# IRON

## Battle of the ironclads

Ploughing with ease into her opponent's wooden frame, the ironclad Confederate State Ship *Virginia* marked a turning point in naval history. 'The crash below the water was distinctly heard,' recalled the flag officer of the opposing USS *Cumberland*, 'she commenced sinking, gallantly firing her guns as long as they were above water.'[1] But her fire simply bounced off the *Virginia*'s impenetrable iron hull.

During the American Civil War in March 1862, the CSS *Virginia* attacked the Federal ships at Hampton Roads in Virginia. The sinking of USS *Cumberland* led to the loss of about a third of its crew in what an officer on her deck described as 'a scene of carnage unparalleled in the water'.[2] The *Virginia* had been rebuilt from a sunken wooden-framed ship, the USS *Merrimack*, with makeshift equipment and poor engines. She had one great advantage: her two-inch-thick armoured plate which her opponent's wooden ships were unable to break. The Union forces panicked; if the *Virginia* could overcome the Union blockade at Hampton Roads, she could steam up the Potomac and shell Washington. That evening President Lincoln 'went repeatedly to the window and looked down the Potomac – the view being uninterrupted for forty miles – to see if the *Merrimack* was not coming to Washington'.[3]

Fortuitously, the Union forces had been developing their own ironclad, the *Monitor*, with an even thicker plate of eleven inches. Hearing of the advance of the *Virginia*, the ship set sail for Hampton Roads. The next day the first ever clash between ironclads took place. A lithograph depicting the conflict, made by the prolific printmaking firm of Currier & Ives, hangs in my office.[4] I bought the print a long time ago because I liked the battle scene, not realising its significance. In the foreground the smaller and lighter *Monitor* darts towards the *Virginia*, both ships with guns blazing, smoke and steam billowing from their decks.[5] 'No battle that was ever fought, caused as great a sensation throughout the civilized world,' wrote eyewitness naval officer William Harwar Parker.[6]

It was an arduous fight: the ships engaged for more than four hours at close range. At first the *Virginia* fired exploding shells and the *Monitor* flung back solid shot, but both simply bounced off the iron hulls 'with no more effect, apparently, than so many pebble stones thrown by a child'.[7] Soon they resorted to ramming tactics, but, by mid-afternoon, with no fatalities, the two vessels disengaged. The ships suffered only dents, and the crews, sealed in isolation behind thick iron walls, were virtually unhurt.[8] Sitting down to eat after the battle, the crew of the USS *Monitor* were all in high spirits. 'Well gentlemen,' said Assistant Secretary Gustavus Fox, coming on board later to commend the crew, 'you don't look as though you were just through one of the greatest naval conflicts on record.'[9]

Iron had embodied masculine strength and aggression long before the Battle of Hampton Roads. Its strength is one of the reasons why life is possible on this planet. Most of the Earth's core is made of iron. As the solid inner core spins, and conversion currents surge through the liquid outer core, a magnetic field is produced around the Earth. This keeps at bay the solar wind, an ionising radiation harmful to life. The first human uses of iron are

difficult to trace due to the ease with which the metal corrodes, meaning that ancient iron objects are much rarer than those made of more durable metals such as gold and silver.[10] However, iron objects begin to appear after approximately 3500 BC in the form of jewellery, domestic implements and, most importantly, weapons. Iron went on to be used as a bloody tool of ancient war in the form of iron swords, shields and spears.

But for thousands of years warships were still built out of fragile and flammable wood. In the background of the Currier & Ives lithograph, these wooden ships keep their distance, an outclassed and soon to be outdated instrument of war. The Battle of Hampton Roads was proof to the tens of thousands of troops, watching from the estuary banks, of the superior might of the ironclad. At the beginning of America's Industrial Age, the *Virginia* and the *Monitor* were the realisation of the power of industrial iron armoury, a force which would go on to shape the politics and wars of the modern world.

## The element of peace

Across the Atlantic, in Germany, the 1860s were the start of an era of great industrial progress and prosperity. The Industrial Revolution had swept out of Great Britain and across Europe. Sitting on the banks of the River Ruhr, the city of Essen was the industrial centre of Germany. Small hillside blast furnaces had been replaced by colossal industrial factories and the once medieval market town was expanding quickly. During the decade, Essen's population rose by 150 per cent. One family, above all others, was responsible for this growth.

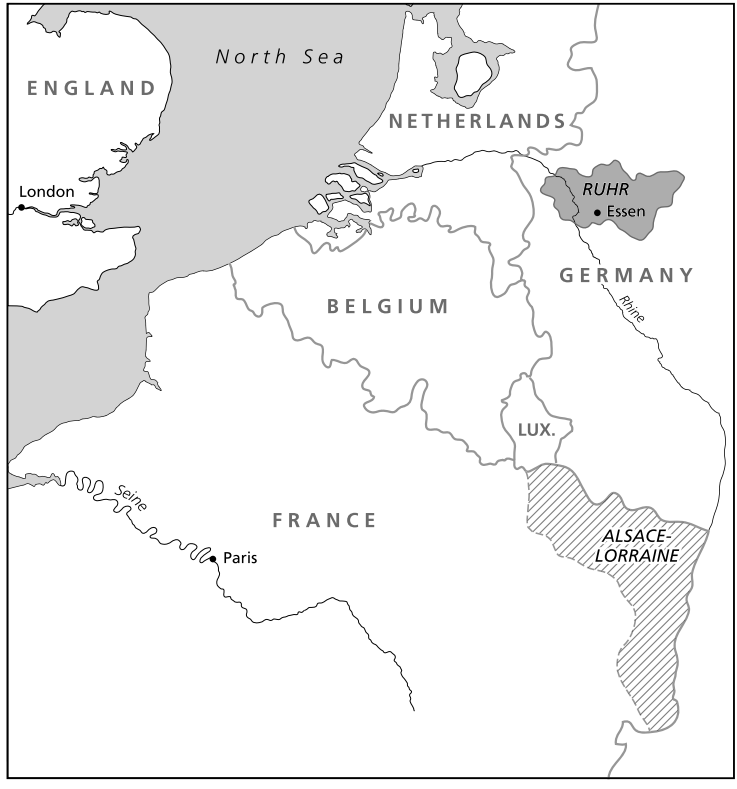
In 1587, Arndt Krupp joined the merchants' guild of Essen. He was the founder of the Krupp dynasty that would last for nearly four hundred years and become the leader not only of Germany's industrial prowess, but also of its machinery of war.

In their armament factories, Alfred Krupp, a descendant, forged the cannons for the wars led by Otto von Bismarck against Austria and France in 1866 and 1870. These weapons were decisive. The cast-iron artillery cannons of the Prussian army had twice the range and were far more accurate and more numerous than the French bronze pieces. In 1862, Bismarck famously declared that the German Empire would not be built on 'speeches and majority decisions' but on 'blood and iron'.[11] Whoever mastered iron, he believed, would master Europe.

In both world wars, Krupp's armaments again proved critical. The vast arsenal of the German army underpinned her strategic campaigns against the enemy. At the start of the First World War, long-range Krupp cannons smashed Belgian forts on their way towards Paris. In the Second World War, Krupp siege guns would fire shells weighing seven tonnes a distance of up to 40 kilometres.[12] The Krupp's iron forges supplied the munitions that enabled Germany to make war. But wars were not only fought with iron, they were also fought over reserves of iron ore and coke. Smelting iron ore with coke produces iron and carbon dioxide. During the industrial revolutions, securing these reserves became a preoccupation among European nations. No one wanted to fall behind in this period of unprecedented economic growth.

The Ruhr region, in which the Krupp dynasty thrived, contained vast reserves of coal and somewhat smaller reserves of iron ore. In the late nineteenth and early twentieth centuries, these reserves became a source of great conflict, during which time France and Germany went to war three times.

In July 1870, France declared war on neighbouring Prussia. Prussia, with the bordering German Confederation states, which it often led, had become an increasing threat over the previous decade. Only four years earlier, Prussia had invaded Austria, leading to the creation of the powerful North German Confederation. France's once small and manageable neighbour now had both a formidable




army and a flanking position on her border. Prussia's population was growing rapidly and its heavy industries were becoming dominant. By 1867, coal mines in Prussia and Saxony (another member of the North German Confederation) were outproducing French mines by three to one. France was being squeezed and decided to go to war.

But France underestimated just how strong Prussia had become. In a matter of weeks, the Prussian army advanced to Paris. After a siege lasting several months, the city fell on 28 January 1871 and the war ended. Prussia had destroyed France's military power and, as a requirement of the Treaty of Frankfurt, it was required

to cede German-speaking Alsace Lorraine, which held valuable iron ore reserves. Only forty years later, France would fight against the now unified German Empire in the First World War. It would regain Alsace Lorraine, once again taking control of the region's iron ore reserves. France was now able to increase its production of steel but as a result it became even more dependent on the coke and coal needed for smelting.[13] When Germany defaulted on war reparation payments, France retaliated by invading the Ruhr. This not only secured coal supplies, but also crippled Germany's own industries. In response, Hitler began to remilitarise the Rhineland, in which the Ruhr sits. Wanting to avoid another war, France put up little resistance, giving Hitler the confidence to pursue a series of increasingly aggressive actions that ultimately led to the Second World War.[14]

The Ruhr's coke reserves were indispensable in the development of Europe's iron and steel industries. But the same resources made it a battleground for almost eighty years. During this time, the Ruhr rose to become the industrial heartland of Europe, but the region's success was also its downfall. In March 1943, the Allied forces made the first of what would become two hundred major air raids on Essen. More than 36,000 tonnes of incendiary and explosive bombs were dropped, the greater part of which landed on the eight square kilometres of Krupp factories. After the war, Essen became a bleak and cratered wasteland.[15] But in little more than five years the Ruhr would be rebuilt and integrated into a new political system that was designed to make iron a tool for peace rather than war.

On 9 May 1950, France's Foreign Minister Robert Schuman made a historic announcement on the radio: France was ready to partner with Germany, and other nations, to form a new European heavy industry community. The European Coal and Steel Community (ECSC) was founded in the aftermath of the Second World War in the hope of ending decades of economic and military competition.

By pooling coal and steel resources, Schuman hoped to create a common foundation for economic development which he believed would make war 'not merely unthinkable, but materially impossible'.[16] Regions that had 'long been devoted to the manufacture of munitions of war, of which they had been the most constant victims' would now use iron to drive industrial development and raise living standards.[17] Schuman believed his simple yet bold plan would herald a new age of growth and prosperity.

The ECSC was the first step in the formation of the European Union, whose twenty-seven member states now constitute the largest economy in the world.[18] It was Europe's first major experiment in supranationalism, forming the foundation of a new entity which was both more stable and integrated. In return for sacrificing a degree of national sovereignty, members would reap economic and political benefits, not least the promise of peace.[19]

The impact is apparent today in the surrounding areas of Essen, which has been transformed from the 'forge' into the 'desk' of the Ruhr. It is a comfortable, modern city, home to many of Germany's largest corporations, not least of Aral, the face of BP in Germany. The Krupp family line had ended, but the name remains in the multinational conglomerate ThyssenKrupp. The Krupp Belt, once overflowing with industrial factories, is now home to the company's modern headquarters and what remains of the region's industrial past is now nothing more than a museum piece.[20]

The unity of the European Union and its predecessor entities has sustained an unprecedented period of peace.[21] Nations have been bound together through not only the interdependence of trade but also the security of common laws. It all started with carbon, as found in coal, and steel, as made from iron. It has been such a powerful tool for securing peace and prosperity because of the great extent to which these elements underpin modern society. Iron is everywhere, used in the construction of monumental skyscrapers, aeroplanes and wind turbines.[22] And, for me, one colossus stands

above all others as a symbol of steel's might and an extraordinary example of what humanity has achieved with iron.

## Sixty thousand tonnes of steel

11 July 2005: it was the ninetieth anniversary of BP Shipping, and to celebrate we held a party at the National Maritime Museum in Greenwich, south-east London. Cocktails were served under the arches of the museum and guests ambled around the 'Nelson & Napoleon' exhibition, marking two hundred years since the Battle of Trafalgar. We sat down to dinner, under the glass dome of Neptune Court, and Bob Malone, the leader of BP Shipping, stood up to give a speech. A lot had happened in those ninety years: for example, BP had at one time owned and operated the world's largest merchant fleet which, during the Second World War, had provided a good part of the transportation of fuel to the Allied forces.[23]

Bob finished speaking and we stood to toast the health of the company, but my thoughts were elsewhere. In the car on the way to the dinner that evening I had received a deeply worrying phone call from Tony Hayward, then leading BP's exploration and production activities. 'It's *Thunder Horse*,' he said, referring to our pioneering offshore oil platform in the Gulf of Mexico. 'It seems to be sinking.'

*Thunder Horse PDQ* is the biggest semi-submersible offshore production platform in the world, 50 per cent bigger than the previous record holder in Norway.[24] The hull alone is a 60,000-tonne mass of thick steel plate that holds a complex network of 50 kilometres of pipe work and 250 kilometres of cabling. This unprecedented construction was necessary to tap the Thunder Horse field, the biggest in the Gulf of Mexico with an expected production of a quarter of a million barrels of oil and 5.6 million cubic metres of natural gas each day. Only strong, abundant and cheap steel could be employed on such a scale and in such hostile marine conditions.

No existing vessel was big enough to transport *Thunder Horse*'s hull from the construction yard at Okpo, South Korea, to the Gulf of Mexico. The MV *Blue Marlin*, at the time one of the two biggest heavy-lift barges in the world, had to be modified by widening its hull and adding a new propulsion system. Even with the modifications, *Thunder Horse* still overhung the ship by 20 metres on either side. Too wide to fit through the Panama Canal and too tall to fit under the Suez Canal Bridge, *Thunder Horse* rode aback the MV *Blue Marlin* around the Cape of Good Hope, travelling 30,000 kilometres and arriving in the Gulf two months later.

In July 2005, six years after BP discovered the field, production was almost ready to be started up. But the Gulf is not only famous for holding some of the world's richest oil reserves; it is also prone to a yearly battering by hurricanes. Hurricane Dennis was the first major hurricane of the 2005 Atlantic season, the most active one on record. On hearing news of its path towards *Thunder Horse*, BP had evacuated the platform. Picking up in intensity as it made its way towards the US coastline, Hurricane Dennis passed only 230 kilometres from *Thunder Horse* with wind speeds of up to 220 kilometres per hour. Now, as the storm cleared, the hulking mass of steel could be seen listing into the sea.

Back at the National Maritime Museum, Bob finished his speech and sat down. His phone was constantly vibrating, but he could not leave the table to find out what was happening. I had decided not to tell him what I knew until after dinner. A rescue effort could not be launched until the sea had calmed and we could get access to the platform; two or three hours would make no difference. As we were walking out of the door I told him of my conversation with Tony Hayward: 'five billion dollars of investment could be sinking into Davy Jones' Locker'. 'I thought something was up,' he said. 'I'd better go and make a phone call.'

At first we could not understand what had happened: *Thunder Horse* had been designed to survive a 'once-in-a-hundred-years'

storm.[25] Sixty thousand tonnes of steel had been brought to its knees, but it was not the weather that was to blame. *Thunder Horse* was already listing at 16 degrees before the hurricane hit and the storm waves only served to worsen the situation. Both mechanical failure and human error had led to malfunctions of the hydraulic control system that keeps the great weight of the platform in balance by moving water between ballast tanks. After several tense days of enquiry and action, *Thunder Horse* was resurrected and since then has stood unmoved by a yearly battering of hurricanes as an example of the immense strength of steel and the scale on which we use and trust it.

## Father of the steel industry

When filling up a car at a petrol station, or flicking the switch on a wall socket, most people rarely see how dependent our energy infrastructure is on steel. All the steps in the energy chain, from exploration to production to refining and generating electricity, rely on technology built with iron. But the strength of structures and pipes does not rest on iron alone. If made from pure iron, the atoms would easily slide over each other; *Thunder Horse* would collapse under its own weight. The strength of steel lies in getting the right balance between iron and carbon. Pure iron is soft, but adding carbon breaks up the lattice of iron atoms so that the atoms can no longer easily slide past each other, thus producing hard steel.[26] Add too much carbon, however, and the iron, called cast iron, becomes brittle and shatters when it is struck.

For centuries, steel was only produced in batches by expensive processes which lacked scale. However, in 1856 the chance discovery of Henry Bessemer, an English inventor, led to a process which carefully controls the balance of carbon and iron on an industrial scale. This invention, which is still used today, has had the single greatest impact on the development of the modern steel industry.

As with many developments in the iron and steel industry, the Bessemer process was born out of a need for better armaments.[27] In 1854 Bessemer met with Napoleon III, who wanted a superior quality metal so as to improve his artillery pieces. For Bessemer, this 'was the spark which kindled one of the greatest revolutions … I made up my mind to try what I could to improve the quality of iron in the manufacture of guns.'[28]

Bessemer's breakthrough came in the summer of 1856. One day he opened the door of his experimental blast furnace and noticed some pieces of 'pig iron', a type of iron of high carbon content, sitting on one side without having melted. The temperature must not have been high enough, he thought, and so he let more hot air into the furnace. Half an hour later, to his surprise, the pieces appeared unchanged. He grabbed an iron bar to push them into the bath of molten metal, but discovered that they were not pig iron, but thin shells of pure iron, the carbon having been almost entirely removed. By chance, air had blown through the molten pig iron, raising its temperature and removing impurities. An outside heat source had always been thought necessary to keep the temperature of the furnace high enough to stop the molten iron solidifying. What if, Bessemer wondered, by simply blowing cold air through the molten metal, he could convert an entire crucible of pig iron into pure iron?

So he built another experimental convertor with six pipes at the bottom of the chamber through which to pump air. He opened the valves and air began to push up through the molten pig iron. Bessemer describes what happened next: 'All went on quietly for about 10 minutes … But soon after a rapid change took place; in fact, the silicon had been quietly consumed, and the oxygen, next uniting with the carbon, sent up an ever increasing stream of sparks … followed [by] a succession of mild explosions, throwing molten slags and splashes of metal high up into the air, the apparatus becoming a veritable volcano in a state of active eruption. No

one would approach the convertor to turn off the blast …'[29]

After the eruption had subsided, Bessemer poured the molten metal into a pan. It cooled and set into a solid bar. He took a carpenter's axe and struck the bar with three sharp blows. Each time it sank deep into the soft metal, gouging but not shattering or splintering, as would be expected from brittle cast iron. The violent reaction had kept the temperature high in the convertor, without the need for any external heat supply. He was left with a pure low-carbon form of iron: Bessemer Steel.[30] Bessemer's innovative process is now the basis of all steel making. It produced a material that was not only stronger, tougher and more malleable than wrought iron, but could be made in a fraction of the time and, more crucially, at a fraction of the cost. The traditional steel-making process, involving the slow heating of bar iron alongside charcoal, took ten days and cost over £50 a tonne (around US $6,000 in today's money[31]). His process made a tonne at a tenth of that cost. Before that process, steel was so expensive that it could only be used for small, treasured objects such as swords, cutlery and valuable tools. Now, ships, bridges and railways, steam boilers and all sorts of machinery could be constructed with cheap, strong and abundant steel. Even the simple nail could now be made quickly and cheaply from steel without the need for lengthy and arduous forging.[32]

The Bessemer process soon spread around the world. Alfred Krupp was among the first to buy a licence and, by 1867, he was operating the largest Bessemer steelworks on the continent with eighteen convertors.[33] Steel production increased most dramatically when the process was rolled out in the US. In 1892, the US had grown its steel output to four million tonnes a year. It would, according to a *Times* article in 1893, take more than three years' production of all the gold mines in the world to pay for one year's production of Bessemer Steel.

Bessemer was not an ironmaster, but an inventor, engineer and businessman in a very broad sense.[34] He believed that his discovery

resulted from the fact that he was not steeped in the traditional practices of making iron. The notion that a blast of cold air could purify molten iron without it solidifying was, on first hearing, ridiculed by many. His earliest and most profitable success resulted not from iron but from a request from his elder sister to help her decorate a book of flower paintings of the many tulips and chrysanthemums cultivated by their father. To do this, he went to a shop in Clerkenwell, London, to buy some 'Gold Powder', made from bronze. Returning the next day to pick up his purchase, he was surprised at its high price of seven shillings for an ounce (about US $40 today). Bessemer was certain he could invent a cheaper way to produce it, and so he did just that without any prior experience in the field. His success in making the powder gave him the confidence and finances with which to pursue a career as an inventor and engineer. As Bessemer would later recount, the request from his sister was 'fraught with the most momentous consequences to me; in fact, it changed the whole current of my life, and rendered possible that still greater change which the iron and steel industry of the world has undergone'.[35]

Sugar-cane juicers, solar furnaces and diamond-polishing machines were all among Bessemer's inventive interests. An inspired genius tamed by a shrewd business mind, he based his inventions on the simple principle of delivering a product that consumers wanted but at a lower price and higher quality than anything that already existed.

Bessemer's success in the iron industry led him to become a founding member and subsequent President of the Iron and Steel Institute, predecessor to the Institute of Materials, Minerals and Mining in London.[36] The Institute was formed in 1869 as a 'closed shop' for British Victorian ironmasters who were worried about competition from Europe. On the walls of the Bessemer Room in the Institute hang numerous awards given to him in recognition of his invention. Bessemer became a fellow of the Royal Society

and was knighted. The Bessemer Gold Medal, introduced during his presidency, is still awarded for outstanding contributions to the iron and steel industry. But the medal is one of the few reminders of Bessemer's name that remains today.

Although Bessemer was lauded in his time, he is now largely forgotten; he lies buried beside his wife in a quiet and unvisited corner of West Norwood Cemetery near their former south London home. Despite being one of the world's greatest inventors and engineers, Bessemer is not thought of alongside Thomas Edison, James Watt or the Wright brothers. Perhaps it is because he is the inventor of a process, rather than a product.[37] We remember world-changing objects, such as light bulbs, steam engines and aeroplanes, and also, by association, their inventors. Similarly, we remember the people, such as the amoral arms manufacturer Alfred Krupp, who have changed the world using Bessemer's process. And we also remember one man who did more than anyone else, in his time, with and for steel. Andrew Carnegie was another President of the Iron and Steel Institute and one of America's most famous industrialists.[38] In the Bessemer Room at the Institute, his portrait hangs opposite that of Henry Bessemer. Under the roof of this aged institution, the inventor and the manufacturer stand as equals, but outside we remember only Carnegie who, using the Bessemer process, became the richest man in the world.

## Andrew Carnegie's steel empire

It was oil, rather than iron, that created Carnegie's first fortune. In 1859, Edwin L. Drake made his momentous discovery of oil in Titusville, not far from where Carnegie was working on the Pittsburgh Railway lines as a telegraph operator and assistant to Superintendent Thomas A. Scott. The discovery brought a surge of wildcat prospectors to the area. Among the more respectable businessmen in this first wave was William Coleman, who had already

made a small fortune in iron manufacturing and coal mining. In 1861, by which time Carnegie had become Superintendent of the Pittsburgh Railway, Coleman invited him to invest in his oil concern. Carnegie received a return that was many times his initial investment and which, in true entrepreneurial spirit, he then invested in his own business.

Carnegie decided to take advantage of his relationship with Scott and Edgar Thomson, the new President of the Pennsylvanian Railway. Many of the wooden railroad bridges had fallen into disrepair during the Civil War and were now rotting. They needed replacing with iron bridges, and Carnegie was just the man to do this. Along with Thomson and Scott, who were still employed by the railroads, Carnegie formed a new company to build iron bridges. Corruption and cronyism were widespread and accepted ways of doing business. It was an environment in which Carnegie flourished; he secured lucrative contracts for his company through friends and business associates, starting with Thomson and Scott.

Henry Bessemer and Andrew Carnegie first met in 1872 when, while on holiday in Europe, Carnegie had visited Bessemer's new steel works in Sheffield. Unlike Bessemer, Carnegie was not an engineer; his skill was in putting proven inventions to their best use.[39] Bessemer became Carnegie's technological brain and Carnegie became Bessemer's salesman. The success of the steel works, and the high-quality steel it produced, was proof to Carnegie of the potential of the Bessemer process. He decided to invest with a recent fortune made by speculating in bonds.

In Pennsylvania there was a clear market for steel. During the Civil War, Thomson had become dismayed by the poor quality of rails on which the Union forces relied for transportation. Made from cast iron, the brittle lines would frequently break. Steel would have been better but it was just too expensive at the time.

Carnegie returned to Pittsburgh and embarked on the construction of a new state-of-the-art steel works, with his old friend

William Coleman, to supply the railways. Though there were eight Bessemer steel manufacturers in the US in 1872, none were in Pittsburgh. Two years later, the Edgar Thomson Steel Works opened; from that point on the growth of Carnegie's steel empire became unstoppable.

When demand slowed, Carnegie would increase, rather than reduce, the output of his steel mills. He would take a contract whatever the profit margin, beating the competition down using his economies of scale. His steel mills were always the biggest, the most automated and hence the lowest cost. He would immediately reinvest profits to expand and modernise his steel empire. He also integrated his business horizontally and vertically, buying up rival plants and bringing coke works and iron ore mines under the umbrella of his steel company. Carnegie's success came from business skills that we would recognise today. But it also came at the expense of his workers. In the drive for profits he reduced wages and increased working hours. These actions culminated in a strike at the Homestead Steel Works.

In July 1882, the labour contract between Carnegie and his workers at the Homestead Steel Works was due to expire. The skilled workers at Homestead were being paid more than the industry average and Carnegie saw an opportunity to save on labour costs. He also wanted to reduce the influence of the Amalgamated Association union at the mill. At the time the union, whose membership consisted of skilled metalworkers, held a powerful bargaining position. Carnegie saw this as restricting progress and profits and so Henry Clay Frick, whom Carnegie had placed in charge of operations at the plant, cut the workers' pay. The union would not agree; the steel industry was doing well, and they wanted a share. When the existing contract expired with no new agreement being reached, Frick locked the workers out and built barbed-wire fences and sniper towers to fend off any backlash. He also enlisted a security force, but, as it made its way towards the plant, it was met

by the striking workers. Tensions mounted and shots were fired. Many union members were killed. Eventually order was restored and Carnegie got lower wages and removed the union from the plant, but at the price of a tarnished reputation.[40]

As Carnegie's business continued to grow, mile after mile of steel railway poured out from his mills. The railroads were the greatest consumers of iron and steel as more goods and more people began moving from the east to the west of the US. The US steel industry, which for years had lagged behind Europe's, expanded explosively. The amount of steel rolled in 1890 was more than three times greater than ten years earlier. By 1900 output had almost trebled again to more than eleven million tonnes, at which point Carnegie's mills alone produced more steel than the entirety of Great Britain. Under Carnegie's leadership, the iron age gave way to the steel age.

Iron conveys wealth and power not only to nations, but also to the individuals who pioneer its production. Carnegie, the child of a poor hand-loom linen weaver from Dunfermline, Scotland, arrived in the US in 1848 practically penniless. By 1863, at the start of his entrepreneurial career, Carnegie's income was around US $50,000 (almost US $1 million today). In 1901, Carnegie sold his steel empire for US $480 million (US $13 billion today) to J. P. Morgan in what was the largest commercial transaction of its day to consolidate into US Steel.[41] Carnegie became the richest man in the world.

## Andrew Carnegie's 'Gospel of Wealth'

In 1986 I was invited to sit on the board of the Carnegie Mellon University Business School by Elizabeth Bailey, the Dean of the School. Elizabeth, an economist, was also an influential member of the Board of the Standard Oil Company of Ohio, where I was the Chief Financial Officer.[42]

I remember pausing and thinking as I scanned the letter-head. *Carnegie Mellon University*. I knew a little about Andrew

Mellon: a nineteenth-century American banker who later became the Secretary of the Treasury. I knew a lot more about Andrew Carnegie; his name was everywhere: Carnegie Hall in New York; the Carnegie Libraries across America and Great Britain; and the Carnegie Foundation for Peace. The Carnegie Mellon Business School was one among many prestigious institutions to which Carnegie, through his philanthropy, has attached his name. We may have forgotten Henry Bessemer, whose steel-making invention underpinned Carnegie's success, but by giving away his fortune Carnegie ensured that we still remember him today. It was all part of his grand vision, which he described in his 1889 essay, 'The Gospel of Wealth'.[43] That immediately caused an outcry among well-heeled capitalists. Carnegie planned to give away his fortune and urged his fellow tycoons, such as J. D. Rockefeller, Jay Gould and J. P. Morgan, to do the same.

At that time, the wealth generated from the industrial revolution in the US was exacerbating the divide between the rich and the poor. Rockefeller became the world's first nominal billionaire in 1916, when many Americans still lived in slums with no running water or electricity. Carnegie believed that this disparity in wealth demanded action 'so that the ties of brotherhood may still bind together the rich and poor in harmonious relationship'.[44] Carnegie's call for wealth redistribution has resurfaced in recent years. Today the top one-tenth of a per cent of all earners in the US take home about 8 per cent of the country's total income.[45] Contemporary billionaires, including Warren Buffett and Bill Gates, ask why the super-rich are not taxed more, and, like Carnegie, support giving money back to society through targeted philanthropy. Just as in the days of the strike at the Homestead Steel Works, sections of the public feel intense anger towards the rich, towards business and towards the political class.

The duty of the man of wealth, Carnegie claimed, was to set an example by living a modest and unostentatious life. All surplus

revenues, he wrote, should be considered 'simply as trust funds, which he is called upon to administer … to produce the most beneficial results for the community'.[46] The wealth of the individual had been created by the wider community, and so it should be returned to them. This is the great paradox of Carnegie. His desire to give back all that he earned to society 'encouraged him to be an even more ruthless business man and capitalist … the more he earned, the more he could give away'.[47] Cutting wages and increasing workers' hours were all part of his broader philosophy; he was convinced that he had a moral obligation to increase profits, rather than improve the welfare of his workers. He believed that his 'superior wisdom and experience' enabled him to administer this wealth 'better than [workers] would do or could do for themselves', but he also believed that he should only help them to help themselves.[48] In this way he set a trend that exists to the present day; his philanthropy was designed for people's self-improvement rather than subsidising them day to day. As a result, he invested heavily in education, building libraries and providing free tuition for Scottish university students.[49] He also opened scientific research institutions, music halls, art galleries and even a natural history museum in Pittsburgh. In 1900, he founded the Carnegie Technical Schools, which would later merge with the Mellon Institute of Industrial Research to become Carnegie Mellon University.

His work had a great impact on Rockefeller, who wrote to him after the Carnegie Library opened in Pittsburgh: 'I would that more men of wealth were doing as you are doing with your money; but, be assured, your example will bear fruits, and that time will come when men of wealth will more generally be willing to use it for the good of others.'[50] Yet, in private, he discussed the apparent vanity in Carnegie's philanthropic donations. The manager of one of Rockefeller's charitable trusts wrote to him that Carnegie gives money 'for the sake of having his name written in stone all over the country'.[51] In comparison, Rockefeller's donations were discreet,

perhaps so that he could not be accused of trying to curry favour in the face of Standard Oil's trouble in the courts.[52]

In 1910 Carnegie founded the Carnegie Endowment for International Peace, which is still active today. For a long time Carnegie had been an outspoken campaigner for world peace, opposing foreign intervention by the US and the UK. On the eve of the First World War he founded the Church Peace Union. By promoting moral unification and leadership, he hoped the Union would put an end to war for ever. Iron, or more accurately the profits from iron, was again being used as a force for peace. By the time of his death in 1919, Carnegie had given away 90 per cent of his wealth. He arranged for the rest to be distributed through the Carnegie Corporation of New York.

Despite the events of the strike at the Homestead Steel Works, we remember Carnegie as a benevolent philanthropist. Even Henry Clay Frick, the antagonist of the tragedy, is now remembered by a glorious collection of art on Fifth Avenue in New York.[53] Men are remembered by their ends, by their ultimate generosity, rather than the process by which they achieved those ends. As we look at the Vermeers, Holbeins and Rembrandts in the Frick Gallery we think of beauty and benevolence and not of the innocent lives lost at Homestead.

## The sky's the limit

In mid-1971 I had been living in New York for about six months when a friend of mine, a professional cellist, invited me to a concert at Carnegie Hall, which sits across Central Park from the Frick Collection. We went to listen to Paul Tortelier, the famous French cellist, playing *Variations on a Rococo Theme*, a piece by Tchaikovsky in the warm and colourful acoustics of the hall. When the hall opened in 1891, with a concert conducted by Tchaikovsky, it quickly became a New York City icon. The striking Italian

Renaissance-style façade of terracotta and iron-spotted brick was as fascinating to many visitors as the illustrious artists performing inside. The hall was designed by the architect William Burnett Tuthill, himself an amateur cellist. He decided against the use of steel support beams, but as a consequence had to build concrete and masonry walls several feet thick. Stone simply cannot carry the same load as steel. It is the thickness of the walls, along with the smooth elliptical hall interior, that lends Carnegie Hall its fine acoustic properties (and helps to drown out the rumble of traffic from 57th Street and Seventh Avenue outside). In 1891 it was already being overshadowed by a new breed of building, shooting up across the city: the skyscraper.[54] Just six-storeys high, Carnegie Hall was dwarfed by headquarters of the *New York Times* and *New York Tribune*. Ironically, it was the availability of cheap and abundant steel produced by Carnegie that supported this growth.

As early as in ancient Greece, iron had been incorporated into buildings so as to improve stability, but never had an entire load-bearing structure been fashioned entirely out of iron. In the 1820s cast-iron columns and beams were introduced into buildings in Chicago and New York. Architects and engineers were impressed by its compressive strength and durability and soon whole buildings' fronts were being made from cast iron. As an added bonus, unlike wood, iron did not burn but it did, however, melt. In the extreme heat of Chicago's Great Fire of 1871, building fronts buckled and collapsed and iron fell out of favour. Soon stronger and safer steel, pouring out of Carnegie's steel mills, enabled steel skyscrapers to rise upwards.

Architects and the public alike still worried whether they could trust steel to support such gigantic structures, but there was a need to find new space in the increasingly cramped cities. Great social and economic changes were sweeping New York. Immigrants were arriving daily from Europe, sailing past the steel-framed Statue of Liberty. Trusts and corporations were growing quickly and all

wanted office space in the financial and business capital of the US. Land prices were rising rapidly and the only direction in which to expand was upwards. Traditional stone was just not suitable. The taller the building, the greater the downward weight and therefore the thicker the base had to be. Early plans for the nine-storey masonry structure of the now demolished Tribune Building show basement walls that are two metres thick, a huge waste of valuable floor space. For architects to reach above six floors they had to rely on steel. Between 1870 and 1913, New York was raised from a city of six-storey buildings to one of fifty-storey skyscrapers.

When I arrived in New York on St Patrick's Day, 17 March 1971, I hated it. I did not know anyone, the hotels were shabby and the people were rude. But, becoming a resident of Greenwich Village, I soon grew to love the city. Fast-paced and full of interesting people, New York was, and still is, one of the most exciting places in the world. Like other great world cities such as Venice, Tokyo and London, New York is a unique and unmistakable urban environment. In particular, I remember being struck by the city's fantastic architecture. Elegant brownstone town houses are interspersed with imposing gothic and art deco skyscrapers. The city would rise up around you on all sides to a vertiginous height. It was very different from anything I had seen in Europe.

At weekends in New York I would cycle around the city. Leaving my apartment off Washington Square, I headed south through the then almost deserted district of SoHo, which is the site of the most significant and largest collection of nineteenth-century cast-iron buildings. I would head back north and just above Houston, in a rather grimy and run-down office area, one building stood out. It was called the Flatiron Building and it symbolised to me the growth of New York, over the last one hundred years, into the thriving metropolis of the 1970s. As its name suggests, the shape of the building resembles an old clothes iron, with a stark triangular cross-section that rises up to a height of 87 metres. The

twenty-two-tiered structure may seem squat in comparison to New York's modern-day mega-structures, but, on completion in 1902, the Flatiron was a significant feat of engineering.

It was built by the George A. Fuller Company. George Fuller was an architect and pioneered the building of skyscrapers in the US. In 1900, long before the first steel struts of the Flatiron were raised, Fuller died and the presidency of the company was assumed by his son-in-law, Harry Black. For some time he had had his eyes on the small triangular plot of land at the intersection of Broadway and Fifth Avenue. The site would be perfect for the company's new headquarters, acting as an advertisement for his rapidly growing business. Six months after Fuller's death, with the company now in his control, Black bought the land. The prime motivation for building upwards was profit. An editorial in *Life* magazine in June 1901 declared, 'here in New York the price of land determines the height of the building'.[55] And land prices were very high. Only above the tenth floor would investors break even on the land purchase. The tiny plot of land, just 9,000 square feet, had cost Harry Black $2 million ($55 million today).

As a result, aesthetics and economics were often at odds as skyscrapers began to dominate the city skyline. Many worried that the city would be overshadowed by unimaginative yet towering monstrosities. The Flatiron was designed to make the most out of the oddly shaped triangular plot of land, but Harry Black would often argue with the architect, Daniel Burnham, over the building's soft, curved edges. Why, Black would demand, were 93 square feet of valuable floor space being wasted? The Flatiron soon began to rise up from the wedge-shaped site. Thousands of steel columns, joists, struts and rivets arrived truck by truck and were put together much like a child's constructor set. Finally, the builders, standing on wooden platforms that hung down the length of the building, laid the terracotta-tile skin. In June 1902, it was complete.

The Flatiron was different from any other skyscrapers in the city.

Many architectural critics regarded the building as a feat of engineering but a failure as a work of art. But the building was embraced by the public and artists alike. The *New York Tribune* reported in 1902 that the Flatiron would attract crowds of 'sometimes 100 or more' and was painted and photographed more than any other building in the city.[56] Symbolically modern, the Flatiron appeared to change shape depending on where you were standing. On a winter's day in 1902, photographer Alfred Stieglitz stood looking up at the Flatiron and, pressing the shutter button, created a memorable image.[57] 'With the trees of Madison Square covered with fresh snow, the Flat Iron impressed me as never before,' he wrote. 'It appeared to be moving towards me like the bow of a monster ocean steamer, a picture of new America still in the making … The Flat Iron is to the United States what the Parthenon was to Greece.'[58]

The unique shape and location made the Flatiron another, and instant, New York City icon, but it was far from being the tallest building in New York. For one reason, its height was restricted by the strong winds that blew down 23rd Street, which bordered the southern edge of the Flatiron. Build too high, so the architects worried, and the building might be brought tumbling down. Locals placed bets on how far the debris would fall if this were to happen. It was an unlikely event as the Flatiron was designed to withstand four times the maximum wind force that it would ever come up against. In part, this strength lay in the building's odd shape. A triangle is the strongest of geometric shapes as it is a self-supporting structure: applying pressure at one point creates greater resistance at the other two points. Soon after the first tenant moved in, a 100 kilometres per hour windstorm braced the city, but inside the Flatiron not a vibration was felt. One tenant claimed that not even the filament inside his desk lamp shook. In fact, it was the Flatiron that held control over the wind. The shape of the building would channel the wind into blustery down draughts that could raise the skirts of female passers-by. Men would loiter around the

tower in the hope of catching a rare glimpse of ankle, the police calling out '23 skidoo', since the Flatiron is on 23rd Street, to move the chancers along. One local dressmaker even created a 'wind-defying' skirt.[59] Hats blew off heads and umbrellas were turned inside out, but the wind could also create more serious havoc. On the surrounding streets shop doors were blown open and plate-glass windows smashed. One February afternoon in 1903 a fourteen-year-old messenger boy, who was attempting to make it around the prow of the Flatiron towards Broadway, was blown into the middle of Fifth Avenue and killed by a passing motorcycle.

As more skyscrapers rose around the Flatiron, the sharp wedge shape lost its propensity to channel wind and the gusts died down. Cycling along Broadway in the 1970s, the Flatiron was no longer as imposing, overshadowed by the nearby Metropolitan Life Tower. But the building continues to attract people to the area and is a constant reminder of a period of unparalleled growth in the city.

Skyscrapers are built to accommodate more people in a city centre; building upwards is just a more efficient use of the land. Iron's strength and abundance underpins this concentration of the human population into small pockets dotted about the world. These hives of activity foster innovation and so support human progress, raising humanity from simple rural communities to prosperous urban societies.

Skyscrapers were also built as symbols of economic and political power. Some of the first inhabitants of New York's pioneering buildings were the executives of the corporate trusts, such as Standard Oil and US Steel (formed from the Carnegie Steel Corporation and several other major producers), which resulted from the industrial revolution. Prestige was vitally important to Rockefeller, Carnegie and the other American robber barons and so these buildings were beautiful as well as big.

The World Trade Center's Twin Towers were the tallest buildings in the world when they were completed in 1971. For thirty

years they stood as symbols of America's economic eminence, and this is why they were chosen as targets in the terrorist attacks on 11 September 2001. The Twin Towers went down, and with them 200,000 tonnes of steel. On the day of the attacks, New York City mayor Rudy Giuliani declared: 'We will rebuild. We're going to come out of this stronger than before, politically stronger, and economically stronger. The skyline will be made whole again.' The Ground Zero site is being restored to its former standing as a centre for global economic activity; on completion, One World Trade Center will be the tallest skyscraper in America.

## The Iron Lion of Cangzhou

At the beginning of 2012 there were, for the first time, more people living in cities than in rural areas. Nowhere is this dramatic shift more apparent than in Asia. The Petronas Towers in Kuala Lumpur, Malaysia, are the biggest twin towers ever built, while Dubai's Burj Khalifa is the world's tallest skyscraper, standing 830 metres high. Iron and steel have made this possible; China is now the world's biggest consumer of iron ore.

Every time I visited China in the 1980s and 1990s, new ramshackle and purely functional apartment and office blocks would have sprung up with extraordinary speed. In this period of rapid economic growth, the pragmatic prevailed over the aesthetic; there was little time to consider how to create a sustainable and beautiful city environment. Today, many of these early buildings have been knocked down and replaced with piercing skyscrapers. China's cities are getting taller and sprawling faster than anywhere in the world. The simple, elegantly curved Shanghai World Financial Centre and the oddly pleasing Beijing headquarters of China Central Television, colloquially known as 'the big-shorts', are Flatirons of the twenty-first century.

These are not the first iron colossi that China has built. In the


small city of Cangzhou, 240 kilometres to the south of Beijing, stands the Iron Lion. It is over five metres tall and weighs around 50 tonnes. Originally, the Lion is thought to have lived inside a Buddhist temple, with a bronze statue of Bodhisattva Manjusri riding in the lotus flower on his back. Today it is battered and broken. The Lion's tail went missing sometime around the turn of the seventeenth century, and in 1803 a storm toppled the statue, chipping the beast's snout. It may have seen better days, but the hulking cast-iron mass persists as evidence of the phenomenal Imperial Chinese iron industry that existed over a thousand years ago. When it was cast in AD 953, the production of iron in China was far greater than

anywhere else in the world. Iron output increased sixfold between AD 800 and 1078 to 115,000 tonnes, almost as much as the whole of Europe would produce in 1700. China's growing iron industry was just one face of the great social, political and economic changes that were sweeping through the country during the late Tang and Song dynasties. Joseph Needham, the historian of Chinese technology, writes that 'China in 1000 had more in common with China of 1900 than it had with the China of 750'.[60]

With this prodigious output of iron, China cast the tools and weapons that it used to become a dominant global power at the beginning of the second millennium AD.[61] Up until 1700, China had the world's largest and most efficient iron industry, which during the nineteenth and twentieth centuries declined. During this period, a Chinese poet, Ji Ruiqi lamented this change:[62]

*Thinking of ancient flourishing glory*
*I sigh for the changes of our times*
*But the Iron Lion still stands,*
*While halls and palaces have turned to thorns and brambles.*

In Europe and the US the industrial revolutions were creating increased productivity and growth; scientific advances had led to an array of innovative low-cost iron- and steel-making techniques. China could now simply not compete. In the late 1950s, Mao Zedong was determined to reverse the decline of its iron and steel industry during the Great Leap Forward. He wanted China to produce more steel than Great Britain but the pots and pans he had collected and melted down produced useless pig iron.[63]

Under the rule of the British Raj, the economy in India was also stalled. Jamsetji Tata, a successful cotton and textile industry entrepreneur, wondered what could be done to reverse this position. With his already-made fortune Jamsetji decided to pursue his own vision: the development of India.

## The house of Tata

Jamsetji believed that four ingredients were necessary for industry to flourish in India. First, technical education and research were needed to reduce India's reliance on foreign technology. Second, he saw that hydroelectricity would utilise India's huge supply of water to generate cheap electricity. Third, he made plans to build a grand hotel, to attract the wealthy international elite to India. Finally, and most crucially, Jamsetji wanted to produce steel, 'the mother of heavy industry', for the building of railways and cities.[64]

The notion that India could succeed in making steel to British standards was ridiculed. Sir Frederick Upcott, Chief Commissioner for the Indian Railways, offered to 'eat every pound of steel rail they succeed in making'.[65] Behind this arrogance, however, was the fear of competition, a fear which for a long time had caused the British Raj to hold back industrial development in India. It was not until the 1890s that the Raj began to support the development of the iron industry in India, when Great Britain saw itself slipping behind the booming iron industries in Germany and the US.

Jamsetji finally earned government support when he met Lord Hamilton, the Secretary of State for India, in 1900. Now sixty and wealthy, Jamsetji explained to Hamilton that his efforts to develop a steel works were for the improvement of his home country rather than personal profit. Hamilton told him that he would have full government backing. At once, Jamsetji left for the US, where he sought the advice of Julian Kennedy, America's foremost steel expert and manager at Carnegie's well-known Edgar Thomson Steel Works. Then he hired a geologist to seek out suitable iron ore reserves, a task he had started almost two decades earlier.

In 1904 Jamsetji Tata died. Of his four great plans for India, only the Taj Mahal Hotel had been completed, built with ten pillars of spun iron that still hold up the ballroom ceiling today. The execution of his vision was continued with equal determination by his

sons, Sir Dorabji and Sir Ratanji Tata. Three years later, Dorabji found the perfect site for the Tata steel plant at the small village of Sakchi, which had had a good supply of iron ore, water and sand. Sakchi was later renamed Jamshedpur in honour of Jamsetji. In 1912, the Tatas' plant produced its first ingot of steel, marking the birth of India's new iron industry. During the First World War, Tata Steel exported 2,500 kilometres of steel rails, leading Dorabji to comment that if Sir Frederick Upcott had fulfilled his promise to eat every quality steel rail produced he would have suffered 'some slight indigestion'.[66]

The Tatas' first steel mill might never have been built if it had not been for their nationalist vision. Seeking investment for the Sakchi steel mill, the Tatas appealed to their fellow Indians to invest in a project that would help industrialise India. One observer recounts how '… from early morning till late at night, the Tata offices in Bombay were besieged by an eager crowd of native investors. Old and young, rich and poor, men and women they came, offering their mites; and at the end of three weeks, the entire sum required for construction requirements … was secured, every penny contributed by some 8,000 native Indians.'[67]

At all Tata's industrial enterprises, the wellbeing of the workers was a priority. Jamsetji introduced humidifiers, fire sprinklers, sanitation disposal and water filtration into his early cotton and textile mills. He was also a pioneer of pension funds, accident compensation and equal rights. Unlike Carnegie, the Tatas did not pursue profits at all other costs; they believed that a business that supports the development of a nation must also support the health and wellbeing of its people. A century before Western business had defined corporate social responsibility, enlightened self-interest and the triple bottom line, he had already got there.[68] Tata knew that consideration for society must be integral to every aspect of operations. When shareholders complained of the great expense going into building workers' accommodation on the site of the Tatas' first

steel mill, Sir Dorabji would tell them: 'We are not putting up a row of workmen's huts in Jamshedpur, we are building a city.'[69] In 1895 Sir Dorabji wrote: 'We do not claim to be more unselfish, more generous or more philanthropic than other people. But we think we started on sound and straightforward business principles, considering the interests of the shareholders our own, and the health and welfare of the employees, the sure foundation of our success.'[70]

There are few more eloquent expressions of the proper relationship between business and society. Even today many businesses have failed to catch up with Tata. Some still follow American economist Milton Friedman's mantra that 'the only business of business is business', and believe they can ignore the external world.[71] In doing so, they risk their reputation, their licence to operate and their customers. Today, as the scrutiny of business becomes more intense than ever, and as governments call on business to do more and more beyond their core activity, we would do well to refer to Tata's example, and to observe the success it became, not only for his dynasty but for India as a whole.

In *The Argumentative Indian*, Nobel prize-winning economist Amartya Sen considers the role that our sense of identity and social motivation play in the determination of our economic behaviour. 'Within the limits of feasibility and reasonable returns,' he writes, 'there are substantial choices to be made, and in these choices one's visions and identities could matter.'[72] For the Tatas, a nationalist vision of India's industrial development led them to behave quite differently in their business practices from the American robber barons.

Like Carnegie, Jamsetji Tata also gave money to support the needs of his nation. With the large fortune that Ratanji and Dorabji inherited, they set up philanthropic organisations, with a focus on education, health and founding institutions of national importance. They continue to hold a large shareholding in Tata today. Jamsetji Tata is remembered in India in the same way as Carnegie

is remembered in the US. They differ in how they acquired their wealth. Carnegie sought to amass as much wealth as possible, whatever the cost to his workers, so that he would have more to give back to society, while, for the Tatas, their personal wealth and that of India were one and the same. Both used iron to develop the industrial power of a nation, to form the foundations of a long-lasting business and, ultimately, to give back to society.

Their approaches were successful in their own time and place, but neither would be entirely successful today. In the lawless early days of the American industrial revolution, cronyism and corruption were the only ways for a business to survive and grow. Today such behaviour would provoke an immediate and powerful public backlash; a business would not grow or survive. Even the Tatas' pioneering and enlightened approach to business is not wholly sustainable in today's business environment. Dorabji's decision to build 'a city', rather than 'a row of workmen's huts', would run contrary to the fundamental business principle of maximising shareholder value.[73] Dorabji's shareholders were the people of India, whereas today shareholders are largely private individuals. In the current business environment, social investment remains a vital aspect of ensuring business sustainability, but there is a need for something more. In the face of growing inequality, philanthropy remains a vital mechanism for redistributing the wealth that individuals acquire through their use of the elements. In Carnegie and the Tatas we find lessons for today.