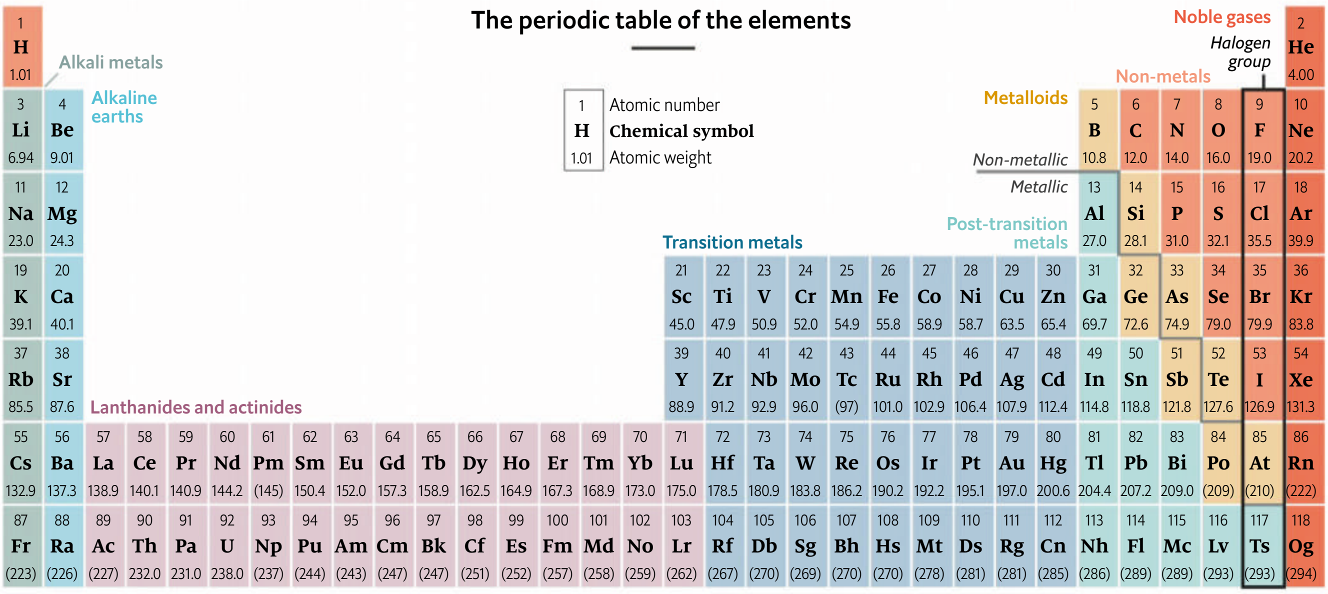


The periodic table

The heart of the matter

One of science's greatest creations is 150 years old this week. How it was created is a perfect illustration of the process of scientific progress

"*La république n'a pas besoin de savants ni de chimistes.*" With that curt dismissal a court in revolutionary France cut short the life of Antoine-Laurent de Lavoisier, argued by some to be the greatest chemist of all. Lavoisier's sin was tax farming. He had been a member of the firm that collected the monarchy's various imposts and then, having taken its cut, passed what remained on to the royal treasury. That he and many of his fellow farmers met their ends beneath a guillotine's blade is no surprise. What had distinguished Lavoisier from his fellows, though, was what he chose to spend his income on. For much of it went to create the best-equipped chemistry laboratory in Europe.

Nothing comes of nothing. Where the story of the periodic table of the elements really starts is debatable. But Lavoisier's laboratory is as good a place as any to begin, for it was Lavoisier who published the first putatively comprehensive list of chemical elements—substances incapable of being broken down by chemical reactions into other substances—and it was Lavoisier and his wife Marie-Anne who pioneered the technique of measuring quantitatively what went into and came out of a chemical reaction, as a way of getting to the heart of what such a reaction really is.

Lavoisier's list of elements, published in 1789, five years before his execution, had 33 entries. Of those, 23—a fifth of the total now recognised—have stood the test of time. Some, like gold, iron and sulphur, had been known since ancient days. Others, like manganese, molybdenum and tungsten, were recent discoveries. What the list did not have was a structure. It was, *avant la lettre*, a stamp collection. But the album was missing.

Creating that album, filling it and understanding why it is the way it is took a century and a half. It is now, though, a familiar feature of every high-school science laboratory. Its rows and columns of rectangles, each containing a one- or two-letter abbreviation of the name of an element, together with its sequential atomic number, represent an order and underlying structure to the universe that would have astonished Lavoisier. It is little exaggeration to say that almost everything in modern science is connected, usually at only one or two removes, to the periodic table.

The mighty atom

The Lavoisiers' careful measurements had discovered something now thought commonplace—the law of conservation of matter. Chemistry transforms the nature of substances, but not their total mass. That fact established, another Frenchman, Louis-Joseph Proust, extended the idea with the law of definite proportions. This law, published in 1794, the year of Antoine Lavoisier's execution, states that the ratio by weight of the elements in a chemical compound is always the same. It does not depend on that compound's method of preparation. From there, it might have been a short step for Proust to arrive at the idea of compounds being made of particles of different weights, each weight representing a specific element. But he did not take it. That insight had to wait for John Dalton, a man who was the polar opposite of the aristocratic bon vivant Lavoisier. Dalton's parents were so poor that he had been put to work at the age of ten. The man himself was an ascetic, colour-blind Quaker. And he was English.

Dalton lived in Manchester, at a time when it was the world's largest industrial city. He made a modest living tutoring, but spent most of his energy on scientific research, including into colour-blindness, a condition still sometimes referred to as Daltonism. That inquiry came to nothing. But during the first decade of the 19th century he took Proust's concept and showed not only that elements reacted in fixed proportions by weight, but also that those proportions were ratios of small whole numbers. The simplest way to explain this—and indeed the way that Dalton lit upon—was to suppose each element to be composed of tiny, indivisible particles, all of the same weight. The Greek word for indivisible is "atomos". Thus was the atom born.

Dalton based his system of relative atomic weights on hydrogen, the atoms of which he found to be the lightest. And it was quickly picked up by someone who, though less famous than Lavoisier, perhaps because of his grizzly end, was arguably the greater man. Jacob Berzelius, a Swede, furnished chemistry with its language. It was he who came up with the idea of the abbreviations that now occupy the periodic table's rectangles. It was he who combined those abbreviations with numbers, indicating the proportions involved, to make formulae for chemical compounds: H_2O (water), H_2SO_4 (sulphuric acid), NaCl (table salt). And it was he who used these formulae to describe reactions: $H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$ (sulphuric acid plus zinc becomes zinc sulphate plus hydrogen). Though Dalton invented atomic theory, it was Berzelius who embedded it at the heart of the subject.

And Berzelius did more. He used Alessandro Volta's recently invented battery, which created electricity from a chemical reaction, to do the reverse. He employed electricity to drive chemical reactions in solutions (for example, releasing metallic copper from a solution of copper sulphate), a process called electrolysis.

Back in England, Humphry Davy, inventor of the miner's safety lamp, picked up the idea of electrolysis and supercharged it. He employed a more powerful version of Volta's battery to decompose molten materials, rather than solutions. In this way he discovered sodium and potassium in 1807 and magnesium, calcium, strontium, barium and boron in 1808. He also showed that chlorine, previously thought to be a compound of oxygen, was actually an element.

After Davy's work new elements began to flow in thick and fast. Iodine (1811). Cadmium and selenium (1817). Lithium (1821). Silicon (1823). Aluminium and bromine (1825). By then there were enough of them for the next step on the journey to be taken.

It had been apparent from the time of their discovery that sodium and potassium were similar, as were calcium, strontium and barium. Lithium, when discovered, proved similar to sodium and potassium. Likewise, bromine and iodine proved similar to chlorine. In 1829 Johann Dobereiner, a German, noticed a curiosity about these trios (members of groups now known, respectively, as alkali metals, alkaline earths and halogens), and also another triplet that shared similar properties: sulphur, selenium and tellurium. In each case, if the members were arranged in order of atomic weight, the middle element (sodium, strontium, bromine, selenium) had a weight that was the average of the lightest and the heaviest of the three. Dobereiner called this the law of triads. It was the first hint of some underlying pattern.

The stamp collection continued to grow. Thorium was discovered in 1829 (by Berzelius, as it happened). Lanthanum followed in 1838, erbium in 1843 and ruthenium in 1844. Then, in 1860, Robert Bunsen, inventor of the burner that bears his name, showed how new elements could be recognised from brightly coloured lines in the spectra obtained when materials containing them were heated in a flame. This approach was an instant success. Bunsen and his colleague Gustav Kirchhoff added caesium (1860) and rubidium (1861) to the list. Others, copying them, added thallium (1861) and indium (1863). Spectroscopic analysis's greatest triumph, though, was helium (1868). This was recognised not from a sample in the flame of a Bunsen burner but in the spectrum of the sun.

As more and more elements turned up, so the search for order intensified. In 1864 John Newlands, a Briton, almost got it. He published what he called the law of octaves. Arranging the known elements in order of atomic weight, he believed he had discerned that, like a musical scale, every eighth element "rhymed" in the ways that sodium rhymed with potassium, and chlorine with bromine.

The trouble with Newlands' scheme was that an awful lot of the rhymes were forced. A glance at a modern periodic table shows why. For the tall, outer columns (and discounting hydrogen, which is a law unto itself) Newlands' octaves work perfectly for the lightest elements then known. From the row beginning with potassium (K, from the Latin *kalium*, meaning potash), however, the tall outer columns are split asunder by the intrusion of ten other, shorter ones known as the transition metals. To deal with that intrusion using data then available required a mixture of luck and genius. And a few years after Newlands published, a lucky genius wrestled with the question in his study in St Petersburg.

Mendeleev

Albert Einstein, dapper in his youth, cultivated a waywardness of appearance in old age that has contributed to the trope of the mad professor. Dmitri Mendeleev (pictured overleaf) looked like that from the beginning—having his hair cut just once a year by a shepherd, using wool shears. He


ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

основанной на ихъ атомномъ вѣсѣ и химическомъ сходствѣ.

			Ti=50	Zr=90	?=180.
			V=51	Nb=94	Ta=182.
			Cr=52	Mo=96	W=186.
			Mn=55	Rh=104,4	Pt=197,4.
			Fe=56	Ru=104,4	Ir=198.
			Ni=Co=59	Pl=106,6	Os=199.
H=1			Cu=63,4	Ag=108	Hg=200.
	Be=9,4	Mg=24	Zn=65,2	Cd=112	
	B=11	Al=27,4	?=68	Ur=116	Au=197?
	C=12	Si=28	?=70	Sn=118	
	N=14	P=31	As=75	Sb=122	Bi=210?
	O=16	S=32	Se=79,4	Te=128?	
	F=19	Cl=35,5	Br=80	I=127	
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204.
		Ca=40	Sr=87,6	Ba=137	Pb=207.
		?=45	Ce=92		
		?Er=56	La=94		
		?Yt=60	Di=95		
		?In=75,6	Th=118?		

Д. Менделѣевъ

Mendeleev's dream

also behaved like a mad professor. He was prone to dancing rages that put one biographer in mind of the protagonist of "Rumplestiltskin", a children's fairy tale. Also like Rumplestiltskin he proved, metaphorically at least, able to spin straw into gold.

For a time, Mendeleev had worked in Germany with Bunsen and Kirchhoff, but he had fallen out with them and returned home. In 1869 he was professor of general chemistry at the University of St Petersburg and was writing a Russian-language textbook on the subject. On February 14th of the Julian calendar then in use in Russia (February 26th by the Gregorian calendar employed in most of the rest of Europe), having addressed halogens and alkali metals, he was racking his brains for an organising principle to act as a template for the rest. The 14th was a Friday, and the problem obsessed him more and more over the weekend. But on Monday 17th, while waiting for a sleigh to take him to the railway station for a trip to an estate he had bought in the countryside, he had a brainwave.

Mendeleev was an inveterate player of patience. His brainwave was to recognise that, just as games of patience require the player to organise the pack as a grid of suits in order of the value of the cards, so the elements might be arranged by their atomic weights in "suits" that shared chemical and physical properties. By making his own pack, with each card representing one of the 63 then-known elements, he was able to embark on what was arguably the most important game of patience ever played.

He claimed subsequently that the answer had come to him in a dream. Perhaps. But after having worked for four days on the problem without much rest, the boundary between sleep and wakefulness must have been pretty blurred. Whatever the details, the result was a grid of cards that arranged the elements in a pattern (see picture). He published it two weeks later.

His grid was not perfect. Indeed, it was full of holes. But those holes (some of them, anyway) turned out to be keystones. Though there was no reason, in the 1860s, to believe that all the elements had been discovered, Newlands had behaved as though they had been. Mendeleev had enough confidence to leave gaps in order to make the pattern work. At the time, some took this as a sign of weakness. In fact, it was a sign of strength—the more so because, for several of the gaps, he described in detail the properties of the elements he predicted would fill them, and these predictions were, by and large, fulfilled.

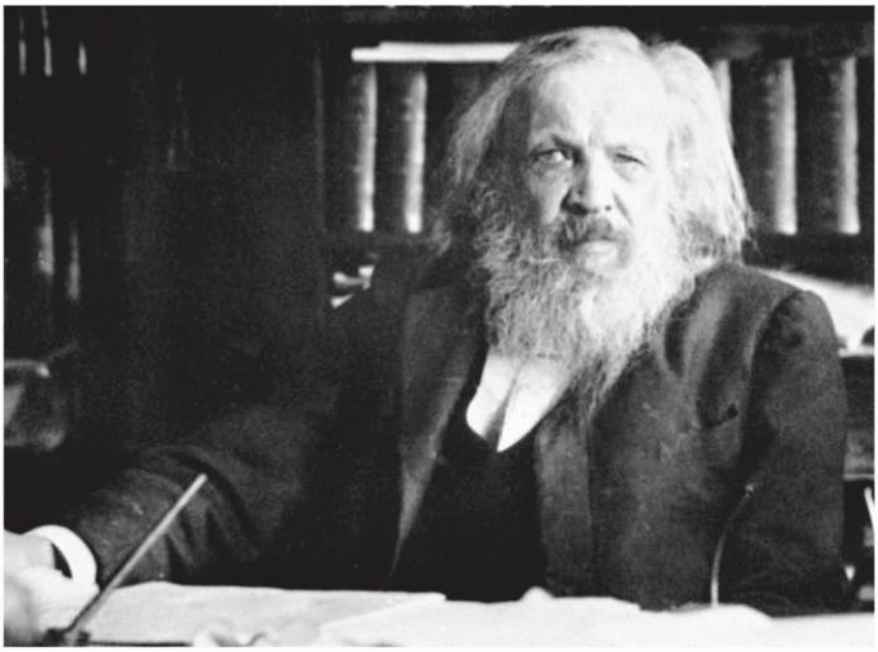
Similarly, there are places in Mendeleev's original table where it works only by cheating—that is, by swapping two adjacent elements between the places to which their atomic weights assign them. Here, Mendeleev argued that the accepted weights were incorrect, and needed re-measuring. Sometimes, he turned out to be correct about this, too. But not always. A few such pairs, cobalt and nickel for example (which actually share a slot in the published table), remained stubbornly out of kilter, providing evidence that atomic weight was really a proxy for some deeper structural principle

Crucially, Mendeleev was not constrained, as Newlands had been, by preconceptions about how things ought to be. At points where the octave rule did not work, he let the grid burst out of its corset. This can be seen at both the top and the bottom of the published table.

The upper-right-hand extension contains the transition metals. Here, subsequent discoveries have proved Mendeleev more or less correct in his insights. The lower-left-hand one is more problematic. Its contents are a grab bag, though it does contain all of the then-known members of the set of elements called lanthanides. Arguably, Mendeleev was lucky that by 1869 only three lanthanides had been discovered. In a modern table there are 15 and, together with the actinides below them, they form an awkward interpolation that is often relegated to the bottom as an asterisked footnote. Whether Mendeleev's game of chemical patience would have been helped or hindered by having more lanthanides in the pack is an intriguing question.

There was also an invisible gap, the filling of which was one of the table's greatest triumphs. Helium, which Mendeleev ignored because its atomic weight could not be established, turned out to be the lightest member of a whole, new row (or column, in a modern table). These are the noble gases, undiscovered previously because they are chemically inert. The others are neon, argon, krypton, xenon and radon.

Like Davy's discoveries, the noble gases came all of a tumble. All but radon were the work of William Ramsay, a Briton. With various collaborators, Ramsay isolated argon in 1894, helium in 1895 and neon, krypton and xenon in 1898. Instead of chemistry, he used physical processes. All except helium were products of the newly developed technology of cryogenics, which he used to liquefy air and then separate it into its components, according to their boiling points. Helium, he found by heating a mineral called cleveite.



There's antimony, arsenic, aluminum, selenium. And hydrogen and oxygen and...

The transmutation of the elements

The 1890s also saw the first inklings that atoms themselves might not, despite the meaning of their name, be truly indivisible. The initial evidence that atoms could spin off parts of themselves, and must therefore have smaller components, came in 1896. That was when Henri Becquerel, who was investigating the nature of phosphorescence, wrapped some uranium salts in photographic paper and found that the paper got fogged. Thus did Becquerel discover radioactivity.

The following year, J.J. Thomson worked out that "cathode rays" emitted into a vacuum by a negative electrode were electrically charged particles that weighed far less than any atom. Then, in 1899, Ernest Rutherford, a former student of Thomson's, showed that Becquerel's radiation had two components, which he dubbed "alpha" (heavy, positively charged particles) and "beta" (light, negatively charged ones).

Becquerel himself, in 1900, showed that beta particles were the same as Thomson's cathode rays. Seven years later, Rutherford demonstrated that alpha particles were helium ions (thus incidentally explaining why cleveite, which is an ore of uranium, is also a source of helium). The stage was now set for some of the most important experiments in history: Rutherford's attempts to find out what atoms looked like.

One previous guess had been that they were vortices in the luminiferous aether through which light and radio waves were thought to propagate. That hypothesis, however, died with the aether itself, when the latter's existence was disproved experimentally in the 1890s. Rutherford's experiments, conducted between 1908 and 1910, probed matter by firing alpha particles at gold foil. Most sailed through, to be recorded by a scintillation screen beyond the foil. But a few were deflected from their courses, to be recorded by other screens, including one behind the source. This screen's recording of alpha particles returning whence they had come was described by Rutherford as being "almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you". His explanation, now abundantly proved true, was that the atoms in the foil had tiny, positively charged nuclei, which were reflecting the positively charged alpha particles, and that these nuclei were surrounded by electrons.

Regardless of an atom's exact nature, losing alpha and beta particles necessarily changes it. Such radioactive decay proved a source of yet more members of the periodic table. Polonium and radium—decay products of uranium—were found in 1898 by Pierre and Marie Curie. Actinium, the lightest actinide, followed in 1899. Radon was recognised in 1900. Protactinium in 1913.

Models of the atom also became more sophisticated. In 1913, Rutherford and a Danish colleague, Niels Bohr, suggested electrons orbit the nucleus as planets orbit the sun, with electrical attraction playing the role of gravity. In the same year Henry Moseley, another of Rutherford's confrères, found a mathematical relationship between an element's x-ray spectrum when bombarded with electrons and its atomic number in the table. In pairs like cobalt and nickel, where the table had been fudged, Moseley confirmed the fudges to be correct. He tidied up the lanthanides, predicting missing elements as Mendeleev had done. He also predicted two new transition metals, with atomic numbers 72 and 75, which duly turned up in 1923 (hafnium) and 1925 (rhenium).

Moseley's x-ray spectra demonstrated that an element's atomic number does not depend directly on its atomic weight. Rutherford soon showed that the atomic number is actually the number in a nucleus of a positively charged particle that came to be known as a proton. Even though protons weigh almost 2,000 times as much as electrons, the two have equal (though opposite) charges. An atom, which has equal numbers of both, is therefore electrically neutral. Protons are not, though, heavy enough to account for measured atomic weights. That requires a second, electrically neutral particle, the neutron. This was discovered in 1932. Neutrons are also the reason that an element can have atoms of different atomic weights, known as isotopes. These isotopes have different numbers of neutrons.

The Bohr-Rutherford model of the atom had a problem, though. Electrostatic forces should pull the electrons into the nucleus rather than keeping them in orbit. Here, the new science of quantum mechanics came to the rescue. Quantum theory requires objects to be both particles and waves. The wavelike aspect of electrons means that when they circle an atomic nucleus they settle into self-reinforcing three-dimensional standing waves, called orbitals. The stability of these standing waves stops the electrons being drawn into the nucleus. And here, at last, is the explanation for why the periodic table is the way that it is.

Spdfg

For reasons deep in the heart of quantum mechanics, each orbital can have either one or two electrons in it, but not more. The orbitals themselves come in different types (see diagram) and these are arranged in shells around a nucleus. The first shell has one type "s" orbital, for a maximum of two electrons. The second, a type s and three type p, for a maximum of eight. The third has one s, three p and five d, for a maximum of 18. The fourth, one s, three p, five d and seven f, for a maximum of 32. Et cetera. The names are derived from the spectral lines seen by Bunsen and his followers. The colours of these lines represent energy released as light by electrons moving between orbitals.

It is the shells that define the table's rows. In the first row, which consists of hydrogen (one electron) and helium (two), the first shell is filled up. In the second row, from lithium to neon, the second shell is filled. The third row, from sodium to argon, fills the s and p orbitals of the third shell. The fourth, from potassium to krypton, fills the s and p orbitals of the fourth shell and the d of the third shell (which has ten electrons altogether, for the ten columns of transition metals).

Compounds are created either by unpaired electrons from different atoms forming joint orbitals called covalent bonds, or by the complete transfer of unpaired electrons between atoms, to create paired orbitals in the recipients. When this happens, the resulting positive and negative ions are held together by electrostatic forces—a process called ionic bonding. The repetitive order in which the shells are filled in each row means that elements in each column of the table have the same combination of unpaired electrons, and thus similar properties. For example, the noble gases are inert because they have no unpaired electrons. Further analysis showed, moreover, that the difference between metals and non-metals depends on how easy an atom's outer electrons are to detach (if easily detached, they can flow as an electric current, reflect light in the way that makes metals shiny, and confer ductility on the solid form of the element). And that, essentially, is chemistry solved.

It is not quite, however, the end of the story. In the 1930s physicists discovered that radioactivity could, in essence, be reversed by bombarding atoms with subatomic particles to increase their atomic numbers. This way, new elements can be produced. Technetium, created in 1937, was the first such. Two years later francium, the last to be discovered in nature, was isolated as a decay product of actinium. From that moment the extension of the periodic table became work for physicists, not chemists.

Technetium is strange. Despite its low atomic number (43) it has no stable isotopes, and is thus found only transiently in nature. This is a quirk of the physics of protons and neutrons that it shares with promethium (61). But at the heavy end of the table, beyond lead (82), radioactivity is compulsory for all. And beyond uranium (92) it is so compulsory that "transurancis" were once thought not to occur in nature.

This part of the periodic table was the playground of Glenn Seaborg, an American physicist. In 1940 Seaborg was part of a group at the University of California, Berkeley, that made neptunium (93). When the group's head left later that year, Seaborg took over. On his watch americium (95), curium (96), berkelium (97), californium (98), einsteinium (99), fermium (100), mendelevium (101) and nobelium (102) were all created. But his first discovery, plutonium (94, in 1941), was the most important. On July 16th 1945, the first atom bomb, a plutonium-implosion device, was tested at Alamogordo, New Mexico. On August 9th of that year another of the same design destroyed Nagasaki, in Japan.

Americium has its uses, too. Since it was a synthetic product, it was patentable, and Seaborg did, indeed, patent it. It was (and is) employed in smoke detectors, and he drew a tidy income from that fact for many years. Beyond 95, though, the practical point of extending the table became less and less obvious as elements became less and less stable.

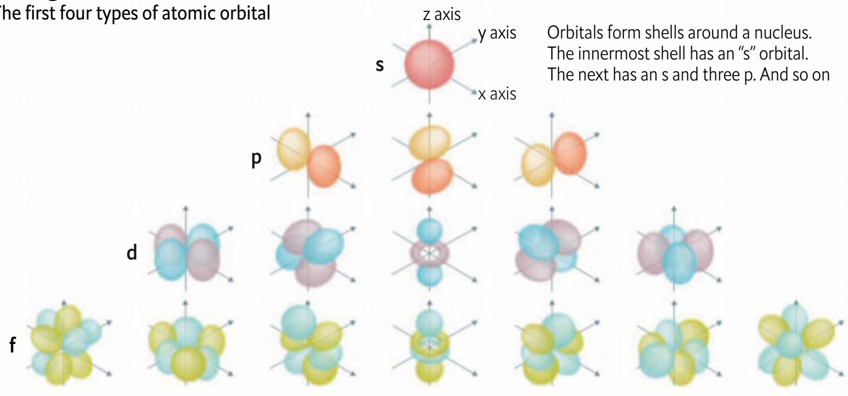
Efforts to make new elements slowed down after 1955, though there was a pick up again in the mid 1990s. Neither chemistry nor the wider world, however, reverberated with excitement at the creation of darmstadtium (110), roentgenium (111), copernicum (112) and nihonium (113) in the way that they had with the discovery of potassium, or helium, or radium or plutonium. What started as stamp collecting has returned to its roots—except in one regard. This is that, thanks to Mendeleev's brilliance, element-hunters now have an album in which to stick their discoveries.

The heaviest element of all, oganesson (118), was created in 2002, though named only in 2016. Oganesson completes the table's seventh row. Chemically, it should be a noble gas. But, with only a few atoms of it to play with at a time, and with those atoms having lifetimes measured in milliseconds, it seems improbable anyone will ever know for sure.

Despite physicists' best efforts, then, the eighth row has not been reached. But as Mendeleev himself said, "To conceive, understand and grasp the whole symmetry of the scientific edifice, including its unfinished portions, is equivalent to tasting that enjoyment only conveyed by the highest forms of beauty and truth." For those who share this view, and see in the periodic table a supreme example of nature's poetry, the row-completing, album-filling addition of oganesson may seem as good a place as any to stop. ■

Shell game

The first four types of atomic orbital



Crime

American scourge

Mass shootings get plenty of attention. But ordinary violence causes far more damage to the most vulnerable people

An American Summer: Love and Death in Chicago. By Alex Kotlowitz. *Doubleday; 304 pages; $27.95*

Walk through Bronzeville on Chicago's South Side and there is plenty to suggest that a once-troubled neighbourhood is on the up. A supermarket has replaced a housing project, the Ida B. Wells Homes, that was notorious for gangs, drugs and murder. In Peach's, a bustling corner restaurant, a customer who is tucking into breaded catfish and collard greens talks of a local revival. He marvels that brownstone houses nearby used to go for a song, when many were boarded up and abandoned. Now they sell for $1m or more.

Some locals fear gentrification, or the loss of a proud black history. In the 1950s over 110,000 African-Americans called Bronzeville home. Artists such as Louis Armstrong, Duke Ellington and Josephine Baker would play and party on 47th Street. As the neighbourhood smartens, incoming white and Hispanic residents put a welcome dent in segregation. But poorer blacks are being squeezed out, as they are elsewhere in Chicago. The city has lost over 230,000 black residents so far this century, most from the South Side.

Above all, crime festers. Although Bronzeville has become safer in the past few years, it still endures levels of crime unthinkable in richer (and whiter) places. The number of homicides in Chicago as a whole has dropped since 1991, when 927 people were killed. The city nonetheless sees more of them (538 last year) than more-populous New York and Los Angeles combined. As many as 4,000 people are shot and wounded yearly, one every two hours. Many of them are paralysed.

Some observers liken the neglected districts in the South and West Sides of the city to war zones. The term "Chi-raq" (a combination of Chicago and Iraq) has grown popular in recent years, adopted by rappers, T-shirt makers and the film-maker Spike Lee. Once acquired, such a reputation is terribly hard to shake. Take the word of Eddie Bocanegra for that. He is a former gang member who tries to steer youngsters away from violent crime. At a recent meeting in a red-brick YMCA in Bronzeville, he spoke of how his brother, a soldier who just ended a tour in Syria, refuses to move to Chicago because of its lawlessness.

How people confront that violence and deal with its consequences is the subject of Alex Kotlowitz's new book. His first, "There Are No Children Here", was published at the peak of killings, in the early 1990s. It remains a model of powerful writing on a painful subject. For years Mr Kotlowitz, a journalist and author who lives in the city, immersed himself in the lives of two brothers, Lafayette and Pharaoh, as they became young teenagers. His book tells, in intimate detail, of their growing up in public housing, threatened by gangs and guns.

In his new book, "An American Summer", Mr Kotlowitz returns a generation later to the same topic. Depressingly, much continues as before. In the past 20 years over 14,000 people have been murdered in the city. Again he sets out how sudden deaths, injuries and constant dread cut apart the already fragile lives of the most deprived. Mr Kotlowitz spent four years among some 200 interviewees. He tells some of their stories, set in the hot months of 2013 as a surge in killings occurs. "Sun's out, guns out," as sardonic locals say.

He tells Mr Bocanegra's story, describing his persistent sense of guilt for killing a rival when a teenager, how he served his sentence and has since tried to make amends by counselling others to prevent more violence. More distressing are the profiles of near-random victims, such as a girl hit by a stray bullet from a shoot-out. She died in her living room while dancing at her 11th birthday party. Mr Kotlowitz notes how many parents "take out life insurance policies on their children", fearing the cost of a funeral.

Mr Kotlowitz is a sympathetic, fluent writer. He is not one for policy prescriptions, but the accumulating accounts of ▸▸

suffering serve to condemn the city for letting the violence drag on. The author meets a quadriplegic man in his 20s who can find care only in a dementia home. Victims who survive are among the likeliest to become perpetrators, or victims again. The law is hardly a deterrent: only one in ten shootings leads to even a charge. Many witnesses to murders are terrified or set on revenge; few are willing to testify. Though Mr Kotlowitz does not dwell on it, relations with police are often tense. Barely a quarter of murders are cleared up.

The shifting nature of violence is also troubling. Mr Kotlowitz picks out two trends. First, many killings today seem purposeless. Although he does not romanticise the criminal past, he notes that a few well-structured gangs such as the Gangster Disciples and Vice Lords used to fight to control territory and Chicago's drug trade. Then, many killings could at least be understood as part of those clashes.

Since the police broke the large gangs, hundreds of tiny cliques—police estimate 625—have risen. These can have as few as ten members, often young teenagers on a residential block. Such boys are anxious to prove themselves fearless to peers. All have easy access to guns. The cliques quickly turn to violence after a petty spat, or to assert status on the street. "People get into it over nothing", "just because", as one miserable teenager explains.

In your face

A second change adds to the trauma. In the past many killings were somewhat hidden. They took place in dark corners of enormous public-housing towers where gangs battled. Many such buildings have been demolished in the past few decades. Another writer, Ben Austen, last year published "High-Risers", a gripping account of the rise and fall of Cabrini Green, one of the most notorious of such complexes.

The removal of towers that concentrated poverty, dysfunction and mayhem is welcome—it is part of what lets neighbourhoods like Bronzeville begin to recover. But a side-effect is that violence now occurs more often on ordinary residential streets where youngsters play or chat. Some murders are even streamed on social media by bragging rivals. As Mr Kotlowitz writes: "The thing about Chicago's violence is it's public—very public—and so each shooting or its aftermath is witnessed by many, children and adults alike."

Where will all this end? Hopeful evidence from neighbourhoods like Bronzeville (or cities like New York) shows that economic rejuvenation, better policing and training for young people can all bring violence down. More worrying is that such facts have long been known, but officials and others have done far too little. In the face of inaction, tragedy is inevitable. ■

Classical music

Steel and strings

CLEVELAND

Orchestral music is thriving in a rock'n'roll city

When the Cleveland Orchestra moved into Severance Hall in 1931, the state-of-the-art design let well-heeled patrons call their cars from their boxes and be whisked home without having to linger in the cold midwestern air. By 1963 its music director, George Szell, was on the cover of *Time* and its albums were bestsellers. But after the imperious Szell died in 1970, the orchestra, now in its centennial season, came to lack a distinct identity. "We give a great concert and Szell gets a great review," griped a former music director in 1997.

The trajectory reflected the decline of the city itself. Once the fifth-largest in America, a steelmaking hub and sports powerhouse, Cleveland for decades was known mostly for losing games, money and people—shedding half its population in a generation. What is now the 51st-largest city in the country is an unlikely home for a top-tier orchestra. In the late 20th century Cleveland was more associated with rock'n'roll (a term coined by a local DJ in the 1950s). A museum celebrating that sound opened in 1995, and seemed poised to oust Severance Hall as the centre of the city's musical life.

Yet the 21st century has seen—and heard—a revival of the orchestra's glory. Both financially and artistically, the outfit is stronger than ever. Much of its success can be credited to the latest music director, Franz Welser-Möst. The Austrian-born conductor arrived in 2002 and began reshaping the band. One Cleveland board member confides that he was chosen over more famous conductors because he pledged to upend the status quo: "Franz was the only one who said, 'There's something different I'd like to do'."

Absolute precision has been the orchestra's hallmark since Szell. Mr Welser-Möst prefers a lighter touch. "You can't have total control," he says. "Szell would tell the English horn player which optician to go to. That doesn't work any more." Now the music breathes more. Before his current job he endured a rocky stint with the London Philharmonic Orchestra, but in Cleveland he is well-liked by both his players and the wider community. When the orchestra visits local schools or plays at pop concerts on holidays, he goes too. "It makes a difference to people if they see you and say: 'I know this guy'."

More Clevelanders are indeed getting to know him: subscriptions and attendance are rising. The audience is the youngest for any American orchestra, with more than a fifth of classical concert-goers aged 25 or under. Just as important, the patrons are charitable. Statutory funding for the arts is less munificent than in bigger cities and more left-leaning states, but Cleveland's long tradition of private giving is holding up—crucially, since the institution's endowment covers only a fraction of the operating budget. Last year the orchestra raised almost $25m; it has managed more than $20m for the past five years.

That is a handsome haul for any arts organisation, especially one in a mid-tier city. Concert-goers seem to take pride in the underdog character of their musicians. "It's not a huge population here, but it's a very generous community," says André Gremillet, the orchestra's executive director. "They're proud that north-east Ohio can produce great American culture." ■

Poco a poco crescendo

The past returns

Fragments and ruins

Time Song: Searching for Doggerland. By Julia Blackburn. Illustrated by Enrique Brinkmann. *Jonathan Cape; 304 pages; £25. To be published in America by Pantheon in August; $26.95*

TO LIVE BESIDE the sea is to be reminded of absences. Bones, mammoth tusks, fossilised creatures and even ghostly footprints are washed up on the beach or uncovered under layers of sand, hinting at generations of bygone residents, human and animal. The coastline of East Anglia in England has inspired many writers, notably W.G. Sebald, a German who walked and meditated on its history. That stretch of shore is also one of the places where evidence of Doggerland—the huge area of forests and plains that connected Britain to mainland Europe before it was submerged by the rising sea—has recently appeared.

A search for traces of Doggerland is the starting point for "Time Song" by Julia Blackburn, a writer and poet who lives in Suffolk. Blending nature writing with memoir and poetry, her book is an unconventional attempt to "learn prehistory hand to mouth". The result is a meditation on the Mesolithic and what people are truly looking for when they turn to the past.

Like many of the people in the book—a Dutch customs inspector with an interest in mammoth bones, a young British fossil-hunter—Ms Blackburn is a collector with an eye for minutiae. Like an archaeologist's shelf, her writing is filled with detail. A friend has a "wonderful breathing bellow of a laugh"; a row of bungalows resembles biscuits in a tin. She relays what the experts she meets say and do, but also notes the muffins they eat, and her nervous chuckle when one of them comments on her untidy handwriting. These mildly eccentric folk, and Ms Blackburn's responses to them, strike a humorous note rarely found in nature writing.

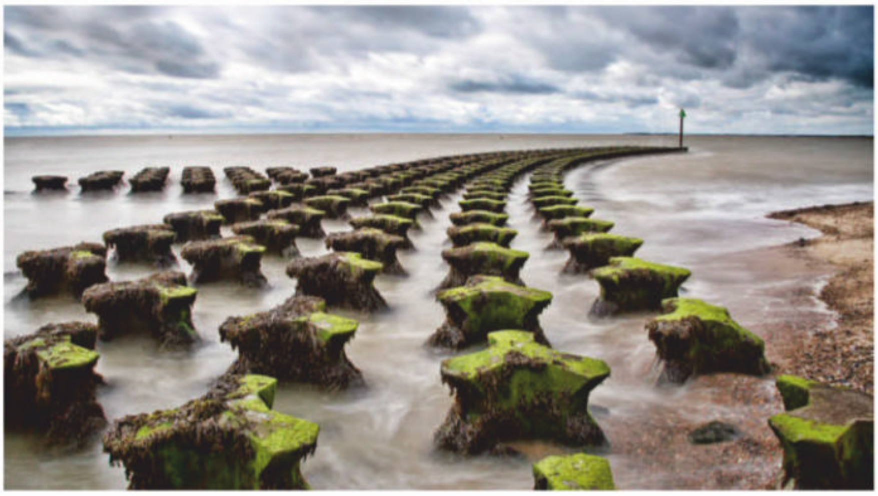
But it is in her descriptions of the sea and her imaginings of the land it submerged that Ms Blackburn's book is most arresting. In her evocation of Doggerland, and how it may have looked or felt before being flooded by rising seas around 8,000 years ago, she is quick to see a parallel with modern climate change:

> I have watched starlings thickening the evening sky, seals gathered in their breeding colonies, an exodus of toads too numerous to count; but every year there is less to see and my memory tries its best to forget what it has known, for fear of being made too sad by the reality of that loss. We learn to grow accustomed to the absences, because it seems we have no choice.

"Time Song" is not overtly political. Brexit is mentioned only briefly, despite the obvious echo of Britain once again trying to sever connections with the adjacent landmass. But it is deeply concerned about the environment, and how people treat and remember the landscape.

And with another, more personal loss: of Ms Blackburn's second husband, Herman Makkink, a Dutch artist. As Ms Blackburn searches for the elusive Doggerland, his absence becomes palpable, too. Her journeys back and forth between Britain and the Netherlands recall earlier trips they made together. In the face of the Tollund Man, the prehistoric body found in a bog in Denmark in 1950, she catches a glimpse of her husband's features as he died: "They had the same pattern of lines across the forehead, the same arch of the nose, the same inward smile."

Ms Blackburn's poetry, interspersed throughout, is less compelling than her lyrical prose. Yet the combination of wry observations and personal reflections makes "Time Song" gripping. In searching for a landscape she can never fully grasp, much as she reaches out for her husband's hand in the night to find it missing, she discovers a sort of comfort. The book arrives at an acceptance of loss—of small personal sorrows, if not larger environmental ones. The director of the museum that houses the Tollund Man tells Ms Blackburn that seeing the shrunken, preserved body each day made him realise that "death is not so bad; it is nothing to be afraid of". ■


The shallow blue sea

Hungarian fiction

Ghosts of Budapest

Katalin Street. By Magda Szabo. Translated by Len Rix. *NYRB Classics; 248 pages; $15.95. MacLehose Press; £12.99*

THE HUNGARIAN writer Magda Szabo, who died in 2007, knew from personal experience what it meant to have dreams smashed by arbitrary power. As a young poet she won her country's chief literary honour, the Baumgarten prize, in 1949. On the same day, the communist regime cancelled this award to a "class enemy". She lost her civil-service job, went to teach in a primary school, and only began to publish novels a decade later as a thaw began.

Her fiction shows the travails of modern Hungarian history from oblique but sharply illuminating angles. In novels such as "The Door" and "Iza's Ballad", intimate dramas are entangled with public upheavals: the repressive governments and Nazi occupation of the 1930s and 1940s; the sudden annihilation of Hungary's Jews; the soul-sapping compromises and betrayals of the Stalinist era. In "Katalin Street", published in 1969 but only now translated into supple, graceful English by Len Rix, three neighbouring families live through the shocks that batter Budapest between 1934 and 1968.

Readers meet the upright, naive headmaster Mr Elekes, who will see his obedience to authority traduced by two kinds of tyranny, and his wife and daughters: sensible, thoughtful Iren, who narrates part of the story, and scatty, lovable Blanka. Next door lives the affable Jewish dentist Mr Held, with his wife Anna and dreamy daughter Henriette. On the other side resides the kind-hearted warrior Major Biro with his housekeeper-mistress Mrs Temes and son, Balint. The fate of this tarnished golden boy, a mediocre but weirdly charming medic, anchors a plot that jumps back and forth through the decades. ▸▸

To these adjacent households on a quiet street between the Danube and the castle, public tumult often feels as remote as the distant sounds of unrest that reach survivors during the anti-communist uprising of 1956. They dwell most happily in memory, in longing, even in fantasy. Their pasts haunt their present: "The dead are not dead," Szabo writes, "but continue living in this world."

Devoted to order and ritual, headmaster Elekes seeks to "impose stability on the uncertainties of life". History, with its "concentrated unreality" of cruelty and absurdity, will wreck all such hopes. Szabo summons the cosy, closed world of the three clans with a lyrical, quicksilver touch. That makes the thuggish intrusions of despotic power—the Helds' deportation, the shooting of Henriette—all the more wrenching. In a striking departure from her usual delicate realism, the author makes the dead girl return as a phantom witness to later events. The post-war years see persecution, exile, grief and eviction fray or snap this tight circle of allies. Symbolised by the ghostly Henriette, former times shadow the new, with "the living experience and the old memory sitting neatly side by side".

Szabo is no nostalgic sentimentalist. The pre-war bourgeois idyll between river and castle had defects aplenty. Yet gilded recollection fortifies and binds the families; Iren and Balint, tetchily married in the end, have both "seen the same blue sky shining, before the thunder broke". That thunder blew trust and justice out of daily life. Now, only force and chance hold sway. "Life isn't a schoolroom," Balint says when the mercurial Blanka defects to the West. "There aren't any rules." ■

Johnson Laying down the law

What to look for in a usage and grammar guide

WHY DO PEOPLE buy books on English usage? The obvious answer, "for authoritative advice", doesn't square with what people actually buy. For decades the best-selling grammar book in the English-speaking world, by far, has been William Strunk and E.B. White's "Elements of Style". It is breezily readable, but neither comprehensive—a recent edition is 95 small pages—nor even always reliable.

It is not the only book in that category. Lynne Truss had a mega-seller with "Eats, Shoots and Leaves: a Zero Tolerance Guide to Punctuation". Never mind that "zero-tolerance" needs a hyphen; Ms Truss's style—sometimes crisp humour, sometimes camped-up outrage—was the real selling-point. A gentler humour is on offer in Gyles Brandreth's contribution, "Have You Eaten Grandma?", which follows Ms Truss in making a joke of a missing comma. It calls "Most of the time" a subordinate clause, among other lapses. But it too has sold well. It seems that people prize attitude over expertise.

At the other end of the spectrum lie venerable reference books. The "Chicago Manual of Style", in its 17th edition, is a bible for American copy editors. Bryan Garner, a lawyer and lexicographer, produces well-researched tomes. "Merriam-Webster's Dictionary of English Usage" is one of the best in the business. But these hefty books cannot be zipped through like those of Ms Truss or Mr Brandreth.

Some journalistic outfits, including the Associated Press, the *New York Times* and *The Economist*, offer advice in a smaller package. And a few individual writers have done the same in recent years, with "Accidence Will Happen" by Oliver Kamm (the language columnist for the *Times* of London), "The Joy of

Syntax" by June Casagrande (a copy editor and columnist) and "The Sense of Style" by Steven Pinker (a Harvard psychologist). All three are natives, not tourists, in the study of language, but their books can be read for fun. And so can "Dreyer's English", the newest entry. Published only last month in America, it is already in its fifth printing—quite an achievement for a 60-year-old first-time author with strong opinions on the en-dash.

Benjamin Dreyer is the copy chief at Random House, a New York publisher. For four decades he improved others' prose without showcasing his own. His experience and good sense are established as early as page 9, where he dispels what he calls "the big three" unkillable myths—that you can't start a sentence with a conjunction, end one with a preposition or split an infinitive. Do all three, says Mr Dreyer. "You'll have a certain percentage of the reading and online-commenting populace up your fundament to tell you you're subliterate. Go ahead and break them anyway. It's fun, and I'll back you up."

Although he enjoys killing off bogus rules, Mr Dreyer is more concerned with injunctions you should follow than with ones you should discard. In some places he is conservative (singular *they* is on the rise, but he can't quite endorse it). In others he is unconventional (he does not use question-marks with so-called tag questions, which can jar, can't it). But on every page, the serious stuff is spiced with his distinctive humour.

On some, the serious-to-spice ratio is reversed. The section on proper nouns is heavy on Broadway. The section on redundancies probably didn't need "assless chaps" ("chaps are by definition assless. Look at a cowboy. From behind"). But these digressions are delivered with a wink. One reviewer called the book "for the 1%", but that missed the point, and the percentage. This book is not for a financial upper crust, but an intellectual one, and not just a slim sliver. It is a democratic and liberal-minded book for readers who care for grammar, usage and a good read at the same time. Judging from the book's sales, more than 1% might want that. All the better that it is informed by decades of dealing with subtleties, edge cases, language change and the rest. Where Mr Dreyer delivers a sharp "do this, not that" on a matter of dispute, he admits that you are getting his opinion, not some unchanging rule on stone tablets.

Mr Dreyer says he considered calling the book "The Last Word", but decided against: "There's no rule without an exception (well, mostly), there's no thought without an afterthought (at least for me), there's always something you meant to say but forgot to say. There's no last word, only the next word." This is what to look for in a language book: authority without arrogance. There is always more to learn.