to choose from: 26 letters in the alphabet, so 26 possible letters for the first letter, then 25 for the second, 24 for the third and so on.

Modern code-breaking

Modern methods work not on letters but on bits (1s and 0s) in the memory of a computer. Encryption and decryption use a secret key, which is a long sequence of bits (1s and 0s). A key 256 bits long today is thought to be quite sufficient to prevent a code-breaker using a supercomputer to find the key by brute force (i.e. by trying every possible key).


CODEBREAKING
DPEFCSFBLJOH
(+ 1 letter)
GEORGE
JHRUJH
(+ 3 letters)
ANNIE
ZMMHD
(–1 letter)

‘Wowzers!’ said Annie. ‘Props to you, Bez!’ She went back to typing on her phone.

‘Is that *really* an Enigma machine?’ George gazed at it with longing. He couldn’t believe that yet another amazing gadget had found its way into the Bellises’ house. He wished for the millionth time that he’d been born into this home instead of his own.

‘It is,’ said Beryl, smiling at him. ‘And I’m giving it to Eric. As a present.’

Eric gasped. He’d clearly had no inkling of her intention. ‘You can’t do that!’ he exclaimed.

‘Yes I can!’ Beryl was firm. ‘It’s for your Department of Maths at the university. You are exactly the right person – with your work on quantum computers, I can’t think of a better home for it.’

‘What’s a quantum computer?’ George asked. This was news to him – and exciting news too. He remembered that Eric had been very secretive for quite some time now – George hadn’t been able to get anything more than a very vague answer from the great scientist as to what he was working on at the moment.

But tonight, Eric seemed in a much chattier mood than usual.

‘It’s the next wave of change,’ he told George. ‘We’ve had the *digital* revolution in information, and now we are on the brink of the *quantum* revolution. If we could make a quantum computer – and control it, which looks very difficult right now – we could do things that are unimaginable with the current generation of computer technology.’

ENIGMA

Wartime secrets

By the time of the Second World War (1939–1945) the warring nations were using machines such as the *Enigma* (in Germany) and the *Typex* (in Britain) to encrypt important messages. The operator of the Enigma machine typed the message on keys on the front of the machine, and the machine produced the encrypted text, indicating each scrambled letter by lighting a small electric bulb. The encrypted message was recorded by hand, turned into Morse Code and finally sent by radio.

Three rotors

The Enigma machine had three rotors – *wheels* – containing complicated wiring. The rotors could be taken out and put back in a different order, then rotated so that each of the three could be in any of 26 different positions. This meant that there were six possible ways of setting the three rotors (3 × 2 × 1) and then 26 × 26 × 26 positions of each letter. To make this even more complicated, up to ten short wires could be plugged into a plugboard at the front of the machine – each of the many ways of doing this would create an entirely new set of 26 × 26 × 26 cyphers for a message to use. At the receiving end, there would be another Enigma machine set up in exactly the same way, and the scrambled text would be typed in. The original text could then be recovered by recording which lights lit up. The idea was that each day, every Enigma operator would know which rotor to insert where, in what position, and with what connections on the plugboard.

Breaking Enigma

The encryption system relied on a shared secret, in this case the daily instructions for setting up and using the machine – and the problem was how to securely share it with many people. A mistake by any of them could give away important information, and printed instructions could also be stolen or captured. Through a combination of German errors, advanced mathematics and ingenuity, code-breakers – first in Poland, and then later at Bletchley Park in England – managed to discover the settings of the Enigma machines and were able to decrypt German messages. A crucial part of the method was a

particular machine – a machine designed by Alan Turing, a maths genius, known as the *Bombe*. Another important machine developed at Bletchley Park was the Colossus – the first electronic, programmable digital computing machine – which was used to break code produced not by Enigma but by another German cypher machine called the *Lorenz*.

THE UNIVERSAL TURING MACHINE

An imaginary device

In 1936, a ‘computer’ was a human being performing calculations. The Turing Machine developed by genius mathematician Alan Turing was intended to be a simple imaginary device capable of reproducing everything a human computer might need to do while calculating. The machine is therefore a mathematical, rather than a real-world, device to be used to understand what computation is, and what can be achieved by computation. But it could not exist in reality; for example, it is assumed to have both infinite ‘memory’ and an unlimited time in which to operate, neither of which are feasible.

A string of 0s . . .

The operation of a machine is first defined by a finite list of coded instructions. Imagine a very long tape on which is written a very long string of 0s (as long as the tape itself). The tape stretches out for ever in both directions (assume it is infinitely long) and represents the ‘memory’ of the computing machine. Sprinkled among these 0s are finitely many 1s which represent the ‘data’ given to the machine. Sitting on this tape is the processing device (the processor) that can read just the one symbol that is currently directly beneath it and it can leave it as it is, or replace it with either 0 or 1.

It also has a clock which ticks steadily, and at each tick of the clock, the processor reads the symbol it can currently see. It then does one of two things depending on what it just read and its current state. It can:

- change the symbol beneath, marking it as 0 or 1, then move one position either left or right along the tape, maybe change to a different state, and wait for the next tick.
- or do the same but then halt (turn off).

What it *actually* does depends on the rules (the ‘program’) we give it, and what it finds on the tape. As an example, let’s assume that the machine starts out in state 0, with a long string of 0s on the tape, and that somewhere to the right of it some of the 0s have been replaced by 1s – these 1s form a pattern which is the binary number we give the machine as its input.

Then a good rule to start with is: *if in state 0 and we read 0, then switch to state 0, write 0, and move right*.