Some London heroes of science and technology

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I'm dead chuffed to come here. It's really exciting, it's a great place, it's been going for 400 years. Gresham College has housed, or harboured, or whatever the word is, some of the finest scientists that we've had in this country, so it's absolutely terrific to be invited to give a lecture here. I love too the Museum of London, which has been kind and generous and helpful to me on a number of occasions. I'm sorry about this weapon (referring to his walking stick). It's my folding Kalashnikov, and I use it for prodding old ladies and lift buttons and tripping up terrorists. I'm expecting a medal from George W. Bush any day! I'm also expecting a new hip in a few weeks, so that's why I'm hobbling around like an old person!

I want to talk about some heroes of London, and they're all scientific. I'm going to cover these people roughly in chronological order, not entirely accurately. They're not all Londoners born and bred, as you will guess from Cornelius Drebble, who was a Dutchman.

He came over to this country in the late 16-teens, and with a whole mass of wonderful ideas. I don't know why he came over; perhaps he thought this was a hotbed of innovation where he could get himself a good patent. We'd incidentally just started the patent system in 1614. Anyway, the first and most spectacular thing he came up with was the submarine, which was allegedly the world's first submarine, and it was essentially two rowing boats, one the right way up, and the other upside down stuck on top of it, with a greased leather seal in between to keep the water out. The first one had probably only four chaps in it, but now we've got, well it's either six chaps with two oars each, or twelve chaps in there. It went along underwater, and they can row – and if you think about it, you can row under water. You've got to feather your blade rather carefully so it goes through the water sideways and then turn it round and pull it back. They offered the king a trip in this submarine, and he remembered a pressing engagement somewhere else! They allegedly rode this thing from Westminster to Greenwich and back under water in three hours. Now I reckon you could do it in a police launch, but in a submarine, a submarine which had a maximum speed of maybe two or three miles an hour, a submarine where you couldn't see where you were going? There aren't any windows on this thing, you know, and they didn't have compasses, so how on earth…so it all seems to me a little bit dodgy, but allegedly, allegedly this was the world's first submarine.

We jump forward to our first Gresham man, Robert Hooke. This I have to say, this is not Robert Hooke! There is no known portrait of Robert Hooke, although Lisa Jardine would disagree, but there is no generally accepted portrait of Robert Hooke. The only one that was known to exist mysteriously disappeared when Newton took over at the Royal Society after Hooke had died – they were not the best of friends, those two. Robert Hooke was an extraordinary man, born on the Isle of Wight at Freshwater. He came to London to be educated at Westminster, and then he went off to Oxford, to work with Robert Boyle and others. He was Robert Boyle's his hands and his eyes, because Robert Boyle had terrible eyesight and was not very good with his hands. Hook made him all his apparatus and probably worked his stuff for him. He certainly made his air pump, with which they did some wonderful experiments, and they essentially invented the barometer.

Torricelli had realised that if you put mercury in a tube and you tilt it up, and the bottom is in a pool of mercury, the top will rise only 75 centimetres, 30 inches, above the level of the mercury. Above that, you get a gap in your tube, and there was tremendous argument about whether this was a vacuum. People said no, no, nature abhors a vacuum, it can't be a vacuum, there must be air bubbling up. So you bring the tube down again and the hole fills up with mercury, so clearly there isn't any air there. They argued and argued, and Hooke and Boyle looked at this thing, and they realised that the level goes up and down a bit

from day to day. They thought that may be the level of mercury in the tube was to do with the phases of the Moon, and that when you had high tide; you had high mercury and so on. They watched it every month, and they found it had nothing whatever to do with the Moon, it was all to do with the weather, so essentially they invented the barometer.

That was one of Robert Hooke's first things. He came to London. He became curator of experiments at the Royal Society, and he became Professor of Geometry at Gresham College, and he held this post until he died, a remarkable man! He had great skills. Some people say he was the greatest experimental scientist of all time. Unfortunately, he had the habit of when somebody invented something brilliant, Hooke would say, oh yes I made one of those last year and it worked better than yours! When Newton wrote his first ever paper about the colours of the rainbow in 1672, it was given to Hooke to comment on, and Hooke wrote what I reckon was meant to be sensible peer review, but unfortunately he said that Newton 's critical experiment didn't work and that his theory of colours was entirely wrong. Newton took this as personal insult, and he refused ever to publish anything again about optics until after Hooke had died – that was the beginning of their great dispute.

In 1665, Hooke, which was the year he was appointed Professor of Geometry here, Hooke produced this amazing book called "Micrographia". It was the world's first scientific bestseller, or if you like, popular science book. All the previous important science books had been written in Latin, and indeed subsequent ones were as well, but this was in English, and it's very readable, it's immense fun! It's a huge book. I have a facsimile edition, which I love dearly, and I have to keep taking it down off the shelf to check things out. In it, there are the loveliest drawings, because he'd made himself a microscope. The microscope had been around for 60 odd years, but nobody had actually used it, or almost nobody had used it for scientific things, and he did, and he drew these great pictures. A famous one is his flea. It comes towards the end of the book, and it's a pullout thing, so the flea is very big; it really hits you in the eye. Before then, everyone thought fleas were little black dots that bit you, and suddenly they could see it was a great monster with claws and teeth. And all sorts of other things he did. He drew a lovely picture – he was a great artist - of some taffeta linen, just the threads interwoven, seen through his microscope. That inspired a Dutch cloth merchant, called Antony van Leeuwenhoek, who was so intrigued that he made his own microscopes, and actually he was a much better microscopist than Hooke, although a rotten artist, and he saw bacteria. He had a microscope that would magnify 300 times, and he invented microbiology, as a direct result of seeing Hooke's book.

Hooke also, in the same book, had pictures of the Moon. He looked at the Moon through a telescope. He said: "The vale on the Moon seems to give a much fainter reflection than the more barren tops of the hills, so the vale may have vegetables analogous to our grass, shrubs and trees." It's wonderful how people have to guess from the imperfect observations they make. I was lucky enough to be at around in the middle of January when Halgon's probe landed on Titan. It was wonderful. The moment pictures came off the computer screens, everyone there was speculating wildly about what they were - were they clouds, were they this, were they that – and it's exactly the same with Hooke. This was the best he could get of the surface of the Moon, and so he wondered whether there were grass, shrubs and trees. Well you know, we now have better pictures, we've been there, we know there aren't, but it was a lovely example of scientific deduction and the best guess you can make.

He was a great frequenter of coffee houses, which had come in around 1650, the first one in Oxford, and then they proliferated in London, and it was in coffee houses where everyone did all their gossip, swapped stories, finance, political intrigue, they read newspapers, they wrote newspapers. Hooke mentions visiting 154 of them – that just gives you some idea. They were a bit like the pubs are today, I guess, or the wine bars of the City, where I gather the brokers go and unload their troubles over gin and tonic, or maybe they don't bother about the tonic any more!

In the coffee bars, he would meet, every day, two great friends. He was a very sociable guy, was Hooke, and one of his great friends was Edmond Halley. Halley was the second Astronomer Royal, another remarkable man. He gave up his degree at Oxford, he didn't bother to finish it, he went off to Ascension Island and started observing the southern sky, which wasn't much good because the weather was too awful, but everyone thought he was wonderful. He came back. He remained friendly with Isaac Newton, one of the few people who remained a friend of Isaac Newton for many, many years, and he persuaded Newton to write "Principia". Newton couldn't be bothered, and Halley went to see him and said you'd worked out some mathematics about gravity, could you possibly let me have a copy? Newton was actually bullied into writing things down, and eventually the outcome was "Principia". The Royal Society wouldn't publish it because they'd just published some enormous biological book, and so Halley actually paid for the

publication of “Principia”. Without him we wouldn’t have had what is arguably the world’s greatest textbook.

And then he made this fantastic prediction – it was one of the great things of science. Science is all about observation and experiment and prediction. If by making observations and guessing what’s going on you can then make a prediction if it comes true, then you may be right with your suggestion, your theory. Halley observed this comet in 1682, and he said I think we’ve seen this before, I think it’s he same one that was seen in 1607, and in 1531, and in 1456, and therefore it’s coming back every 75 years, and I predict with some confidence that it will return in the year 1758, and it did, on Christmas Day. Unfortunately, he didn’t live to see it – very few people live to see Halley’s Comet twice – but it came back, and that was one of the great predictions of science. It turns out that that same comet had actually been seen in 1066. It’s woven into the Bayeux Tapestry, which is basically a strip cartoon of the Norman invasion of Britain, and there over the top is the comet coming in – it’s wonderful. The Chinese had seen it for ages and ages, but it was lovely that Halley knitted this all together. He also invented the diving bell and various other things. He’s generally an all-round good egg.

And the third of this trio of friends – Hooke, Halley – was Christopher Wren. This is a poem written about him, Sir Christopher Wren, which said, I’m going to dine with some men, if anyone calls, say I’m designing St Paul ’s. A great poem by Edmund Clerihew Benson, who wrote I think only about three of them that are worth remembering, and that’s one of them. Wren was another extraordinary bloke. He went to Oxford, where he got involved with the group that met there, with Robert Boyle and others, and then he came to Gresham College to be Professor of Astronomy, and it was in his rooms at the Royal Society, or the fledgling invisible college as Boyle sometimes called it, used to meet. Some of them met in Oxford, some of them met in London, and it was in Wren’s rooms. It was at a meeting in 1660 that they decided to make themselves more formal and to invite 14 new members. They drew up a list of them, and they asked the King to join and eventually he agreed, and they became the Royal Society, and then the Royal Society of London for the Improvement of Natural Knowledge. I don’t know why they changed the name; it would have been better just to call it the Royal Society, wouldn’t it? Anyway, he was, if you like, the founder of the Royal Society, and a great man. Hooke wrote a wonderful thing about him in the preface of his book, “Micrographia”. He said there scarce ever existed since the time of Archimedes a man with such a delicate hand and such a philosophical mind. It was a very moving tribute.

Wren was a great thinker and a brilliant artist. He probably would have been a good scientist, but he never got round to finishing very much. He had so many things on the go that he was always running from A to B, and sometimes he got things slightly wrong, from some people’s point of view. For example, soon after they’d persuaded the King to set up the Royal Society, Wren invented a new instrument, which was a sort of micrometer; it was an improvement on the micrometer of William Gascoigne. Basically, he had a telescope, and at the focal plane of the telescope, he had cross hairs which he was able to move sideways with little micrometer screws, and he trained this telescope on the Moon, and then he moved his micrometers to pinpoint the positions of all the craters he could see on the Moon, and the mountains and so on, so he was able to get a very accurate map of the Moon by using this new instrument he designed. And then he made a beautiful globe, a model of the Moon, about the size of a football, out of alabaster I think it was, and he told the people at the Royal Society, and they said, oh good, why don’t we give it to the King and then he’ll be really chuffed. So Wren went straight to the King and gave it to him, and the people at the Royal Society never saw this globe of the Moon, and they were bit pissed off about that – sorry, that’s a technical term that astronomers use!

Then his uncle or someone said oh, you’re a very good artist, why don’t you design a building? Pembroke College in Cambridge needs a new chapel, why don’t you design it? So he did, and then he designed the Sheldonian Theatre in Oxford, which I went to last summer to see a degree ceremony and unfortunately the roof’s leaking, so he didn’t do a very good job, did he?! But it’s a beautiful building… And then there was the Great Fire of London, and London had to be rebuilt, and the King said why don’t you rebuild London? So he dropped all his science and he became an architect – just like that. He never went to architecture school or anything, he just did it. He had a wonderful gig with St Paul’s, because he put in a design and the church commissioners refused it, and he put in another one and they did it again, and he put in another one and this time he gave it to the King, and he said would you mind approving this, and the King said yeah great, and so the church commissioners said oh, that’s a really good design! What Wren had done, very cunningly, was to say the architect has the right, for any reasons he deems necessary, to alter the design where it seems like a good idea – in other words, he was allowed to build absolutely anything! The picture he drew was complete nonsense. So in the end, he made this thing with a vast dome, at enormous expense, and it was very beautiful, and they were very unhappy about it, but it has stood

there for whatever it is, 400 years, and it was his masterpiece.

So I'm proud of Christopher Wren. I think he was a terrific chap, and I also learnt another thing about him. I was taken to Greenwich, to the Royal Naval College, and we went into the wonderful hall with the painted ceiling, the painted hall, and I actually went up above the ceiling into the roof space, and saw how he arranged his roofs, and it was absolutely brilliant. Inigo Jones had been to Italy, and had come back with an idea of the king post truss, which I will try and explain. Tudor roofs had walls, and then they had rafters, and then they put all the roof on top of the rafters, and the result was there was tremendous force pushing down and pushing the walls outwards, and that was a real problem. The idea of the king post truss was that they put a beam across over the walls, up from that they put a post to the top, and the post upwards was held up by the rafters. It stuck on the shoulders, on the vertical post, which was the king post, and then the weight of the roof was actually taken by subsequent rafters sticking outwards, so that all that weight was on that king post, which was the intention, and the beam going across the top of the walls held the weight and the walls were not pushed outwards. This had two effects: first, the roof did not collapse because the weight on the walls was straight downwards; and second, you had this beam going across over the walls and you could hang a ceiling under it, and he hung them as beautiful ceilings, great flat ceilings, which people said was impossible, because until you had that design, you couldn't do it. Wren extended this to the queen post truss, which is having two verticals and putting a flat piece across them, between them, and that's why he was able to do that painted ceiling. And there's lovely story about the Guild Hall in Windsor, which is a similar design, a lovely room with a great flat ceiling. The people who had commissioned that were dead worried about this ceiling, they were sure it was going to collapse, so they told him to build pillars inside. Very reluctantly, he did, he put in a whole lot of pillars, and according to legend, he deliberately made them one inch short, and there was still an inch gap between the pillars and the ceiling! So that was Christopher Wren – a great scientist, a great architect, and another all round good egg!

Now, Eleanor Code – she was a very remarkable woman. She was born in Exeter in 1733, her dad was a wool merchant, not very successful, he went bust. She came to London to escape her family problems, she worked a bit for a milliner, and then in 1769 she set up an artificial stone factory on the South Bank, roughly where the Festival Hall is today. Indeed, right outside the Festival Hall, in a rather dingy bit of concrete bank on the Embankment, is allegedly one of her millstones, just set into the concrete. 1769 incidentally, when she set up the place, was an extraordinary year for innovation. James Watt took out his first patent, Richard Arkwright took out his first patent for the cotton spinning machine, Nicholas Cunio in France built the world's first steam powered vehicle, and Wolfgang von Kempeland build the mechanical chess player, the turk, which was an extraordinary and improbable creation. Anyway, she set up her artificial stone factory, and she began making artificial stone, and she continued to make it for 51 years until she died, very successful, very beautiful pieces, and you know, very unusual for any woman to run any business in the 18 th Century.

There is a lion on the south end of Westminster Bridge, just across from the Houses of Parliament. It's actually looking upriver towards MI6, which is presumably why it has this snooty expression on its face! It was originally made for the Lion Brewery, which is why it's a lion, and you'll notice that it's very elegant, it's very beautiful, it's definitely a lion – it's not a horse or a dog or anything. It's got great artistic merit, and it's in incredibly good nick. This is 200 years old – it has not eroded, it's not worn away by the grime and the smog and all that, because her artificial stone simply does not erode. It's a ceramic material. It's like stoneware you use for casseroles and things like that. She would take clay, mixed with various secret ingredients, grog and stuff, force it into moulds, then take off the mould and finish it off by hand, and then fire the whole thing in a kiln. So she must have had a huge kiln, because this thing is about ten feet long, and it shows no sign of having been made in two pieces. So it's very, very impressive, and the result was these amazing pieces, which last essentially for ever. There are 650 of her pieces still in existence. There is a river god at Hamhouse in Surrey. There's Captain Bligh's tomb. There are a couple of pillars holding up Shambrook House in Pall Mall, and I'm told that the entrance to the zoo at Rio de Janeiro is code stone, so if anyone's going there, please send me a postcard. Somebody did send me a postcard from Rio but it wasn't the zoo, so it's not quite the same thing. So she was a splendid woman.

There is a piece at the Naval College at Greenwich, about 40 feet long and it's on top of a building. It commemorates all of Nelson's battles, and has Britannia holding the dying Nelson in her arms, and Copenhagen and Trafalgar and so on all the way round. A really remarkable piece! This must have been made in several bits. You couldn't have a 40 foot kiln, I don't believe it. There's a chap down in Illminster called Philip Thomasson who's worked out the secret formula and is now making code stone himself, and if

you go down there, you can buy wonderful urns and great shell bird baths and statues and goodness knows what, so it's nice that code stone is continuing.

And now we move on to the astronomers. We're heavy on astronomy here at Gresham. Neville Maskelyne, was another astronomer. He was one of the rotters who wouldn't give John Harrison the money for his marine chronometer, because Maskelyne thought that the problem of longitude could be solved by astronomy. On the other hand, he did one really heroic thing, which I'm very fond of. He was the first person to measure the mass of the Earth. When Isaac Newton wrote "Principia", he said that if you hang a weight on a piece of string, it'll hang straight down towards the centre of the Earth, it's pulled down by gravity, unless there's a mountain nearby. If there's a mountain nearby, it will be attracted by the mountain because the mountain has mass as well as the Earth. That came to be called the attraction of mountains, and it was a pity if you wanted to survey a mountainous region because it meant you couldn't get a true vertical. But then Maskelyne had the bright idea that if you could find one big mountain all on its own, and you went and hung a plumb bob beside it and measured how much it was attracted to the mountain, then you could estimate the mass of the mountain and, from that, you could work out the mass of the Earth, because you'd have the relative masses of the Earth and the mountain.

The Royal Society thought this was a great idea, and they hired Charles Mason, who was just back from surveying the Mason-Dixon line in North America, and they sent him off around Scotland on a horse, at half a guinea a day plus expenses, to find the best mountain. He came back and he said the best mountain was called Maidenpap by the Southerners, but the locals called it Shehalian. It is 40 miles north of Perth. So they had their mountain, they had the plan, but who was going to do it? Maskelyne said to Mason, okay you go and do the experiment, and Mason said, no sorry I'm busy, and so the Royal Society said to Maskelyne, well why don't you do it, it was your idea? And he said, no, no I'm much too busy, and besides, I'm the Astronomer Royal, I'd have to get permission from the King. And the King said, yeah great idea, why don't you go and do it? So then he had to leave his cosy house in Greenwich, and he went off by sea up to Perth, and then he got on his horse and went 40, 45 miles into the hills, and then he set up camp, about half way up the mountain, on the south side. He had a bothy, and he had a 17 foot high tent which he'd found in the basement of the Royal Society, and he had a zenith sector, and he started observing the stars, watching them as they went straight over head. The weather was so bad he couldn't make any observations at all for three weeks, but eventually, he made 343 separate observations of various stars. He simply wanted to find out what his position was, so he used his plumb bob to measure a vertical, and then he looked up and he measured the stars, and then he calculated his latitude. Having done all that, he then moved round to the other side of the mountain and did all the same thing all over again and worked out his latitude there. From his two latitudes, he could work out the distance between the two camps. He worked it out as one mile, 480 yards, the distance between the two camps. Meanwhile, a team of surveyors with chains and theodolites and so on had been tramping through the heather measuring the real distance between the two camps, and they measured it at exactly one mile, so there was a discrepancy of 480 yards, and that was a direct result of the attraction of the mountain. Maskelyne hadn't enjoyed this very much at all, because it was snowing and it was horrible, and he didn't feel the attraction of the mountains at all! Anyway, then he thought, oh right, we've got this wonderful figure of 480 yards, how do we turn that into the mass of the Earth? He hadn't a clue how to do it, and so he turned to an old friend who was a mathematician, Charles Hutton, who was Professor of Mathematics at Woolwich. Hutton thought about this for a bit, and he realised that what he needed to do essentially was to differentiate, and so he imagined that the mountain was made up of a whole lot of thin columns. Imagine hexagonal columns, like pencils, standing on their ends, all at different heights. The surveyors had given him lots and lots of different heights all over the mountain, so he was able to, as it were, trim his pencils to match the heights of the surveyors' points. Then he still had to work out the volume of this thing. He writes in his paper that he joined with a faint pencil all the points at equal height in order to make rings, and in fact he invented contour lines in order to solve this problem, a lovely incidental invention. He had to guess the density of the mountain, but he did all that, and eventually they worked out that the mass of the Earth was five million, million, million tonnes. From that, they were able to work out the masses of all the other things in the solar system because they knew the relative masses, and so that was an absolute major achievement. Unfortunately, they were slightly wrong – the correct mass is about six million, million, million tonnes, so they were about 20% low, and in fact Newton had guessed it more accurately than they'd measured it, but nevertheless this was a heroic measurement combining the experiment by poor old Maskelyne and a brilliant bit of maths by Charles Hutton.

Now we jump on to another very strange character, Henry Cavendish, who was born with loads of money,

so he never had to do any work. He lived on Clapham Common, he loved science, but he hated meeting people and speaking. It was said that he spoke fewer words than a Trapist monk. He came downstairs in his house one day and met one of the servants on the stairs, and he was so alarmed by this that he had a second staircase built so it would never happen again! He just left notes for them saying what he wanted for his meals, and so on. He did some really elegant experiments. One of the series he did was to explode hydrogen oxygen mixtures, and he worked out that water is H 2O. It was a fundamental thing, it seems obvious to us now, but it had to be worked out, and he let off a whole series of devastating explosions. He didn't tell anyone, except his friend, James Watt, who was therefore I think one of the first to publish it, but nevertheless, he did these wonderful experiments. We went to recreate this on Clapham Common. You know down where the pond is, there's a bit of flat ground there, and we let off a whole lot of explosions – we put hydrogen and oxygen in balloons. There were half a dozen police cars parked there, and we were slightly worried that it was a criminal offence to let off explosions on Clapham Common, but every time we let one off, they all just turned away, and then we realised there's a greasy spoon café there and they'd all come for breakfast. It was obviously the best breakfast in south London and attracted the entire police force, and they certainly weren't going to interrupt their breakfast to pay attention to us. So that was Henry Cavendish.

And then Benjamin Thomson, not exactly a Londoner – he was born in New England, and he came over here. Well, let me say first of all, he was a poor teacher, and then he married the richest widow in the state and bought himself a commission in the local army and became a major. Then he started spying for both sides as the American War of Independence broke out, and it became a little bit hot for him, so he abandoned his wife and baby daughter and came to England, where he wrote an enormous and very, very boring paper which was called "Some new experiments upon gunpowder". Actually none of the experiments is new, and the first 20 pages are complete nonsense because he spends 10 pages describing an experiment and then says it doesn't work, and then spends 10 pages telling you why it doesn't work, so you might as well have started at page 21 because it would save an awful lot of time. Anyway, this got him elected to the Royal Society, for reasons that I shall never understand, and he then decided to go off to Bavaria, and he persuaded the King to knight him. He said if he was a knight, then he'd be better as an ambassador in Bavaria, so he got knighted, he became Sir Benjamin Thomson, he went off to Bavaria, and there he performed some extraordinary feats.

He decided that the streets were full of beggars and the army had no clothes, so he swept the beggars off the streets, put them in factories and got them to make clothes for the army, having investigated the thermal insulating properties of a whole lot of different clothes. He also invented new stoves and coffee machines and so on, and transformed the social life of Bavaria, and so the Elector – the boss – made him a Count, a Count in the Holy Roman Empire, so he called himself Count von Rumford – Rumford was the first place where he'd been teaching in New England. He had a couple of mistresses and maybe a couple of children over there, and then he came back to England and said I am the Bavarian Ambassador to England, and they said oh no you're not, you're English! So he said, oh all right, I'll found the Royal Institution then, so he did. In 1799, he founded the Royal Institution, to be a place where serious research in science would be done and where the public would be taught scientific ideas, and it still does those things today. Then he did the best thing in his whole life, which was to go away again, because if he'd stayed there, he would have ruined the place – he had that hand of death, you know. He left it in the competent hands of Humphrey Davy and went off to Paris to marry La Boisier's widow. La Boisier had his head chopped off by the revolutionaries, and so his widow was there, and Romford married her, and they hated one another on sight! When he heard she was going to have a dinner party – they lived in a great house in the middle of a square garden – he went and locked the garden gates so nobody could get in, and she had to shout at her guests over the gate, and so she went and poured boiling water on all his favourite flowers. It was absolutely charming. When he died, nobody came to his funeral, nobody at all. He was a scientist, spy, serial adulterer, an all round bad egg, but he did found the Royal Institution, and for that we have to give him credit.

Now, Mark Isambard Brunel – he was a French engineer who fell in love with an English girl in France, but then the Revolution came in France, and he ran away because he was a Royalist. He went off to New York, and he became City Engineer in New York, and then his heart was pining for this English girl and he came to England to find her, and indeed he married her, Sophia Kingdom, and they lived happily ever after. He came here with two brilliant ideas – no, he came here with one brilliant idea, and I'm going to cheat and do the second one first, because he decided that there needed to be a tunnel under the Thames, and so he started to build it. This was going from Rotherhithe to Wapping. It had already been tried and almost done

but not quite, and Mark Brunel had an amazing series of schemes to do it.

First of all, he built a great round tower out of brick on the bank in Rotherhithe, and then they dug the earth out from the middle and the tower sank down in the ground, and they dug a bit more earth out, and it sank all the way down, and it is still there – it's part of the station at Rotherhithe, an extraordinary structure, and from that, they then tunnelled northwards under the river. He invented a tunnelling shield with which they could do it. If you imagine I'm one of the tunnellers and I'm standing here in a sort of cupboard, almost a vertical coffin – it's just over 6 foot high, and it's about 2 foot deep – and in front of me, there are 12 planks across, and what I have to do is take out one of these planks, hack away the earth from behind it, 4 inches, and then put the plank back, and then take out the next one and do it again, and by doing only one plank at a time, if it begins to leak, I can stop the leak quite easily, and beside me, there are 11 other chaps. There are 12 men in a line, all doing this together, and there are three rows, one above the other, so there are 36 people all digging away, laboriously, plank by plank by plank, and when they've dug away all the earth from all 12 planks, then the entire shield is pushed forward by scree jacks, 4 inches, and brickies come in behind and brick up the bit of exposed earth behind it and then they go forward again. It was a wonderful idea. He said he'd had this idea by looking at ship worm, and I keep some for, you know, for old memories' sake, in the handle of my walking stick. This is carved, this is French bamboo from the south of France, and a piece of driftwood, and it has ship worm in the handle, and I talk to it at night when I'm lonely – hello, are you in there?! It bores through the timbers of ships, and Mark Brunel claimed that was how he invented this tunnelling shield. They had terrible, terrible trouble doing it. For one thing, it was dark down there, they just had some candles; for another thing, the air was absolutely foul because the roof leaked, and what leaked was not pure water but raw sewage, because the Thames was just a sewer, so all the men got very ill. Brunel himself got ill, and he had to bring in his son, Isambard, who was only 21, to run the show, and various catastrophic things happened terminating, or almost terminating, in January 1828, when there was a dreadful leak, and Isambard Brunel was severely injured internally and was pulled unconscious from the water. Quite a number of people were killed, and in fact they didn't finish this until 1843, and finally Mark Brunel was knighted and there was great hoo-ha. The tunnel is still in use today on the East London line.

Mark Isambard Brunel produced a watercolour of the tunnel, a section of the tunnel, showing chaps walking along through it. It's a double tunnel. It's wonderful down there. I've actually walked down it and you can see both stations at night. The painting shows Isambard in the back, being rowed along on the river above – a very sweet watercolour.

Now, the idea that Mark Brunel came to England with was about pulley blocks. On every ship, there are many, many pulley blocks. There are miles and miles of rope, and the rope always goes through pulleys to improve the force you can exert on the sails and the masts and all the rest. A ship of line I'm told had 922 pulley blocks, so making these pulley blocks was very important. They were all made by a firm called Taylor Walker in Southampton, and they were all made by hand, every one individually, and Mark Brunel reckoned it would be better if you could make them by machine, for two reasons: one, it would be cheaper, and second, more important, they would then be interchangeable. They would all be the same. The sheaths would be the same size, the wheels would be the same size, and so on and so forth, so if something broke, you could put in another part, and you didn't have to have a whole new pulley block. He went to Taylor Walker and said look I've got this wonderful idea for a machine to make pulley blocks, or a series of machines, and they said no, no, we've studied this for 20 years and we know the best way to do it. So he went to the Admiralty and said look I've got this wonderful idea, and they said all right, we'll see if it works.

So he then had to find a mechanic to do it, and he looked around and he was encouraged to hire this man, Henry Maudsley. Maudsley had gone off to work for Joseph Brammer, to build his precision locks, and he'd become an extraordinary craftsman. Then he had a row with Brammer. He'd worked there for 15 years, I think it was, and married Brammer's housekeeper and had three children, and was still being paid only 30 shillings a week, and he said could I have a raise, but Brammer was a Yorkshireman! So he left and set up on his own in Wells Street, and he put in the window a precision screw that he had made. Mark Brunel saw this screw, and went in and said I think you might be the man to make some machines for me, and he took in a drawing of one of the machines. There were going to be 26 of them. Maudsley said yes, I can make that, give me a week, and so after a week, Brunel went back with another drawing, and Maudsley said, ah I see you're going to make pulley blocks, and he was able to work it out from two drawings. So first of all they made models of these machines, which are still I believe in the Maritime Museum at Greenwich. I haven't seen them, but they're wonderful things. And then they went ahead and made the full size things, and these were the first ever iron production line tools, production tools in a production line, and they were

set up in the block making house at Portsmouth, and some of them are still there now – really amazing – and within five years, they were making all the pulley blocks for the navy, 100,000 a year. It was an extraordinary achievement, and it was straight down to Mark Brunel's idea and Henry Maudsley's great skill as a mechanic. One of his workmen said he was a genius – he was incredibly skilled with any tool, but a genius with an 18 inch file. I can't quite imagine how you can be a genius with an 18 inch file. I wish I'd been there to see it.

He had all sorts of simple ideas. For example, if you want to make flat surfaces, you can make 2 surfaces and see whether they fit together, but of course they could both be curved, one convex and the other concave, but if you make 3 surfaces and they all fit together, then they must be flat. That was one of Maudsley's ideas. He built a machine, a screw micrometer, which could measure to a ten thousandth of an inch, and he called it the Lord Chancellor, because it would settle any dispute in the workshop! He spawned a whole series of people who came to work with him and then went off on their own, like John Roberts, who built various sorts of machinery; James Naismith, who invented the steam hammer, and Joseph Whitworth, who standardised nuts and bolts, and until a few years ago, you could still buy a three-eighths Whitworth nut, or a three-eighths Whitworth bolt. The great thing was they all fitted together. It was the same sort of idea, coming straight down from Maudsley, so Henry Maudsley was a remarkable character.

Now we leap on to Humphrey Davy, remember he'd been set up from Rumford to run the Royal Institution. He was a Cornishman. He had dark curly hair, and glittering blue eyes, and the ladies loved him, and he would lecture on chemistry at the Royal Institution, and it was so popular – there was no tele in those days of course, so no movies, so you could either go to see Shakespeare in the West End or you could go and see Humphrey Davy lecturing about electro-chemistry. It was so popular that the carriages jammed in Albemarle Street, and it was the first one-way street in London in order to prevent the traffic jams that had been set up. He was a precocious lad, but a great scientist, there's no doubt about it.

He discovered, or made, for the first time sodium and potassium. Remember there was a poem about Christopher Wren. There was another one about Humphrey Davy: "Sir Humphrey Davy detested gravy. He lived in the odium of having discovered sodium." He made sodium by electro-electrolysis. In 1799, the electric battery had been invented by Volta in Italy, and the news spread like wildfire, and at the Royal Institution, they made huge batteries and did all sorts of things with it, and they became the leading experiments of electrical science, he and Michael Faraday who followed him. He used it to electrolyse things and he electrolysed sodium salt, and after a bit, they saw tiny silver globules of molten sodium, and in his report of the experiment he said "and we observed small silver globules of sodium". His assistant said that he was so excited that he danced round the room and it was many minutes before he was able to recover his composure sufficiently to carry on with the experiment. I love the idea of a scientist being so excited.

I saw exactly that when I went to watch the Huygens Probe landing on Titan in the middle of January. In the morning, all the scientists were absolutely shitting bricks – that's another astronomical experiment – because they thought the whole thing might fail. They had no information. They didn't know if it was going to work, or if it was going to send back data, and then in the afternoon, all this data suddenly appeared on the computer screens. They hadn't slept the night before because they were so worried, and then the moment the data came, the Champagne flowed and they didn't sleep that night because they were so excited and they were working out the results, and so by the next morning, they were sort of bleary-eyed and almost unconscious but grinning from ear to ear, and I think that's probably exactly how Humphrey Davy was when he first made sodium – a very remarkable chap.

His successor was Michael Faraday. In fact, Humphrey Davy when asked what his greatest discovery had been, he said, "My greatest discovery was Michael Faraday." Michael Faraday was a Londoner born and bred, born in Newington Butts, just by the Elephant and Castle. He never went to school, he went to work for a book binder, and instead of just kicking the books about, he began to read them – amazing – and the two books that really influenced him, apparently, were the Encyclopaedia Britannica and a chemistry textbook written by a woman called Jane Marcet who we will come to in a minute. He was so fascinated by this that he wanted to be a scientist, and so when a satisfied customer gave him some tickets to the Royal Institution to hear Sir Humphrey Davy, he went along, and he was fascinated. He sat in a seat above the clock, and he took meticulous notes, and he bound them up, because he was a book binder, and sent them to Sir Humphrey, and said dear Sir Humphrey, could I have a job, and eventually he got one and he took over.

He was one of the great experimental scientists of all time, and one of the great lecturers. He had no mathematics – he'd never been to school – and so it was all intuition, but when he looked at a magnet, he could sort of sense what he called the lines of forces – we still call them lines of force now – looping from one end of the magnet to the other, and he worked out a way of showing this by putting the magnet under a piece of paper and putting iron filings on top. He wrote a whole book, and he gave a series of Christmas lectures – he invented the Christmas lectures – gave a whole series on the chemical history of a candle, and again, beautiful to be able to spend a whole series of lectures just on the candle – a remarkable man, and I think a very charming man too.

As I say, he was heavily influenced by Jane Marcet. She was born Jane Holderman, and she married a Swiss, hence the name Marcet. She was obviously a great writer, and her first book was "Conversations on Chemistry", which is written in slightly arcane language – I've got a bit of it here – but it was a huge best seller, and she went on to do a whole lot of other books, which were not quite as successful, but she did extremely well. This is from the introduction: "In venturing to offer to the public, and more particularly to the female sex, the author herself a woman conceives that some explanation may be required." It's quite hard work to read this book, because it's couched in this very convoluted language, but it obviously was very powerful stuff. We have a lot to thank Jane Marcet for.

William Banting was an undertaker toward the middle of the Victorian period, and he was only 5 foot 3, or something like that, and he got terribly fat, and he got so fat that he puffed and blowed all the time, and he couldn't tie his shoelaces, and he had to go down stairs backwards to avoid damaging his knees. He found this very embarrassing because, as an undertaker, you shouldn't be so obviously unfit. He asked doctors, and he was prescribed gallons of physic which he drank and it had no effect. They told him to take exercise, and he rode for three hours every morning, and he just got hungrier and ate more, and got fatter and fatter. Eventually he went to a doctor in Soho Square and was given a diet, and it was an extraordinary success, and he lost two or three stone, and he wrote a letter on corpulence addressed to the public, a little pamphlet. It was a huge success, thousands of people bought this thing, and it became very fashionable to be banting. The verb "to bant" entered the English language – are you banting, my dear. His diet – I've got a bit of it here – it is quite complicated, and it's essentially the Atkins diet of 1862! You'll see that for breakfast you're allowed beef or mutton, but not pork, and dry bread and black tea, and for dinner, 10-12 ounces of any fish except salmon, any meat except pork, any veg except potato, so they're cutting down the carbs a bit, fruit for pudding, and any poultry or game. Now that's a hell of a lot of lunch, it really is! Even I at my greediest am pushed to eat 12 ounces! And you're allowed with that two or three glasses of good claret, but no beer or Champagne – presumably the bubbles are very fattening. For tea, more fruit and a rusk or two and black tea, for supper, 6-8 ounces of meat or fish, and that's another pretty hefty thing, and one or two glasses of claret, and as a nightcap, a tumbler of gin, whisky or brandy! Well I'm not averse to a tumbler, but you know, how a man can actually lose weight on that diet, I cannot think! Nevertheless, that's apparently what he had, and it was a great success. So I now do not do the Atkins diet – I do something quite different.

Thomas Crapper – he was a very successful plumber. Born at Thorne near Doncaster, he came to London, set up his plumbing business in 1861, and it's still going. You can still buy a Thomas Crapper high flush suite – I have one in my downstairs loo. He did the drains at Sandringham. He's made hundreds of manhole covers – there are lots in Westminster Abbey, for example – but he didn't actually invent anything very much. He took out 13 patents, but he did not invent the flush lavatory, he did not invent the water closet, he didn't invent anything very interesting. He just had a wonderful name! And of course it lives on in all sorts of advertisements still. His manhole covers were very successful.

At the Crystal Palace – I'm now going to gallop through a bit because of course I've gone to slowly, I'm hopeless about this – at the Crystal Palace in 1851, which was built for the Great Exhibition, they had public lavatories, and the public lavatories were installed by a flamboyant plumber called George Jennings, who announced that he was going to charge people to use them. The organising committee were absolutely horrified – they said, "People aren't coming to go to the lavatory! They're coming to see the exhibition!" But nevertheless, 827,000 people chose to use the cubicles and to pay a penny, and that's probably where the expression "to spend a penny" comes from.

George Jennings' was never a man to be backward, you know, he would have said his closet was the best thing since sliced bread. It would of course have had a mahogany or oak seat, and you flushed it by pulling up a handle, which opened the valve, and so on and so forth. A good egg was George Jennings!

Joseph Bazalgette was a chap who built all the sewers under London – absolutely wonderful. After the great stink of 1858, debated in Parliament, they decided they really needed sewers, and he built five great interconnecting sewers, the biggest engineering project ever in this country to that date, and they're still there, and they're still in remarkably good nick. I had the slightly dubious pleasure of going down one of them a couple of years ago, and you can still see the amazing brickwork, which is largely as it was and unchanged; it needs repaired occasionally. So that was an extraordinary achievement. Of course, because most of his stuff was underground, when he did get above ground, he really went to town, for example with the Abbey Mills Pumping Station in the Lee Valley. All this thing does is to pump the sewage up 40 feet so it continued to flow downhill towards the sea, but it's an enormous great building with a gold cross on top – a monument to excrement! Even the doors are impressive. You do not need doors like that on a pumping station, but it is truly wonderful, and it's matched by the one at Crossness on the South Bank, equally wonderful, like a cathedral inside.

Henry Bessemer invented all sorts of things including Bessemer steel, the Bessemer converter, a way of grinding up sugar cane to get the sugar out, a new sort of stamp, a way to make gold paint, and so on and so forth – he took out 115 patents I think – but my favourite thing was the Bessemer ship. He was terribly seasick, and so he invented this boat in which you could not be seasick. She was very, very, very, very long so she would sit over four or five waves and couldn't pitch fore and aft, and inside, the cabin was on truneons, so that if the ship is horizontal, the cabin is horizontal, and if the ship rocks like this, because there's a great weight underneath, the cabin remains horizontal. It just swings with a huge weight underneath, and never shifts. You never get seasick in this boat. Everyone said it wouldn't work, but he built her anyway, and on her maiden voyage on the 8 th of May in 1875, she sailed from Dover and very, very slowly crossed the Channel, a beautiful calm spring day, the sea was like a millpond, and she comprehensively demolished the pier at Calais – rather like somebody seems to have done last week. The captain said that she was totally unsteerable, with this enormous weight swinging about, there was no way the ship could possibly be steered. She never put to sea again, and he spent £40,000 on that ship - £40,000 quid, a lot of money in 1875! Anyway, inventors sometimes do things wrong.

And now we have Liborio Pedrazzoli, who you will be astonished to know was an Italian, who came over here about 1860, set up a business making mirrors and selling them in Hoxton, and he invented swimming umbrellas. The idea was that as you put them forward, he said the "apperati" closed and offered no resistance to movement, and when you pull them back, they open out and give you a tremendous grip on the water, enabling you to swim at a speed hitherto impossible. Well it's true – I've tried them – they do close up when you go forward, and they do open up when you pull back, but the trouble is they're always slightly in the way. Swimming with things in your hands is just slightly difficult, so it makes life a bit more difficult, and as you pull them back. It takes about a foot for them to open up, so you pull them and they open up and you've got the very weakest bit of your stroke, the last six inches or something like that, where you've got no power at all, to get this tremendous grip on the water, and all the rest of the time they're slightly in the way, and after about half an hour, I reckoned I was better off without them, which may be why you don't see them very much these days! A lovely idea nonetheless!

And finally, we have this splendid lady, who was born plain Jane Marks. She was the daughter of a Polish Jew, and she changed her name to Hertha, for reasons I'm not sure of, and then married Professor Ayrton, so she acquired this tremendous name. First she became the world expert on the electric arc, and she sent a paper to the Royal Society but she was not allowed to read it because she was a woman, and she had to get a colleague of her husband's to read her paper to the Royal Society – disgraceful! And then she made a wonderful observation on the beach at Margate, where she went for a holiday. She looked at the ripples in the sand, and she noticed that they are normally at right angles to the way the sea is coming in, so if the sea is coming in from the south, then the ripples will run east-west. She wondered why this was, and she began to do the mathematics of ripple formation, and it turned out to be an enormously prolific field, and she wrote a paper about this, and then she was allowed to read a paper to the Royal Society. She was the first woman who was allowed to read a paper to the Royal Society, in 1904, really remarkable. And with the mathematics she worked out for this, she then spotted a problem. During the First World War, when the trenches were filling up with poison gas, she realised that she could actually reverse the mathematics of the sea coming and making ripples, and by making ripples, she could drive the poison gas back out of the trenches, and so she invented what came to be called the Ayrton fan. Thousands and thousands of these Ayrton fans were sent to these squaddies in the trenches in the north of France. Sadly, they were sent without instructions and most of them were just used for firewood, but the fact is that she invented this by doing pure mathematics from a vision on the beach, she invented this wonderful thing to drive poison gas

out of the trenches, and secondly, she was the first woman who was allowed to read a paper at the Royal Society.

And there, ladies and gentlemen, you have my London heroes.