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This paper examines how the library building accommodates books and how the library catalogue allows the management and use of those books; all in the context of the great increase in book numbers after the establishment of printing with moveable type in Europe from about the year 1500. The following subjects are studied in particular: furniture for storing books, how this is laid out and how it develops; the practical and intellectual concerns behind the development of the library catalogue; the design of library buildings, particularly internally, to house, provide, and preserve increasing numbers of books; the intellectual changes brought to the catalogue by physical developments, such as paper slips, cards, and computerisation; the era of the remote library warehouse, accessed only indirectly. Examples are sought throughout Western Europe and North America, with particular attention paid to two of the UK's legal-deposit libraries, the Bodleian Libraries of the University of Oxford, and the British Library. It is found that these institutions anticipate a reduction in the number of printed books and other matter that they must ingest but are unable to reliably predict when this will occur and have subsequently planned for a short- and medium-term of continuing growth.

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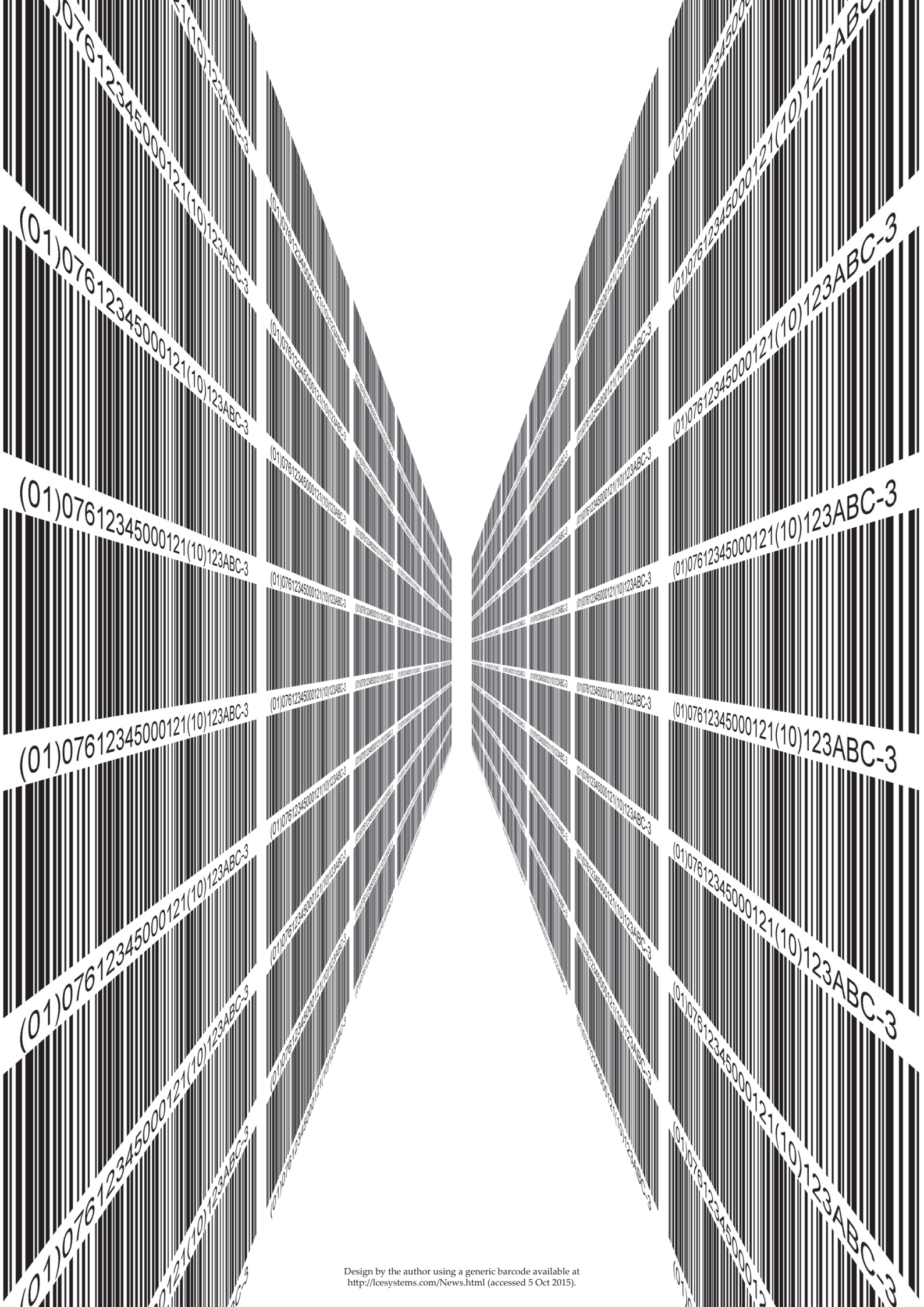

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RESEARCH PROJECT REPORT

ACCOMMODATE

> *"I fear we shall remain for a long time in our present confusion and indigence through our own fault. I even fear that after exhausting curiosity without obtaining from our investigations any considerable gain for our happiness, people may be disgusted with the sciences, and that a fatal despair may cause them to fall back into barbarism. To which result that horrible mass of books which keeps on growing might contribute very much. For in the end the disorder will become nearly insurmountable ; the indefinite multitude of authors will shortly expose them all to the danger of general oblivion ; the hope of glory animating many people at work in studies will suddenly cease ; it will be perhaps as disgraceful to be an author as it was formerly honorable."*
>
> Precepts for advancing the sciences and arts / Gottfried W. Leibniz.

These words demonstrate that Leibniz genuinely feared that the 'book flood', as it has since been described by Markus Krajewski (2011, p.9), which swelled after the establishment of printing with moveable type in Europe after 1500, led to such a glut of learned writings that the project of human advancement might not just be thwarted but abandoned. Leibniz the librarian did a great deal to address the problem he described, but later floods such as that due to the industrialisation of printing in the 19th century, and the considerable growth of academic research and publishing after the Second World War, led to similar concerns that benefits would be lost and effort duplicated if people's writings were not discoverable.[1]

Leibniz is famously a character in one of the best-known intellectual disputes – that between him and Sir Isaac Newton regarding the discovery of the differential and integral calculuses. Leibniz wrote about the benefits of having a complete reference to the established propositions of geometry in his *New Essays on Human Understanding* (1704).[2] Leibniz's optimistic and rational approach to the sciences led him to hope that similarly formulaic solutions to all of the fields of human enquiry might be sought and found. Needless to say such discoveries are not (at least not yet) to be counted amongst his successes, but he is rightly given credit for many advances – including some in librarianship, such as supervising the construction of the first free-standing purpose-built library "in the modern era" (Leibniz; Remnant & Bennett, eds., 1996, p.lxxiv).

Leibniz lived at the end of the early modern period. Its beginnings are contemporary with that great technological advance mentioned above, Gutenberg's printing press. This is not a coincidence.[3] In the 15th century libraries were still repositories for manuscripts and typically integral to monastic enclosures, though the early universities were building their own collections, chiefly by donation. In monastic libraries acquisitions were likely to be copies made in-house, often of other copies (Harris, 1995, p.112-3). The printing press was initially used to imitate the conventions of the manuscript – Gutenberg's groundbreaking Bible was deliberately given the appearance of a superior product of the scriptorium (Lerner, 2009, p.83). But an era of mass production had arrived and a new industry, with an infrastructure to support it, began to form. To become part of this infrastructure libraries had to adapt (Harris, p.127). The architectural historian James W. P. Campbell agrees, yet

1 For example, the Science Museum's S. C. Bradford, cited in Newman, 1966. Also see Norman, 2012.

2 The Newton-Leibniz calculus controversy could be blamed on the parties' reluctance to publish. A clearer example of how Leibniz suffered due to lack of contemporary mathematical knowledge, and further references, are provided in the author's essay to be found in Appendix B of the original submission (omitted here).

3 See McLuhan, 1962 and Bacon, 1620; Hobbes, on the other hand, thought printing "ingenious" but "no great matter" (Leviathan, p.100).

goes further in stating "the history of libraries has been a story of constant change and adaptation" (2013, p.15). However, in the early modern period change did not come quickly.

The 16th century

In the 1500s even the best libraries were monuments to the handwritten word. Michelangelo's Laurentian Library (*Laurenziana)*[4] of 1571 in Florence is an outstanding extant example. A long narrow room furnished with lecterns (*banchi*) that would have originally housed bound and chained manuscripts, which could be brought out from their flat storage position on the shelf below for reading while seated at the desk; all illuminated by the daylight coming in from the side windows.[5] A permanent shelf list at the end of each lectern listed its contents, and each lectern was arranged in a mode typical of medieval libraries, perpendicular to the walls. The *Laurenziana* was designed to hold a specific collection that was considered complete and not to be expanded – a stationary library. As much as being a place to access the manuscripts it was also a way to demonstrate the dominant Medici family's wealth, power and culture (O'Gorman, 1972; Campbell, 2013, pp.104-6). This stasis therefore also had some political symbolism, but this showcase library represented a format that was reaching its limits.

In the 16th century, if volumes were not stored in lecterns they would have been in cabinets or *presses*,[6] behind doors. The following century would see amalgamations of the two methods of storage but libraries were rather slow to respond to the cheaper, smaller, printed book. An engraving of Leiden University's library from 1607 shows a perpendicular arrangement of lecterns, though in this case the lecterns are taller and designed for standing rather than sitting readers (Campbell, p.108). Also like the *Laurenziana*, which was built on top of older monastic buildings, the library at Leiden was on a mezzanine in a church nave and so benefited from large clerestory windows. In this respect Leiden was somewhat similar to Duke Humfrey's[7] Library, which was built over the Divinity School at Oxford. This had been completed in 1480, stripped of its books by the King's commissioners in 1550, and restored to use by Bodley in 1598, though it would not be ready to reopen until 1602 (Clapinson, 2015, p.9). One hundred years later Sir Christopher Wren would be called upon to reinforce the Divinity School's bulging walls with buttresses.

Petroski (1999, p.64) conjectures whether "the standing lectern might have evolved from the sitting one as a space-conserving measure," which would allow more lecterns, and therefore more books, in a given area. If so, this is a good analogue of how high-density storage facilities such as warehouses are laid out today, with high shelving in narrow aisles in order to exploit the floor area and building volume as effectively as possible. The 1607 engraving of Leiden certainly shows lecterns that are densely packed. Back-to-back lecterns may have a similar origin – that of saving space. This would have been inappropriate in church, where the pews must face the altar; but in a library such a focus is not necessary.[8] Using lecterns for storage rather than locking books in *armaria* is also a space-saving measure in itself. Not only are the closed presses bulky but space must be allowed for their doors to be opened. Petroski also explains the perpendicular arrangement of the lecterns with respect to the walls. As the books were chained, they could not be moved to the light, so the light had to reach them. The best way to achieve this was illumination from the side, which suited the reader (pp.59-67). It also suggested the perpendicular arrangement of lecterns, which was also space efficient.

4 Also known as the Medicean Library. See Clark, 1901, p.234.
5 A 19th-century extension unfortunately saw most of the windows on one side blocked up.
6 In Latin, *armaria*. See Clark, p.20.
7 Humfrey, Duke of Gloucester; brother to Henry V, Agincourt veteran, and manuscript collector.
8 Interestingly, Petroski also gives examples of library lecterns being converted for use as pews elsewhere after libraries are refurbished with higher-capacity shelving in the development away from chaining manuscript volumes.

The 17th century

Bodley's refit of Duke Humfrey's Library, while maintaining a similar floor plan, replaced the absent original lecterns with furniture altogether more capacious. The Duke Humfrey became what Clark defined a "stall-system" library (1901, p.172). The layout seems medieval (a mistake repeated in the "few" books on the history of library architecture)[9] but the first was built "at the beginning of the early modern era" at the end of the 16th century. Essentially, lecterns were replaced by shelving, forming distinct "bays or stalls" (Campbell, p.113)[10] – an early example being Henry Savile's work at Merton College, Oxford. At Duke Humfrey's Library some two thousand volumes (many sourced from the college libraries) lined the shelves on the "impressive three-decker book presses" with reading desks (Clapinson, p.9).[11] Jackson suggests the source for the design of these was the "then quite-up-to-date" style at Hereford Cathedral (1974, p.152). "The books were divided by size; the folios being chained to the desks, and accessible to all readers; the quartos and octavos being shelved apart and kept under lock and key" (Norris, 1939, p.144). Shelf lists were framed on the end of each bookcase – something that came to haunt James and his successors as the collection grew and the concept of permanent locations for particular volumes was stretched to breaking point (Clapinson, p.53). Jackson (p.260) observes that in the 18th century it became a "nightmare" that one could not expand a collection and have permanent shelf locations. Krajewski concurs (p.29).[12]

It is worth noting, as Petroski does, that it has by now become conventional practice to shelve books vertically; on medieval lecterns and in *armaria* they were stored flat. This is simply an ingenious – and to our enlightened minds, obvious – way of maximising the available space (Petroski, p.77). He also, from Streeter (1931), explains that the shelf lists at Hereford referred not to shelves, as such, but *partitiones*; ie, the compartment between vertical dividers, which were most likely there not to hold books upright as much as to prevent the shelf above from sagging. This might seem a fine distinction but it does suggest that, though 17th-century bookcases look very much as those of today, their users at the time were still thinking of them in terms of the *armarium* or cabinet, with its separate compartments. This also helps to explain how the word press came to be used for both closed book cabinet and open bookcase. In practice, books were filed from left to right across the entire bookcase before continuing on to the next shelf level down. This is the contrary of modern practice in which an upright tells the reader to continue on the shelf below, forming what are now called tiers, sections, or bays. The shelf marking system at Hereford confirms this (Petroski, pp.92-3).

To continue describing Duke Humfrey's Library, the windows being relatively low, the higher bookcases made the interior rather dark[13]; unlike at Leiden, with its high church windows. Merton had dormer windows fitted to improve illumination but this was impossible at the Duke Humfrey. In another example, at Queen's College, Cambridge, a transition can be traced between the original lecterns and their gradual conversion into tall presses.[14] Once chains were deemed unnecessary thanks to "mass-produced printed-editions" and books could be removed, desks and seats could also be removed, leaving more space for books (*Ibid*., pp.87-8). This stall system was a "peculiarly English form" rather like medieval monastery carrels, such as those found at Gloucester Cathedral. On the Continent, an alternative was imminent (Campbell, pp.110-18).

9 Campbell claims to have written *The Library, a World History* because he could not find such a book, either as a student or today (p.15). However, he is much in debt to Clark, as this author is to him.

10 Campbell seems to assume that a stall is the area between two presses but Clark (p.172) and Norris (p.187) rather identify the term with the press itself. For Norris, it is a bookcase that might be designated a unit for purposes of classification and identified by a letter (p.220).

11 They are still there and can be accessed by anyone possessing a Bodleian Library Card. During a restoration in 1999 they were sympathetically fitted with lighting and mains sockets. The original books are still in place but notices on each shelf request readers not to remove them.

12 Permanent shelf locations have come back into use in 21st-century library warehouses, though with neither classified nor alphabetical arrangement. See *Perpetuate*.

13 Having written some of this dissertation at one of the desks, the author can attest to this. The ceiling bears the University's motto: *Dominus illuminatio mea*, or The Lord is my light.

14 In this later usage press signifies a unit of back-to-back bookcases without doors. Petroski (ch. 5) traces its evolution from *armarium* and lectern.

The Escorial in Madrid, which was completed c.1585, is the earliest surviving example of a large library laid out according to the "wall system" (*Ibid*. p.121).[15] Its books are in cabinet-type presses, but not of the opaque type that were still characteristic, for example, of the Vatican Library. These cabinets were now for display, yet with the books shelved spine-in, but visible through grillework in the doors. As such, the books became part of the decoration that was to become increasingly dominant in libraries of this format.

With printed books on paper becoming the norm, methods of shelving designed for large parchment folios became obsolete. Their size and binding required that they be stored flat on a lectern and were so costly that they also needed to be chained. With paper books the same content could be stored in one or two metres of wall shelving that would have occupied an entire lectern library of the typical size of 300 manuscript folios (*Ibid*., p.125). Nevertheless, the high factor of efficiency in storing information enjoyed by the new printed book was not enough to counteract the sheer increase in the number of titles available. Similarly, as well as becoming larger, libraries themselves also needed to become more space efficient. The Biblioteca Ambrosiana (Milan, 1609) is posited by Campbell (p.127) as the next significant milestone in wall-system libraries, with "all the walls around the room" covered in bookshelves, requiring ladders and a gallery for access. The same features are to be found in the near contemporaneous Bodleian Arts End, which is also a wall-system design. Its galleries are, according to convention, protected from unauthorised access and used for the smaller volumes that would be easier to steal. Folios at the floor level remained chained.

Though England was slow to adopt the wall system wholeheartedly, preferring stalls of increasing capacities, by the late 1600s Sir Christopher Wren was applying his skills to good effect. According to Campbell, "Wren was probably involved in more library projects in the late 17th century than any other architect in Europe and he made decisive advances in library design" (p.137). As a Fellow of All Souls and Oxford's Professor of Astronomy, he would have seen the wall system at the Bodleian and its later implementations at University College, Jesus College and St Edmund Hall (refitted 1668-1682), and had its merits reinforced by a visit to France in 1665. Lincoln Cathedral's is a single-tier wall-system library (1674) – one full-height wall of fixed shelves opposite a wall of windows, with no desks or benches. To an early 21st-century visitor this array of books on open shelving looks entirely conventional, but in its day it was original.

Wren went on to design a fine galleried wall-system library – the Dean's Library at St Paul's Cathedral – which was built in the early 1700s as the cathedral was being completed. However, his greatest design – that for Trinity College, Cambridge – was never realised in its original form, though the concept came to be very influential. Nevertheless, what Wren built in its place defines the *alcove* library, which looks back to the arrangement of monastic lecterns while managing to accommodate a greater number of books than the wall system; all while keeping them readily accessible. The alcove library does this by utilising the wall space between the perpendicular bookcases to house yet more books. The alcoves also help to keep a large library hall to a more human scale. Generously lit by large clerestory windows, Wren's rectangular built design for Trinity is reminiscent of Leiden and even the *Laurenziana*. A long gallery was constructed on an island in the river Cam (with the intervening branch being filled in the process) over a cloister, thus elevating it over any flood waters. Wren cleverly disguised the true height of the floor from the outside so visitors are impressed to find the ceiling so high. The practical effect is that the windows can be larger, admitting enough light to illuminate the alcoves.

> The cases of books at right angles to the walls greatly increase the capacity and divide the room into useful study areas, while the disadvantages of lack of light are overcome by raising the windows above the stalls, freeing up wall space to be used for yet more books. The result is a triumph of classical library design, the first 'alcove' library in the world." (Campbell, p.142)

15 In German the term Saal-system (hall system) is used, giving a clue as to the overall expansion of library spaces in this format.

Wren's 1675 original, and rejected, design for Trinity was very different but interesting and influential – a large round domed 'pavilion' in which the books lined the walls, spines facing out. They were to be accessed – by members of the library staff only – from the other side of the shelves via galleries in the walls. To these staff members the books would have presented their fore-edges. Up to this point it was conventional to shelve books spine-in. Although this is counter-intuitive to us today, spines did not have bibliographical information printed on them; perhaps name and title, otherwise at least a shelfmark, were handwritten instead on the fore-edge.[16] In the days of chained books the chain had to be attached to the fore-edge, allowing it to hang when the book was shelved. In the Escorial there are no chains but the books are nevertheless shelved spine-in. In Wren's time this convention was changing and it was becoming possible to have an array of uniformly bound books. The original Trinity design allowed for this – a grand display for the readers and practical, secure access for the staff (Geraghty, 2007, pp.27-9; Campbell, 2013, pp.143-4).

The design is strikingly reminiscent of much later library designs; for example, for its circular shape and dome, the British Museum Library reading room, but also Yale University's Beinecke Library (1963) and the British Library's St Pancras installation of the King's Library, the King's Library Tower. In these two examples a cuboid glass box both displays and protects the books.

The 18th century

More immediately, the pavilion design influenced Wren-apprentice and draughtsman Nicholas Hawksmoor's early designs for what would become the Radcliffe Camera,[17] though it was built to a revised design by James Gibbs after Hawksmoor's death in 1736. The time between 1749, when the Radcliffe Camera was completed and Wren's first drawing of a round library for Trinity in 1675 was enough for the Herzog August Bibliothek in Wolfenbüttel to take the prize as the first round, domed and free-standing library built. This was Leibniz's library (Leibniz; Remnant & Bennett, eds., p.lxxiv). Constructed in the period 1705-10 to designs by Hermann Korb, it was radical but poorly built (its structure was of wood, preventing any heating, due to fire risk) and demolished in 1886. The reading room was elliptical rather than circular, with books arranged around the walls on two levels (the ground floor and one gallery above) in space beyond the compass of the dome. Indeed, its "use of space was widely admired." The exterior buildings were hidden from view once inside by clerestory windows. The interior was highly decorated but the building was replaced by a more conservative design in stone (Campbell, p.147; Jackson, p.247).

Hawksmoor was responsible for All Soul's College library, built 1716-1720, although the interior furnishing was not completed until 1751 (again, by Gibbs) after Hawksmoor's death. Designed to house a bequest of 12,000 books by Christopher Codrington, the library had to have a Gothic exterior (much like the Arts End of the Bodleian had to match the Gothic Divinity School) but could exhibit the "very latest taste in classical design" inside (Campbell, p.147). The end windows are a fine example of Hawksmoor's skill in this – classical from the inside, Gothic from the outside. In format, bookcases fill all four sides of the long room and are galleried above, except on the main window wall. Campbell states the internal layout as being "entirely original. … [It] is a masterpiece of library design, at once austere and classically correct, yet whimsical in its accommodation of a Gothic exterior" (*Ibid.*, p.150). In this, Hawksmoor's Codrington could be said to be said to be truly of the modern period in that neoclassical styles would dominate library design in England and the US until modernism itself arrived in the 1900s. Towards the end of that century whimsical elements would come to form an essential part of postmodern library design.

16 This explains why shelf lists and permanent locations were so important. Library staff would have to count along the shelf to find the book in question based on that information. A book's title and author might only be confirmed once the book was opened to its title page.

17 Originally proposed to be attached to the Selden End of the Bodleian and visualised in Hart, pp.194, 202.

It has been suggested that library books themselves influenced the neoclassical direction of Georgian architecture. Jackson notes that several colleges had copies of Inigo Jones's English editions of Palladio (p.219). Hawksmoor himself never saw Italy but avidly studied drawings of the buildings of the ancient world, as his own library attests (Hart, pp.34-6).

European library design in the 18th century, certainly in the Catholic south, was defined by what art historians now call Baroque and Rococo. Highly decorative styles, with political overtones of the battle between a resurgent Counter-Reformation church and its new inquisitor, modern science. For the purposes of this study, novel ways of accommodating increasingly large collections of books into a room are of most interest. The grand hall of books finds its apogee with the Hofbibliothek at Vienna and, in most cases, library designs of these styles accommodate a collection in one room. A notable exception is the Biblioteca Joanina (1728) at the University of Coimbra, Portugal, which was designed with three rooms, perhaps for dramatic effect; but the design also increased the wall area available for shelving. Jackson refers to the "predominant" *Italian* style – "a long room in a multipurpose building, with books shelved along the walls, high enough to invite the addition of galleries. Alternatives are the round or oval form, and the "'magazine' device," by which Jackson refers to the stall or alcove format that followed the medieval pattern of books stored perpendicularly to the walls. This, "decidedly, favored filling library space with books more densely" (*Ibid*., p.257).

Austrian architect Johann Bernhard Fischer von Erlach designed the Imperial Hofbibliothek – the largest Rococo library – which was commissioned by Emperor Charles VI and completed in 1730.[18] Rather like the Joanina, but on a much greater scale – the Hofbibliothek reveals itself in stages. Its bookcases are five metres high, both at ground level *and* on the gallery. This could be described as more intimidating than imposing, especially for the men who had to scale ladders on the galleries to reach the highest shelves over the void. Adding to the theatricality, secret doors around the dome access storage rooms lit by external windows.

Hawksmoor had originally intended a second tier of galleries at the Codrington, though Gibbs revised his design to just one level. The Biblioteca Angelica in Rome (1765) is a "rare example of a three-tier wall-system library … [which] successfully creates the illusion of a symmetrical space in which the reader is entirely enveloped in books" (*Ibid.*, p.173). Again secret doors are intrinsic to the design, in this case hiding the spiral staircases that lead up to the galleries. While such elements of the design were hidden, the books themselves were now resolutely to be on display. Though libraries were becoming successively larger it was still possible to design into them a certain static quality in their decoration. Bookcases were commonly denominated by letter. In the library of the Abbey of St Florian (1750) in Austria – a nation home to several remarkable extant Baroque examples – lettered cartouches above the bookcases related to the catalogue for the purposes of *finding*. For example, case 'A' typically contained the Bibles and was the furthest from the entrance. But according to Campbell, "By the 18th century book collections were growing at such a pace that it was not sensible to allocate shelves to particular subjects. Books were being continuously moved around" (p.196). The library of the Abbey of St Gall, Switzerland (1763), offers an effective solution. Shelf lists hinge out from panels between the shelves and false columns. But these were not the perpetual documents of the *Laurenziana*. Slots allowed cards bearing book titles to be slid into place, marked when a book was borrowed, and *rearranged* when necessary.

18 Incidentally, he had been sponsored by Leibniz for entry to the Imperial Academy of Learning.

The 19th century

> "In the 19th century advances in mechanization produced books at ever-increasing rates, forcing libraries to respond…. The use of stacks, the importance of technology and the place of cataloguing in the design of libraries are generally not well understood." (Campbell, p.209)

Another unbuilt scheme, the drawing of which nevertheless proved to be a useful study was that of Etienne-Louis Boullée's for France's Bibliothèque Nationale in 1785. Its dimensions would have put it on a par with a 20th-century aircraft hangar. Indeed, the barrel-vaulted ceiling, with its immense aperture to let in light (and rain) would have seemed almost as high as the building was long. The plan would have been to roof over the courtyard of the former Bibliothèque du Roi, but the concept was more fantasy than reality. What it did contribute, other than the need for vastness, was the idea of stepping back each gallery behind the lower one as it rose. With the materials of the time, this was the closest architects could get to the multi-level iron bookstacks that would soon become part of the very structural fabric of new, larger library buildings.

The first-half of the 1800s saw large libraries mixing the alcove format at ground level with stepped-back galleries using the wall system; for example, the library of the Assemblée Nationale (1830-47, Paris) and Cambridge University Library (1842). In 1850, Henri Labrouste's Bibliothèque Sainte-Geneviève, also in Paris, featured an iron roof supported on iron columns, much like the railway sheds of the time such as the near-contemporary King's Cross in London. It was thought that iron was superior in resisting heat – the Bibliothèque Sainte-Geneviève also featured gas lighting, increasing the risk of fire. Both iron and gas had been seen in earlier libraries but this one is remarkable for the way its architect was happy for these functional elements to remain unhidden. Furthermore, in a nod to Boullée, the shelving in the reading room is tiered, with each tier relatively low in height, and fenced off from the readers by an iron railing. Further shelving is hidden behind the first tier, underneath the upper gallery. However, most of the books were stored below the floor of the reading room, which housed "row upon row of tall shelving units" (*Ibid*., p.227-8). Indeed, the success of the building led to Labrouste being appointed architect for the Bibliothèque Nationale in 1854. One of his first tasks was designing new iron stacks (the *Salle de Magasin*), completed in 1867 and inspired by Anthony Panizzi's recent project at the British Museum, though in Labrouste's case – true to form – the stacks were visible from a window in the reading room.

Panizzi, although forced to justify in detail over many years his plans for a catalogue to trustees and politicians who could not appreciate what the difficulty was (more of which in the next chapter), was otherwise remarkably fortunate for a librarian in that, like Leibniz, he was able to redesign and rebuild his library.[19] Steam power was increasing book production. Panizzi enforced the British Museum's right to legal deposit and "soon books began to pour in, creating ever-increasing storage problems" (*Ibid*., p.231).[20] His solution was the round reading room in the middle of the British Museum's unoccupied central courtyard, to be surrounded by bookstacks. The sketches and ideas were made real by architect Sydney Smirke. The reading room opened in 1857, after three years of construction. The stacks were not completed until 1887, finally housing 1.5 million volumes. They were not accessible or even visible to the readers. As at the Bibliothèque Nationale, the load-bearing iron stacks had open grillework flooring to allow light from the glass roof to penetrate down. Gas lighting was rejected throughout as too great a fire risk. The reading room itself was iron-framed and had reading desks laid out radially, observed by staff at the centre in the manner of Bentham's Panopticon, and the grandly throned librarian at the centre of Wren's original design for Trinity. The round form was not new, but the British Museum design inspired a spate of others, culminating in that of the Library of Congress.[21]

19 To quote Panizzi's friend Mérimée, '"For the first time, let's hope not the last, a librarian has been asked to build a library"' (Jackson, p.374). He can be forgiven for not knowing about Leibniz but the sentiment is telling.

20 Krajewski (p.36) notes that legal deposit tests libraries' ability to ingest books when it is enforced, citing the Hofbibliothek.

21 Though in the Library of Congress reading room the desks run in concentric circles (arcs).

Around the mid-19th century, especially in the US, the cuboid iron-stack reading room became typical for large libraries; for example, The George Peabody Library in Baltimore (1878), with six storeys of books and a precipitous central atrium. Steam driven book elevators transferred stock between stack and reading floor. The Cincinnati Public Library (1874, now demolished) had five-storey iron stacks in the stall format around a central open reading area. This arrangement significantly increased the quantity of stock that could be shelved in the room compared to the wall system employed at the George Peabody. In general, iron-stack reading rooms declined in popularity due to the build-up of heat and humidity at the top (in part a consequence of gas lighting), at the same time as low temperatures at the bottom in the reading areas. There was also little scope for expansion (*Ibid*., p.236/8). Such buildings were driven more by architects wanting to test the limits of new materials and methods more than librarians demanding ever higher stacks. Nevertheless, the books had to be shelved somehow.

The boom in public libraries in the later 19th century led to a movement towards allowing readers to browse the books directly, which had consequences for library design. When stacks were open, a catalogue and a shelfmarking system was essential to ensure that any book in stock could be found. Though printed catalogues were typical in this era, in practice they were cut up and used as slip catalogues in the library itself; the first instance of this was at Harvard by William Croswell in the early 1800s. Guard-books – blank volumes into which the slips were pasted, allowing space for expansion – were arrayed around the central desk at the British Museum reading room. The 1930s Cambridge University library building had a room dedicated to the slip catalogue. Card catalogues were the next advance. Their universal adoption was thanks to Melvil Dewey and his Library Bureau selling the cards and the furniture to house them. Of course, his other great innovation, the decimal classification system, helped greatly in the movement towards making books discoverable – and collections browsable – once it had been widely adopted (*Ibid*., p.242-3). The development of the catalogue will be addressed in much more detail in the following chapter but it is introduced here to acknowledge that, in this period, housing the catalogue had become something that library designers had to plan for.

As a final example for the 1900s, Campbell cites the Fisher Fine Arts Library at the University of Pennsylvania (1891) as a case of how librarian and architect can work together. Here, the library stack room is exstensible over a largely vacant plot. Unfortunately, it was never enlarged because the building's architectural style went out of fashion.[22]

The 20th century

The century of electricity, steel, concrete and glass was even more the century of the book, spawning libraries to accommodate, organise, and perpetuate them on an industrial scale. Take the New York Public Library of 1911, designed by Dr John Shaw Billings, the military surgeon who had earlier created *Index Medicus*. Though conservatively Beaux Arts in style, it was designed internally like a machine for processing books, with seven levels of steel bookstacks below the main reading room. Acquisitions were processed at the lowest level (below the bookstacks), under electric lighting, and raised on electric lifts for storage and reading. Not all of these storage levels were underground, making a steep climb for readers to get to the reading room, but Billings, in line with long-standing convention, had wanted to raise it from the noise and other dangers of the city streets.

About a hundred years after it first opened a proposed renovation and re-purposing of the library – particularly the volume taken up by the original bookstacks – caused controversy. The Central Library Plan (CLP), by Foster & Partners, is a proposal to replace

22 The reader will be introduced to another example of the principle of the extensible library store in the chapter *Perpeuate*.

the original bookstacks with space for the stock of the nearby Mid-Manhattan circulating library and another specialist branch. The bookstacks are an integral – indeed structural – part of the original design but are not capable of keeping the books in ideal environmental conditions. Additional storage has been built underground at Bryant Park behind the building but this has not been fully finished due to cost. The CLP would involve moving a large part of the research collection to Princeton's storage facility in New Jersey.[23] Objections centred on replacing the ('highbrow') research collection with a ('lowbrow') circulating collection while at the same time gutting a key feature of the original building, and moving many books far enough away for them not to be available on the day on which they are requested. The first book delivered from the stacks in 1911 took seven minutes to arrive from submission of the call slip.[24]

Another remarkable advance in library architecture was the Beinecke Rare Book and Manuscript Library at Yale (1963), mentioned briefly earlier with reference to Wren's original proposal for Trinity College Library, Cambridge. Architect Gordon Bunshaft brilliantly designed sealed, air-conditioned stacks for the precious stock that also displayed them to great effect, with high glass walls overlooking a general exhibition area. The effect is enhanced by the translucent marble walls, which look opaque from the outside but provide a suitable quality and quantity of light for the interior (Campbell, p.268).

By 1978, the year Hans Scharoun's Berlin Staatsbibliothek opened, the modernism displayed at the Beinecke had peaked and its less formal, more playful successor, postmodernism, was coming into vogue. Campbell is effusive in his praise: "Highly-complex and free form. … Scharoun's reading-room arrangement is strikingly similar to a theatre foyer – an analogy that extends to his bookstacks, which project from the roof like a fly-tower. The 'library as foyer' arrangement was entirely new" (pp.273-4). The fly-tower is the projecting volume at the roof level over the backstage area of a theatre that houses the rigging. That the Staatsbibliothek's reading spaces are the foyer can only mean that the bookstacks themselves are the main act; impenetrable yet central to the building and its purpose.

France, as did Britain, renewed its national library building in the 1990s. The British Library at St Pancras, designed by Sir Colin St John Wilson and built with the same red Ibstock bricks used by George Gilbert Scott for the Midland Grand Hotel next door[25], opened in 1997. It received Grade I listing in August 2015, but the building had been criticised from various opposing quarters, implying to this author that the architect probably got it about right.[26] One characteristic of its design that was not controversial is the decision to put the bookstacks underground. Of course, going underground is an everyday experience for Londoners and it is fascinating to imagine how the basements (there are two levels, extending under the piazza) of the British Library building relate to the nearby Kings Cross/St Pancras Underground station and the tunnels connecting it. Being underground protects the books from heat and light, and unlike library buildings of previous centuries, late 20th-century building methods and air conditioning can be relied on to maintain the correct level of atmospheric humidity.

However, that would have been more expensive to achieve had the British Library had been sited on the banks of the Thames. The Bibliothèque Nationale, completed in 1996, is on the Seine. Here, the architectural firm Dominique Perrault put the stacks in four book-like towers at the corners of the building. In the end this certainly did not save the French

23 Known as RECAP, this was studied by the designers of the Bodleian's Book Storage Facility. See *Perpetuate*.
24 New York Public Library, 2015; Cole, 2015. A later news story published as this dissertation was being finalised (Mashberg, 2015) states that the Bryant Park underground store will now be finished to accommodate the research stock from the original stacks. Interestingly, the shelving is to be by size, with books and locations identified by barcode rather than by conventional library classification; this in order to maximise storage density in the available volume.
25 Now known as the St Pancras Renaissance London Hotel.
26 See, for example, MacCarthy, 2008.

government any money but it does make for a striking building.[27] The well-publicised cost overruns in Paris would ensure that no similar solution would be tried elsewhere. In the Netherlands, the TU Delft Library (1997) was built partially underground and has the appearance of an artificial hill; "the whole basement (at true ground level) is occupied by bookstacks" (Campbell, p.284). These are rolling stacks – a staple library solution for maximising storage in the available space (Petroski, 1999), especially when access rates are relatively low.[28]

It is too early in this 21st century to write about landmark library designs, excepting the examples that will be discussed in the chapter *Perpetuate*. Not that there are none to discuss, but none fully realised that were not designed and planned in the late 20th century. Concrete may (regrettably) have fallen from favour somewhat, but electricity, steel, and glass have not. For shelving, steel is relatively light, can span long stretches, and steel fittings make shelves easy to reposition. As early as 1934 Giles Gilbert Scott's steel-framed building for Cambridge University Library contained six storeys of "self-supporting" steel stacks behind the facade, with a 48 metre (17-storey) storage tower above that.[29]

Steel's high-tensile strength also allows designs such as that of the José Vasconcelos Library (2006) in Mexico City, in which the shelving is hung from the roof rather than being planted on the floor (Campbell, pp.304/7).[30] Remarkably, this allows the stacks to be tiered in *reverse*, with the densest storage being at the top. The rails supporting this are of steel, but they are themselves supported by concrete pillars. To increase the vertigo-inducing effect, the use of glass is not reserved for the roof and walls, but also for the walkway floors, albeit frosted. This is no doubt also to help propagate light down though the building, much like the lattice floors of the steel bookstacks found in the 19th-century British Museum Library and Bibliothèque Nationale.

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This concludes the opening chapter concerning the evolution of library buildings since the 16th century. Next, the subject changes to the evolution of the library catalogue in the same period.

27 See Fitchett, 1995.

28 Rolling stacks are an interesting example of one way to balance the ratio of room volume taken up by storage and that left free to allow access, issues that will be discussed further in *Perpetuate*. Petroski provides a fascinating analogy from Dewey (p.199) likening mobile stacks in a room to catalogue cards in their drawer. The seeker makes a gap where he or she expects to find the information required; for the rest of the time the cards, or stacks, are collapsed together, with no space wasted.

29 The building looks remarkably like the architect's Bankside Power Station, now Tate Modern.

30 Bookcases hanging from the ceiling were implemented in both the British Museum Library's stacks and in the Bodleian's Underground Bookstore in the early 20th century, though these were on a much smaller scale and were also mobile, for increased storage density.

ORGANISE

> *"I must beg a more than ordinary degree of attention from those who will condescend to follow me through a narrow, rugged, uninteresting path, requiring a patience and labour which few will deem well bestowed on so vulgar a subject as an ALPHABETICAL CATALOGUE."*
>
> Mr. Panizzi to the Right Hon. the Earl of Ellesmere, 1848.

> *"In our precomputer systems much library work consists of mindless drudgery which is an insult to the intelligence of those who carry it out."*
>
> Michael Gorman / Cataloging and the new technologies, 1979.

The compilation of a library catalogue is, in all likelihood, an activity that is seldom performed for the amusement it brings. As Plato wrote in the *Republic* (Bloom, 1991, p.46) "Our need, as it seems, will make it."[1] A catalogue became a necessity.

Before the printed book, catalogues were descriptions of holdings not limited to manuscripts. For example, from a 1956 paper by Ruth French Strout: "A list from Exeter Cathedral, bearing the date 1327, records the opening words of each volume and gives its price. This document is part of a general inventory…" (pp.260-1). This suggests that other examples prior to this were similarly intended and were, therefore, not catalogues in the modern sense. Elaine Svenonius makes clear in her introduction to another paper, this time by Julia Pettee, written in 1936, that inventory lists were the *first stage* of catalogue development (Carpenter & Svenonius, 1985, p.73).[2]

The 16th century

A prime example of a catalogue in the early 1500s, chosen by Dorothy May Norris (1939, pp.126-30) and repeated by Strout (p.262), is that of Syon Monastery, Isleworth, extant in a manuscript of 1526. Typical of the time, this is a classed catalogue (one in which entries are grouped by subject) and the entries themselves being the "opening words of the second folio."[3] Norris also remarks that it is rather inconsistently done, but one innovation makes it remarkable: it is supplemented by an alphabetical author index. This seems such a useful, if not vital, addition that the only explanation of why it was not done earlier is that it was not worth the effort.[4] There were not so many volumes of a given class in any library that a reader could not browse that subsection of the catalogue to find the author he (or she)[5], required.

Certainly in this period, the best work in bibliography was not carried out by those who tended libraries. Natural philosophers and book dealers had a greater interest in taking some control over the works their occupations made use of. Swiss naturalist Konrad Gessner was perhaps the greatest example of the former; Andrew Maunsell, the latter. Gessner published an author bibliography (*Bibliotheca Universalis*) in 1545, complementing it with a subject index (*Pandectarum*) in 1548. Authors were listed by forename but Gessner also included a mechanism to search by surname. Moreover, he included cross-references of

1 More classically rendered as the proverb *necessity is the mother of invention*, or simply, *needs must*.
2 The second being *finding lists;* the third, *bibliographic tools*. Krajewski, Norris, and again, Svenonius write about the early catalogue being an inventory or simple list of holdings.
3 Meaning second *page*.
4 Strout attributes an earlier example to Johann Tritheim of Germany, though his was a bibliography rather than catalogue (p.262).
5 There were also nuns at Syon but they apparently had a separate library, a catalogue for which does not survive.

the *see-* format ("vide"), such as for alternate name spellings.[6] Norris goes so far as to credit him with advancing the cause of cooperative cataloguing by his call for libraries to use his bibliography and index as their catalogues, simply adding shelfmarks as appropriate. An innovation that took hold much sooner was Gessner's concept of providing more than one means to discover a book. With this principle in mind, in 1560, one Florian Trefler, who "believed no library was of any use without a catalogue," took Gessner's subject index as one element of his scheme for a five-part catalogue (*Ibid*., p.135).

Maunsell was an Englishman in the book trade. 35 years after Gessner he was sorting authors directly by surname and even stipulating the rules he followed for entries. Describing bibliography as a "tiresome businesse," he was also motivated by necessity – in this case the need for English booksellers to have a catalogue "as the apothecary his Dispensatorium, or the schoole Master his Dictionarie" (*Ibid*., p.137). The Frankfurt book fair had its own catalogues, which soon developed into a proto-dictionary catalogue: a single alphabetic list comprising facets of author, subject, title; plus subject entries for places and events, and cross-references. Maunsell even implemented abstract subject headings in his bibliography (ie, ones not taken directly from titles). This is also presented as a single alphabetic list, making it even more the dictionary catalogue, long before it became conventional in the 1900s (Jackson, 1974, p.190).

These steps towards order must be seen in the wider context of a 16th-century that saw the destruction and scattering of books. Maunsell detected the need for what would later be called a code but, in Strout's opinion, "the great scientists and philosophers of the age were not much aided in their endeavours by librarians" (1956, p.264). Tellingly, both Gessner and Maunsell only managed to write two of the three bibliographic works they had each originally intended to produce.

Nevertheless, for Krajewski, Gessner was "… The Father of the modern bibliography." He lists many details (what might now be called metadata) and "undertakes an appraisal of the holdings." The *Bibliotheca Universalis* was, unusually, author-alphabetical. The second volume – the *Pandectarum* – is a keyword list, ordered thematically, effectively becoming a scheme of knowledge or information organisation. The third, unrealised, volume was to be an alphabetical index of the *Pandectarum*. However, Krajewski's interest in Gessner's achievements stems more from his methods than his published works. He was the first to describe the use of paper slips for generating alphabetical lists in 1548. It is worth mentioning here that the first card catalogue, at Vienna, was not implemented until 1780. The primary use for sortable paper slips in Gessner's day was *excerption* – a system allowing scholars to manage their notes and references. He specifies an algorithm for the processing of excerpts involving sorting paper slips, which are arranged as needed for a particular task. "This procedure describes a hybrid card catalogue in book form," and a method of writing that itself contributes to the book flood, which that former technological solution will come to organise. To prepare his or her text an author need only rearrange notes (excerpts) to suit the subject at hand, copy them, then replace them in their original order for use another time, in another configuration.[7]

Krajewski's thesis rests on the processing power afforded by sortable units of information. He makes a direct connection between paper slips and 0s and 1s; with moveable type, catalogue cards and punch cards between them in the sequence of related technological developments. Not only is the card catalogue a manual precursor of the computer, it is a machine in its own right – "information … available on separate, uniform, and *mobile* carriers … can be further arranged and processed according to strict systems of order" (2011, pp.3-14).

6 Which would have been much more common in his day, as evidenced by the variations in his own name (Gessner / Gesner).

7 Incidentally, the software this author chose to manage his notes in this study (*Scrivener*) uses the same principle – separate documents (graphically represented by index cards) that can be sorted in order to produce a composite draft.

The 17th century

By the end of the 1600s Leibniz and others had started to put Gessner's ideas into practice, but when considering the library catalogue at the beginning of the 17th century one must look to the work of Thomas James for Sir Thomas Bodley, at Oxford.

The foundation of the Bodleian

In 1598, retired diplomat and Hebrew scholar Bodley had written to the vice-chancellor offering to renovate and reconstitute the University library, which had been left so bereft after the events of the English Reformation that, by 1556, even the lecterns had been sold off. Approval was given, but Bodley was rarely in Oxford during the intervening years before the new library was ready to open on 8th November, 1602. In his place was James, a Fellow of New College who had been appointed by Bodley as Keeper in 1599, recommended by his on-going project to catalogue the Oxford and Cambridge college libraries. He was soon to be busy cataloguing Bodley's acquisitions for the new library, a task that, inevitably, came to be more difficult than anticipated (Clapinson, 2015, pp.1-9).

James's first printed catalogue was ready by 1605.[8] It contained only 36 books in English amongst 5,611 main entries, and many more 'analytical' ones for works bound with others. "On this point Bodley was very vehement, and yet James … seems to have attached little importance to them and frequently failed to carry out Bodley's wish"(Strout, p.265).[9] Bodley was keen to keep standards high and, according to the academic convention of the day, was only interested in Classical texts in their original languages. Chaucer acceeded, but any available quartos of Shakespeare's poems or plays would surely have been considered undesirable "riffe raffes." These would have to wait for James's successor John Rouse, and Robert Burton's bequest of his library in 1640, for their accession to the shelves (*Ibid*. pp.14/31).

Bodley's standards also applied to the cataloguing method to be adopted. James's first manuscript catalogue was completed in 1601 before the library opened for use, but the 1605 printed catalogue was widely circulated and "presumably exerted influence" (Jackson, p.160). Bodley's *Statutes* dictate that the Keeper is to "arrange the holdings according to faculties, preparing corresponding catalogs including full imprint…." The printed catalogue included call numbers and was "fundamentally a shelf list," meaning one page was dedicated to each shelf. Shelf position was determined by classification under the modern scheme of the four faculties: Theology, Medicine, Jurisprudence, Arts. (Norris, p.144; Jackson, pp.159-60).

Given this correspondence between shelf contents and catalogue page, the individual pages were indeed used as shelf lists on the ends of the presses.[10] At this early stage the shelves had spare capacity; and so did the pages. The empty space was ready for accessions but was also used for related entries; for example, where to look for similar works. Call numbers included shelf position and so needed amending if enough new books were added. Jackson lists earlier experiments in compiling call numbers without shelf or even bookcase locations but none was truly "relative-locational" and it is not known if Bodley was aware of them. Some anonymous works were entered under title, which was treated like a subject heading, with similar titles (for example, by place name) listed together. The typically long titles of the age were often abbreviated in this process, but place and date of publication were normally included. Quarto and octavo formats were designated in the call number, as they were stored separately, but folios had no extra reference. An index to the catalogue listed

8 The Bodleian is frequently credited as having the first printed catalogue but Leiden apparently had one (*Nomenclator*) ten years earlier in 1595 but it is not known whether it was *general* (ie, covering all classes).

9 Jackson suggests that multiple works in one volume were the main reason James thought it unsatisfactory to shelve by subject, but he understood that they could be separated in a catalogue (p.164).

10 It seems that Bodley decided on this after increasingly exasperated attempts to get James to catalogue adequately (see Norris, ch.7). In the end he demanded that James "listed each book as it stood on its shelf" (Norris's words, p.143).

authors and titles in an alphabetical list (Jackson, pp.161-2; Norris, pp.144-5).

Norris and Jackson both describe various inadequacies and inconsistencies in the 1605 catalogue. For example, one "deficiency" was its reliance on title terms, which could vary greatly for works on a single subject, meaning that not everything covering the same topic would be found in one place. James retired after publishing a revised and expanded catalogue in 1620 but continued compiling subject guides to individual faculties for the use of undergraduates. Seemingly looking to future publications, there were many headings with few entries; out of 29 subdivisions under Geometry, one contained only one entry (with the heading therefore identical to the title). It would later became a rule for dictionary and card catalogues that this should not occur, after the concept that subject headings should have a degree of generality (Jackson, p.163).

Soon after the Bodleian was established, German preacher Georg Draud was publishing bibliographies with novel characteristics, including measures to improve subject access. For example, including out-of-print works; see-references after outdated terms to current equivalents; and "a striking prototype of the corporate entry." Draud implemented catchwords – a word from a title to 'catch' the work for a particular class.[11] Germany in general gave primacy to the author-alphabetical catalogue (*Stichwort*), with a subject index (*Schlagwort*). 'Term' catalogues (those of booksellers) had differing priorities to bibliographies for libraries. Firstly, they were only concerned with what was currently in print; secondly, language was important, more so than to libraries. Format information is also of more interest to those keeping books than selling them on. Jackson even compares Draud's "atomistic" subject approach to postwar coordinate indexing using 'uniterms', which worked on early computers working with data on punch cards (*Ibid*., pp.193; also see Norman, 2012).

In the preface to the 1620 Bodleian catalogue James recommended leaving classification to the catalogue and shelving the books in simple alphabetical order by title. While this might not seem progressive to readers today, used to well-established classification schemes ordering books on library shelves for the benefit of browsing, it should be remembered that, until the public library boom in the 19th century, stacks remained closed to readers.[12] James's alphabetical method was the one preferred by library staff who frequently had to find and replace specific titles quickly. German scholar J. H. Hottinger observed that "when shelves are closed to the public it does not matter very much what the (classification) scheme is" (*Ibid*., p.181), though it could be argued that it was not his job to fetch the books.[13] Some Continental libraries took organisation by shelving to extreme lengths in the later 17th century, but the larger ones were more conservative and Le Tonnelier of Paris declared in 1677 (agreeing with the James of 1620) that "the great variety of content as well as format made exact subject control via shelving impracticable and that the catalog was the only answer" (*Ibid*., p.197).

Advice on establishing a library

Parisian pamphleteer-cum-librarian Gabriel Naudé sought to influence library policy in his 1627 work *Avis pour Dresser une Bibliothèque*, which was popularised in translation to English by John Evelyn. He recommends both a systematic subject and alphabetical author catalogue ('divided' in the same volume); evidence that these were still more often ideas than realities. He also advised that shelving arrangements must allow for expansion (Strout, p.265), though Jackson comments that he is less concerned with methods of organising books than with acquiring them for his patrons (chiefly Cardinal Mazarin), seemingly unaware of the "expansion just over the horizon," though the Mazarine library came to be the "largest library which had ever been brought together in the world" (p.170). "When Naudé enlarged

11 Common in the 19th century – for example, stipulated by Panizzi – until Cutter made the case for abstract subject headings.

12 Frické (p.12) observes: "Alphabetical arrangement helps searching but not browsing; but, in contrast, form or thematic arrangement helps browsing but not searching."

13 The following chapter will show that warehousing methods allocate shelf positions dynamically or, in some cases, randomly.

the collections at the Mazarine in the 1640s the acquisitions so far outran the cataloguing that access actually did depend – though not by plan! – upon a systematic arrangement…" (*Ibid*., pp.196-7).[14] Nevertheless, Strout credits Naudé with the modern idea of catalogues "as a means of finding books and identifying them bibliographically" (p.265).

Scotsman John Durie undertook his "drudgery" in 1649 in England for the King's Library, though its patron would very soon be without his head. He recommended a subject catalogue, subdivided by language, and printed, with regular supplements; no fixed locations; and no need to clutter the catalogue with less valuable books, though no need for them to be "cast away" either. He also advised that university "doctors" should assess which new works should be acquired and catalogued, something that Humphrey Wanley, of the Bodleian, was to repeat as the 17th century drew to its close. By this point the Bodleian's 1620 and 1674 author catalogues were exceptions to the tendency to organise by subject, particularly on the Continent, perhaps excepting Germany. However, all such were now as much finding aid as inventory, and the importance of uniformity was being realised, with Thomas Hyde's 1674 Bodleian catalogue introduced by the first explicit code of rules.[15] Printed catalogues and supplements were the norm, yet by 1850 Panizzi would be declaring them impossible (Norris, p.179). His solution would owe a lot to the work that Leibniz was doing in the mid-to-late 1600s, after Gessner and Draud.

Krajewski has Leibniz and his colleague at Vienna, Hugo Blotius, putting Gessner into practice "to provide efficient catalogues." Leibniz had acquired an excerpt cabinet and used it to order notes he had made to further his scholarship and professional life. '"Thus he also maintained his library according to topical order, without regard for different formats."' (Von Murr, 1779, quoted in Krajewski, p.19). Leibniz's catalogue for Wolfenbüttel (1691-9) involved "an assistant cutting, sorting, and gluing … a directory that was to remain, into the 20th century, the only general author catalog of the Duke August Library." Leibniz had reported on the need for a "logical or scientific catalog" to satisfy readers who ask for works, not by author, but by subject, demonstrating that a librarian – even Leibniz himself – by this point can no longer be expected to know the collection intimately (*Ibid*., pp.16-21).

The important lesson from these cases is that, whether the subject or author catalogue is considered the primary one, it has been largely accepted that, where a catalogue exists, the one must be supplemented by the other, at least in index form. Subject access has become more sophisticated; in contemporary terms, there are multiple access points. A radically effective and efficient way of facilitating this was tantalisingly close to be being realised.

The 18th century

Though the 1700s saw great advances in general, catalogues did not advance much until it was drawing to a close and were, again, inadequate to the demands of the burgeoning and newly systematised sciences, technologies and industries. "It may have been because libraries were so busy with their growing collections that they now ceased to philosophise about what catalogues ought to be." However, towards the end of the century in post-Revolutionary France (1791), theoretical advances were made by the new government, despite its intention to be purely practical. A national code was written requiring the creation of a card for each confiscated book, with the author's surname underlined for the purposes of filing. If there was no author, then a keyword in the title was to be chosen. This, with the various other requirements such as number of volumes, statement of illustrations, etc.,

14 A systematic shelving scheme the University of Strasbourg in 1613 had been attempted in order to render a catalogue unnecessary.

15 And a lengthy complaint about "the difficulty and weariness of the task" (Norris, p.150). She attributes the preface to Hyde and the catalogue itself to one Emmanuel Prichard. Julia Pettee (writing in 1936 and cited in Carpenter & Svenonius, pp.72-89) attributes modern advances to Hyde's 1674 Bodleian catalogue, including using only one form of name for an author, including translations, and cross-referencing pseudonymous works to the authorised form. Cutter followed suit in his Rules, first published in 1876.

which essentially remain in current codes, makes this code a "steppingstone to the extensive cataloguing developments of the next century" (Strout, pp.266-7). Norris adds: "Not only have we instructions here for a card catalogue, but also for accessioning and shelf guiding" (p.195).

For Krajewski, "… at the beginning of the 18th century it is by no means self-evident that a library should own a directory of its holdings. To find a book on a certain subject, one usually follows the classified shelving of books." Leibniz, however, was arguing that this situation was untenable; "a library without a catalog … resembles the warehouse of a businessman who cannot keep stock" (1679). Krajewski extends the metaphor to one of lost profit due to lack of information. Leibniz's "plan anticipates registering every book merely once, precisely on a slip of paper … Theoretically, this procedure could have made numerous catalogs with the same data set." In practice, only the author catalogue was completed due to lack of resources (2013, p.22), and though paper slips were used they were always to be rebound in book-form. However, the potential is there for (further) recombination. The slip represents the book and can, in many cases, be referred to instead of the book itself (*Ibid*., p.23).

The foundation of the British Museum

This institution was founded by Act of Parliament in 1753, bringing together the collections of Hans Sloane, including some 40,000 printed books and 7,000 manuscripts, with two other library collections – those of Sir Robert Cotton and the Earls of Oxford. Four years later in 1757 these were joined by the Royal Library – the collections that had been assembled by various British monarchs up to George II.

An anonymous *Proposal for building a Royal Library, and establishing it by Act of Parliament* had been published around the turn of the century, possibly by the Keeper of the Royal Library, Richard Bentley. "Urged first were a new building and residence for the keeper, the preferred location being praised for its elevations and "dry sandy ground" and fire-protective distance from the nearest structure" (Jackson, p.213). Jackson also notes that Cardinal Borromeo's (*Ambrosiana*, Milan), James's and Hottinger's writings on running a library all include the advantages of buying collections in bulk. The *Proposal* recommended '"a perpetual yearly revenue for the purchase of books."'

The British Museum library officially opened in 1759 at Montagu House. Pre-existing catalogues of the Harleian collection were on sale "but the reader had no comprehensive index to consult until an alphabetical author catalogue was printed in 1787 – the work of library officers in their two daily "vacant hours" (Norris, p.200). The holdings were arranged as the shelf space in the several rooms seemed to recommend; not until 1790 was a shelf list produced." By 1774 a new reading room offered 120 seats, more light and less damp (Jackson, pp.214-6).

North America and Continental Europe

At this point some libraries in the New World had the right works in their collections to tell them where they stood with respect to libraries in Europe. For example, Harvard owned James's 1605 Bodleian catalogue, Draud's 1611 classified bibliography of Latin and German publications, Bale's 16th-century English national bibliography; all of which did much to demonstrate the limitations of its own collection. Its 1790 catalogue listed 12,000-13,000 volumes; certainly the largest collection in the Colonies. This is after it recovered from a fire destroying everything that wasn't on loan (more than 90%) in 1764. "The only work expected of a librarian at a colonial college which might be considered "professional" was the preparation of a catalog." However, the presidents of both Yale (1743) and Princeton (1760) compiled their library's catalogues. Such efforts inspired the donation of books, but their collections remained so small that "there was no urgency to adopt even the few refinements

displayed in the Leyden catalog of 1595 and the Bodleian guides of 1605 and 1674." Yale started assembling subject catalogues in 1740 but there was no awareness of advances at court libraries in Germany such as that of Leibniz (*Ibid*., pp.219-22).

At the Herzog August Bibliothek Leibniz served the Dukes of Brunswick-Lüneberg as librarian, amongst other offices, while pursuing his own projects of private scholarship. As a book user he was most interested in what was, naturally, useful. For librarianship this meant that his approach was one of creating the best, highly curated, current resource as opposed to collecting everything, or giving priority to classics. He scoured any available "bookseller and fair catalogs, correspondence, the *Journal des Sçavans*, and the Royal Society Transactions;" but also saw the value of a library being able to purchase collections on the market wholesale; something he complained about not having the resources to do. In 1689 in Italy, on a mission for his employers, he "composed a list of some 2,500 titles, arranged first by subject and then roughly by date; based on both classics and recent science." It was a starting point rather than a comprehensive bibliography. His 1702 dossier to his patron, Rudolph Augustus, listed the "increasing rate of book production, the rising costs of books and binding[16], the state of the library's holdings, and comparable data from other collections." He also suggested several positive ideas to raise money. It was under the succeeding Duke, Anton Ulrich, that plans for the new library building progressed. Book acquisition had increased, leading to the need for temporary storage. A vignette of a typical day in the new library is provided by Jackson (p.247): "Despite the librarian's devotion to service to "all," a traveller of 1731 – eight years after the books had been placed there – found just a few scholars using the collection, the staff absorbed in niceties of cataloguing." In general, "… provision of appropriate space seldom kept up with the acquisitions." Another contemporary diarist records "crowding and disorganization" typical of the 100 libraries he visited in Germany, the Low Countries and England between 1709 and 1711 (*Ibid*., pp.245-7).

The German term for shelf list is *Standortskatalog*, meaning 'location catalogue', but because these were separated by subject it became common in larger libraries to also keep an *Accessionskatalog*, which kept everything in one place. New documents such as "learned society transactions, academic dissertations and learned journals confronted the cataloger with numerous volumes of multiple authorship." The solution was to prepare entries for parts of composite works and pamphlets. This had been proposed at the Bodleian (not for the first time) in 1697. But, "Such analytics were to become familiar and valued in many libraries… ." (*Ibid*., pp.258/261-2).

Moving towards mobile data

Krajewski notes the "gradual turn away from fixed shelving and toward more delocalized addressing" (pp.31-2). If, due to the rate of book acquisition, each book can no longer be allocated a specific address relating to the shelf on which it is to be found, then these ordering and addressing tasks are shared by the catalogue. The transition is difficult to imagine for readers or librarians not used to discovering books thanks solely to their systematic physical arrangement, plus an exposition of their bibliographical data in a shelf list. Even if that physical arrangement holds, sheer numbers can make finding a book impractical without first resorting to a catalogue, which, after all, is an abstract and thus more wieldy representation of the collection.[17] The question is how one searches. Up to this point, whatever catalogues exist, the convention is that a systematic arrangement of books will literally guide the searcher to his (or, less likely, her) destination: the book in question or at least a book on the subject in question. Libraries are now reaching the point at which the searching should be done on paper first, which should significantly narrow the physical area to be searched in order to obtain a book. In its turn, the catalogue is under pressure to

16 Books were supplied unbound until about 1830 (p.205).

17 Norris (pp.184-9) gives a representative example of the 17th-century catalogue in that of the Sion College library, 1724. For each entry, a capital letter denotes the press (and the subject), a Roman numeral the shelf, and an Arabic figure in the margin represents "the numbers of the books on the shelves."

accommodate new titles in their respective places, breaking up the linear list and forcing mobility on the bibliographic references. This is rather revolutionary. The programme of the Enlightenment and the Encyclopædists was still to classify under the assumption that this procedure was a process of discovery – of understanding the world as it was – rather than the imposition of an arbitrary, man-made, order; something that loose paper slips or cards seemed too ephemeral or fluid to represent.

Yet at some point in the 1700s someone discovers that playing cards are a practical media for storing and sorting units of information. Krajewski shows that one Abbé François Rozier, while applying the techniques of Gessner in his task to tabulate the publications of the *Académie des Sciences*, make the small step from using slips of paper to '"cartes a jouer,"' which were then produced blank on one side and, "beside their widespread availability, their uniform measurement allowed easy shuffling. They were also able to withstand "robust handling" (p.33).

The *Josephinian catalogue*[18], for the Hofbibliothek in Vienna (now the Österreichische Nationalbibliothek), is "considered the first card catalog in library history." Krajewski reports, qualifies, and then endorses this statement, making sure to stipulate three reasons why it should be distinguished from Leibniz and Rozier's early modern paper slip techniques.[19] These are: "written instructions for the cataloger, a division of labor organized around interfaces, and the duration of the catalog" (p.39). It is stored in some 205 boxes designed to look like bound volumes and comprises 300,000 cards. The boxes may have been a gesture to divert attention from the fact that there was to be a further stage – that of using the slips to create bound author-alphabetical and subject catalogues, estimated to take up some 50 to 60 folio volumes. But the task was too great to contemplate, and the interim card catalogue became *the* library catalogue. "Thus, a failed undertaking tacitly turns into a success story" (*Ibid.*, p.42-3). This project was initiated in 1780.

Blotius's legacy was felt throughout Viennese libraries, however. Franz Stephan Rautenstrauch's catalogue at Vienna university library predates the Josephinian catalogue in its use of procedural instructions and paper slips by two years. Furthermore, this one manages to become a bound catalogue (the paper slips are also maintained).[20] Also, its rules are more generalisable, resulting in them becoming "an imperial standard for catalogs, over thirteen years before the regulation generally cited as the first of its kind,… the efforts to create a French national bibliography in 1791" (*Ibid.*, p.44).[21]

In this period the abolition of the Jesuit order had created a minor book flood for the Austrian libraries developing their paper slip techniques, but the confiscation of sacred and aristocratic collections in the French Revolution, though on a different scale, was to be managed in similar fashion, with the French innovation of using cards. However, the plan fails and, "In the end, not a single volume of the planned national bibliography is printed on the basis of playing cards." Its success is that the principle of standardisation is established, even if the cards are still seen, despite the situation at the Hofbibliothek, as merely a step on the road to a bound catalogue (*Ibid*., p.47).

18 "named for Austria's "enlightened despot" Joseph II" (Wright, 2014, p.33).
19 Although the work was done on paper slips, which were then pasted onto cards (Krajewski, p.41).
20 Johann Wilhelm Ridler, in 1823, renews the 'basic catalogue', complaining of decline and even slips being used "to the foulest ends by library officials.". It is maintained to this day for works published before 1931.
21 For example, Norris credits the French Code of 1791 as the first national code (p.195).

The 19th century

This period saw major advances in cataloguing, albeit somewhat later than the equally major advances in book production, which could now be said to be on an industrial scale.[22] Nevertheless, there was plenty of time for philosophy. In the early 1800s significant disputes about the merits of classed catalogues took place, which would spend the rest of the century waiting for the Library of Congress to implement abstract subject headings, after Charles A. Cutter's *Rules For A Dictionary Catalog* of 1876. One of the disputes concerned what should happen at the British Museum.

Before Panizzi started work there, in cataloguing, William Croswell had delivered a catalogue for Harvard on paper slips in 1817. What is most interesting about this is that, according to Krajewski, he devised the method out of necessity without any knowledge of Gessner or his early modern disciples, nor of the Josephinian catalogue. Tasked with compiling the Harvard catalogue single-handed, Croswell had spent nine years getting dizzy and making little progress. With a final deadline looming he hit upon the idea of cutting up the previous 1790 catalogue and interleaving its entries with manuscript ones for later accessions. It was left to his successor Joseph Green Cogswell to expound the true significance of Croswell's achievement, noting that his system is extensible and reconfigurable – '"the work is done for ever; it may be increased so as to embrace all the books ever printed, without requiring any part of it now done, to be done again"' (Krajewski, pp.74-9).

The catalogue of the British Museum library[23]
Consisting of four previously separate collections, with various and inconsistent catalogues, the British Museum's Trustees recognised that a new and complete catalogue was necessary to render the collections useful to the public. Nothing achieved in the 18th century proved satisfactory and, once George III's collection (The Royal Library, now known as the King's Library) had been added in 1823, another attempt was made, this time by the Rev. T. Hartwell Horne, which also failed.[24] The next proposal was to give the job to Antonio Panizzi, who had been appointed Extra-assistant Librarian in 1834. As part of a Royal Commission, a Select Committee started investigating the British Museum's administration the same year, instigating a lengthy and well documented debate on author versus "classed" catalogues.

Panizzi argued against a classed catalogue – "The continual discoveries in science make classification ridiculous" – but for a subject index to the author catalogue.[25] He also contended that learned society transactions and periodicals should not be entered under subject but new "fixed heads" and also under author. Entries should be transcripts of title pages. For consistency, one person should be "in charge." Admittedly, an author's name might need to be found, but that could be achieved "by using standard bibliographies."

In 1837 Panizzi was appointed Keeper of the Printed Books yet debate continued about who would superintend the catalogue and how it should be done, leading Panizzi and his colleagues to draw up cataloguing codes that were unified into the '91 Rules', which were adopted by the British Museum in 1841 and widely praised as a decisive advance.[26] Carpenter (p.1) states that "All modern codes [that is, up to AACR2] descend from" these 91 Rules. *Main entry* "stands for the one principal entry for a book. References are made to this principal entry, and the rules explain the different classes of references." To give an apposite

22 Jackson quotes statistics from a 1911 issue of the *Bulletin de l'Institut International de Bibliographie*. World book production: in 1838 – 27,838; in 1858 – 65,190; in 1887 – 100,000. Periodical production showed a rate of increase at least three times greater.
23 See Norris, ch. 10.
24 The same Horne produced a classed catalogue for Queen's College, Cambridge in 1827 but Norris (p.219) demonstrates that his scheme is "confused and difficult to follow."
25 Norris also argues that another reason against a classed catalogue is that it would show where the library's collection was deficient (p.224). Oddy (1996, p.27), writing as Head of Cataloguing at the British Library, claims that "the lack of a coherent means of subject access to its collection is a problem which haunts the British Library to this day."
26 *Rules for the Compilation of the Catalogue*, British Museum (1841); reproduced in Carpenter & Svenonius (1985).

example, Rule I reads:

> I. Titles to be written on slips, uniform in size.

The 91 Rules are also noted for giving "great authority to the title page" (Strout, p.268). Subject entry always derives from the title page somehow. This is a long established practice, albeit codified more thoroughly than ever before. Carpenter states that the 91 Rules "continue practices found as far back as the catalogues for libraries in medieval monasteries" (p.2).

Work started in 1839 and the A-volume was printed in 1841. It was the last to be printed. Panizzi had only reluctantly agreed to printing volumes successively and the problems he had predicted arose. For example, "necessary cross-references were continually springing up after the volume had gone to the printers." In 1847 another Royal Commission was appointed to investigate the cataloguing programme and its lack of progress. Panizzi testified that it would take until 1895 to produce a printed catalogue of the library's state in 1854; yet changing the method would mean having to start again (they were up to the letter D). Since 1841, entries had been made in manuscript (ie, by hand) interleaved with the printed Ellis and Baber catalogue of 1819, though it was in poor alphabetical order. In 1849 library employees W. Croker and E. Roy suggested new entries to be written on paper slips, inserted in guard books. Panizzi adopted this and "set a staff on to copy all the titles. [and]… In 1851 the catalogue in 150 volumes was put into the Reading Room" (Norris, pp.208-12).

In the previous year Panizzi had taken the trouble to write to Francis Leveson-Gower, First Earl of Ellesmere, in his capacity as chairman of the Royal Commission.[27] Panizzi's task was to catalogue some 500,000 works for a manuscript catalogue that would then be reproduced in print.[28] Amongst Panizzi's points are that space is a concern, even for the catalogue – calculating the prodigious extra volume required by cards as compared to finer paper slips. He demonstrates that the shelves must be consulted; that earlier catalogues cannot be relied on; and that it is impossible to proceed letter-by-letter, leaving each one complete. He claims:

> "There is no instance of a catalogue equal in extent to that of the British Museum collection of printed books having been attempted, and there is no precedent for rules being embodied to carry into execution even a compilation far inferior in extent."

Crucially, he also shows that a printed catalogue of an increasing library can never be complete. For this reason, the working catalogue in the reading room ought to be in manuscript for it to best serve its purpose (Carpenter & Svenonius, pp.15-47).

Panizzi held on to his job and was even appointed Prinicpal Librarian in 1856. Neverthless, in 1861, the Trustees still wanted a printed catalogue, as Cambridge University had managed to achieve. However, at the British Museum the original 150 volumes of guard books was well on the way to becoming 3,000 (Norris, p.213). In 1842, when Panizzi was in the middle of his difficulties with superiors who expected a printed catalogue, Cogswell's successor at Harvard, Charles Folsom, reverted that institution to a bound catalogue, but, "in doing so, he apparently learns a lesson" and introduced one Charles Coffin Jewett to the concept of the paper slip catalogue (Krajewski, p.79).

By this mid-point in the 19th century the issues being discussed are those of '"modern"' cataloguing (Strout, p.270). She contends that, in 1850, cataloguing practice in the US can be said to advance beyond that in Europe with Jewett's code for the catalogue at the Smithsonian. Jewett accepted Panizzi's 91 Rules with some modifications relating to entry. For example, corporate bodies would be entered under their names without any of

27 Carpenter claims that the Commission's "task was supposed to be the impeachment of Panizzi for insubordination" (p.16).
28 For comparison, in 1849 the number of printed volumes at the Bodleian was some 220,000, though many contained multiple works.

Panizzi's intermediate 'form' headings such as 'ACADEMIES'. Also, his method for dealing with anonymous works rejects the British Museum's conventional approach of finding a catchword from the title to define the work by subject. In general, Jewett was prescriptive, yet efficient, producing only 33 regulations. Cutter's Rules of 1876 supported Jewett in his differences with Panizzi. Cutter makes explicit that the catalogue's goal of being able to show what a library has by any given author requires pseudonymous works to be entered uniformly, even if the title page does not contain the 'authorised' name of the author.

As Librarian and Assistant Secretary at the Smithsonian Institution, Jewett believed that its library was essential to fulfilling its stated objective of promoting the '"increase and diffusion of knowledge among men."' More then creating a great national library, however, Jewett was motivated by the possibility of creating a great national catalogue – "a union catalogue of the holdings of all public libraries in the Untied States." In justifying this he invokes the spirit of Leibniz:

> "How much this would promote the progress of knowledge… how much, by rebuking the rashness which rushes into authorship, ignorant of what others have written, and adding to the mass of books, without adding to the sum of knowledge."

Like Leibniz he is also more interested in books relevant for progress rather than for their own sake, and Svenonius points out that his desire for a universal catalogue distinguishes him from Panizzi, with his large but essentially local project. Jewett proposes that the contemporary printing technology of stereotyping would allow bibliographic records to be stored in print-ready form to be reused whenever required.[29] Jewett appreciated and argued for the level of standardisation that this would require, also because his vision was, by definition, one of cooperative cataloguing. What he was proposing was essentially discrete bibliographic records that could be sorted to suit either an author-alphabetical (his preference, supplemented by a subject index) or a classed catalogue. Like his illustrious predecessors, Jewett laments how poorly understood the task of compiling a catalogue is, describing what "may seem a light task," as "arduous and perplexing." Interestingly, in explaining the cataloguing code he advocates, Jewett notes that some "conform more to the rules advocated by Mr. Panizzi, than to those finally sanctioned by the Trustees of the Museum" (Carpenter & Svenonius, pp.48-61).

Cutter would argue that such a "legalistic" approach to cataloguing was mistaken; it is rather "an art that applies a few highly generalized rules by analogy to specific cases." Cutter's main concern was convenience to the user (*Ibid*., p.49). Jewett made further refinements to the British Museum's 91 Rules, which Cutter "crystallized" in his Rules. These relate to corporate (ie, collective) authorship and mark a distinction between Anglo-American and European practice; Cutter's Rules became the standard in the Anglo-American region but were not embraced in Germany (Jackson, p.380). Jackson also suggests that American libraries, being both not so large as the great European ones and more accessible to the general public (as opposed to the educated elite), naturally preferred author-alphabetical catalogues over systematic/classified ones. Some US libraries reported having a classified index to an author-alphabetical catalogue.[30] Jewett gave less importance to the subject catalogue than Cutter, believing that most library users arrived with specific authors in mind. Pragmatically, (and like Leibniz) Cutter wanted the subject catalogue to stand in for (and assist) the library staff in finding suitable works for readers on any given subject.

At about the same time Billings (later to be of the NYPL, then at the Surgeon General's Office) produced a card-based alphabetical subject catalogue by rearranging

29 In mid-19th century printing a stereotype was an embossed plate from which copies could be printed on a press. The plate was made from a mould of a forme of type, itself comprised of moveable type, plus leading, etc. The advantage was that the pages only needed to be made up once, then stereotyped, allowing the moveable type to be reused while copies could be printed indefinitely from the stereotyped plate. Jackson comments that, in practice, the clay mould often deteriorated before a satisfactory plate could be produced (p.385).

30 In a systematic subject catalogue, works are listed alphabetically by author only under each subject, making the author inferior to the subject.

cards that had been prepared for the compilation of a printed author catalogue. These "masterpieces" were published in 1879 (Index Medicus) and 1880 (Index Catalog of the SGO, vol. 1). Now that the increasing rate of acquisitions was making the printed format's perpetual incompleteness a serious problem, the card catalogue, common since the mid-1850s for current acquisitions, started to become the singular reference of a library's holdings. Cambridge used cards from 1861; Harvard opens its to readers the same year; France and Germany followed (*Ibid*., pp.382-5; Krajewski, p.80).

The 20th century

The decision at Harvard to open the card catalogue to readers was made by library assistant Ezra Abbot, who at the time had his own assistant in Charles A. Cutter. By 1904 Cutter's Rules for a Dictionary Catalog were in their fourth edition. Somewhat ironically, Strout cites the same year (in which took place an international meeting in St Louis) as the one in which it was acknowledged that card catalogues "had won out over the other forms" (p.273). The dictionary catalogue had been the common US format in the latter part of the 19th century and into the 20th (Jackson, p.406). A printed volume (or volumes), it presented authors, titles, series, and subjects interfiled in one alphabetical list. For the reader, this was certainly an advance over earlier classed catalogues; even ones supported by indexes (Norris, p.225). As a printed and bound catalogue, however, and especially for large and expanding libraries, it was subject to all of the difficulties so far illustrated; difficulties that the card catalogue was superseding.

Cutter's status developed in large part due to his production of the highly regarded catalogue of the Boston Athenæum (1874-82). Treating cataloguing more as art than algorithm, he regretted that the availability of printed cards from the Library of Congress since 1901 – something he had done as much as anyone to make possible – marked, somehow, the end of cataloguing.[31] His Rules were relevant yet, both because the Library of Congress had only recently begun distributing pre-printed cards and also because he had grappled the philosophical questions so well that his work would be a reference for cataloguing authorities in the future, however fewer in number they might be thanks to his codifying efforts.

However, his credo, "The convenience of the public is always to be set before the ease of the cataloger," is not necessarily at odds with legalistic approaches. Panizzi and Jewett didn't write all of those rules for their own convenience but for the success of the catalogue.[32] And, as Svenonius presciently noted in 1985, online catalogues allow rigidly constructed bibliographical records to be presented to the searcher in flexible and convenient ways. Cutter's "Objects" [objectives] have been "restated by [Seymour] Lubetzky and in the Paris Principles," marking, as they do, a turn away from long lists of specific rules towards establishing fewer and broader principles, as a basis for cataloguing codes.[33] Cutter's Objects also repeat Leibniz's statement about both author and subject indexes being necessary. Cutter is also credited with properly instantiating corporate authorship into cataloguing, contrary to the "German practice" of treating such works as anonymous (Carpenter & Svenonius, pp.62-7), and paving the way for Library of Congress Subject Headings (LCSH). After centuries of countless alternate systems of classes, filled by catchwords from titles in a specific collection, LCSH is a pre-coordinated, and largely enumerated, controlled vocabulary, alphabetical list of headings" (Frické, 2012, p.200).[34] These allowed readers searching card catalogues to

31 Cutter even described cataloguing as an "innocent pleasure," an untypically positive description when compared to those from other noted practitioners (Carpenter & Svenonius, p.65).

32 Cutter in fact states that "the convenience of the public" and "the ease of the cataloger. In most cases they coincide" (Carpenter & Svenonius, p.66).

33 See Pettee in Carpenter & Svenonius, pp.72-89. The 'Paris Principles' (formally *Statement of Principles*) are the outcome of the International Conference on Cataloguing Principles (ICCP), 1961. They formed the basis for the Anglo-American Cataloging Rules (AACR), and others.

34 Svenonius points out that it is also faceted into Topic, Place, Time and Form (p.179); Oddy that LCSH "are the single most important example of a *de facto* standard that is not based on any codified set of principles."

find books classified under a huge array of specific (and modular – hence "pre-coordinate") headings). This could only have been achieved by allowing one authority – in this case the Library of Congress – to determine both the headings and how to apply them to the US bibliography, then distribute catalogue cards depicting these decisions to smaller libraries The next step was for Melvil Dewey, his Library Bureau and American Library Association, to standardise and commercialise the apparatus of card cataloguing. As Krajewski illustrates, index cards become the basis of information organisation not just in libraries but throughout the commercial world,[35] until they are replaced by their natural successors, computers.

In 1985 Michael Carpenter wrote that, at the time of the ICCP in 1961, "there was some awareness that computers might change cataloguing" (Carpenter & Svenonius, p.177). A few years later, what came to be called automated cataloguing arrived. In the words of Harris, "The Library of Congress has developed a system of Machine-Readable Cataloging (MARC) by which complete catalog cards can be transmitted on electronic tapes and printed out by a receiving library" (pp.272-3). Electronic tape was state-of-the-art and many computers of the day were still using punched tape as data storage medium. More importantly, libraries, including the Library of Congress, were still using catalogue cards.[36] Though MARC has lasted to this day – and is not at immediate risk of being ousted by BIBFRAME[37], its putative linked open data successor – it was designed to produce printed cards; its particular innovation being a standard for encoding bibliographic data that a computer could manipulate.

In her 1996 book Future Libraries, Future Catalogues, Pat Oddy is critical of MARC's limitations, claiming that it, "in its parody of the two-dimensional catalogue card, perpetuates the muddying of the distinction, quite clearly made in the cataloguing code itself [AACR2], between intellectual work and physical manifestation" (p.94). The concept of main entry, which was first codified in the 91 Rules, makes a lot of sense for a physical catalogue, even in card form, but has some undesired consequences, such as separating rather than collocating manifestations of a single work that have variants of their author's name, though that be one person.[38] Machine-readable bibliographic records, nevertheless, were an essential step in making possible what has come to be known as the online catalogue, which would by its very nature undermine the concept of main entry. However, it could be said that, due to MARC, the *process of cataloguing* was not fundamentally changed by computerisation, though perhaps that change is now beginning. It is more certain that the computer changed the catalogue itself.

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This concludes the second chapter concerning the evolution of the library catalogue since 16th century. Next, the subject changes to computerisation and the library warehouse.

35 Interesting examples being the Carnegie Steel Company – later to fund many public library buildings – and the Tabulating Machine Co. (later IBM).
36 The OCLC ceased production of catalogue cards on October 1, 2015 (OCLC, 2015). Production had peaked in 1985.
37 Peters (1991, p.78) notes the inefficiency of storing duplicate MARC records all over the Western world, something that BIBFRAME is expressly intended to address using machine readable linked open data for bibliographic records on the semantic web.
38 Cutter moved to prevent this by use of an authorised form of name, even if that meant deviating from the title page. For works of multiple authorship, including variations across multiple editions, useful collocation becomes more problematic.

PERPETUATE

> *"The collection of books thus obtained and preserved, will present a complete monumental history of American literature, during the existence of the law."*
>
> Smithsonian catalogue system / Charles C. Jewett, 1853.

> *"it is a front end to a database, in fact a suite of databases and the Internet itself, and it could produce any of millions of documents. And, if you imagine it augmented by some automated robot retrieval system, it could also produce physical books from the shelves."*
>
> Logic and the organisation of information / Martin Frické, 2012.

In his book Paper Machines, Markus Krajewski quotes Johann Jacob Moser comparing the composition of a written work by rearranging excerpts on paper slips to soldiers milling before a parade. Any apparent disorder can be suddenly regimented; all that is necessary is to give the signal. Following Krajewski's logic, the same metaphor can be applied to a database of bibliographic references upon the application of a search query. Not only is the online catalogue not to be printed, it is almost never to be seen, except for the occasional glimpse of mere fractions of its contents. Crucially, the order in which the information is stored is irrelevant as long as there is enough meta-information to allow it to be dynamically sorted, just as the soldiers know their places. The metaphor also applies to zeroes and ones in electronic storage, one level of abstraction beyond the database itself. In the opposite direction, it also applies to the books on the shelves in the Bodleian Libraries' Book Storage Facility (BSF). Their locations are arbitrary but they are known, allowing them to be retrieved, in this case, semi-automatically. In the case of the British Library's Additional Storage Building (ASB)[1], fully automatically.

Before developing this argument it is appropriate to examine how the online catalogue is different to its paper and card-based predecessors. After all, Krajewski has made a strong case for the card catalogue being an information processing machine, albeit manually powered and operated. In his 1991 work The Online Catalog, Thomas A. Peters acknowledges that information technology has allowed "libraries to expand access as rapidly as the production of published information has expanded" (p.9). He also foresees that this will largely happen due to that published information being online itself, with the catalogue offering direct access to it. But once a catalogue is decoupled from a local physical collection, that collection need not necessarily be local, nor even a collection. Describing the nature of the online catalogue in technical terms, "All other catalog forms are pre-coordinated. Online catalogs have the capacity to allow post-coordination." This means dynamic combinations of (simple) indexed terms relevant to a user's search terms, to create precision in the results delivered. In pre-coordinated systems, such as LCSH, the indexed terms are combined in advance by the indexer or cataloguer. For Oddy, once post-coordinate linking of data was possible, the distinction between main entry and the consequently necessary added entries, or cross-references, is obviated (p.143), simplifying the catalogue's structure for an untrained user. Frické expresses it in practical terms: "for a computer, once a characteristic is recorded as data for an item, then retrieval, or classification, via that characteristic is usually a trivial and, essentially, a zero cost operation." But some useful characteristics, notably *subject*, "are difficult to implement and apply" (p.14).[2]

1 Known at the British Library's ex-ammunition factory compound near Boston Spa as simply 'Building 31'.
2 Frické quotes Shera (1965) on classification to the effect that true library classification by subject is a "pursuit of impossible goals."

Online, "The bibliographic records are not organized in any meaningful way until the user interacts with the system" (Peters, p.30). And the question today arises of what that system, with which the user interacts, should be. Some academic libraries are questioning the role of the catalogue as something the user chooses to search (Kortekaas, 2012). Already common at such institutions, 'discovery layer' software offers a simple search engine-type box with bespoke indexing and will find 'hits' beyond works on the library's shelves. This is a practical attempt to present a unified interface between a library's physical holdings and the digitally published journals and books it also offers access to. But it also suits the current generation of students who have grown up with Google and have never used a card catalogue.

In practice – and this is what motivated Oddy's comments – users are searching for a "work" more than a particular "manifestation" of it (p.152). Such terminological distinctions are fundamental to the latest generation of cataloguing code, *Resource Description and Access* (RDA) and the conceptual model on which it is based, *Functional Requirements for Bibliographic Records* (FRBR) and the *Statement of International Cataloguing Principles*, 2009 (Maxwell, 2013, p.2). Under this conceptual scheme, Oddy's users are rather searching for a *manifestation* of an *expression* of a *work,* more than they are a singular *item* of it.[3] Indeed, for born-digital documents, the concept of item could be considered superfluous, as many readers can access the same document simultaneously.

Designed to work like a database, FRBR is concerned with *entities* – things that exist and can be recorded – and the *relationships* between them. Talking of relationships, ISBD was to AACR2 what FRBR is to RDA. FRBR/RDA is also designed for a universe of entities broader than those found in conventional libraries. In particular, such born-digital documents – and not only textual ones – can be processed as easily as can books.

> "Understanding this FRBR-based structure is important to understanding RDA. This organization represents a philosophical shift away from AACR2, with its emphasis on creating access points to an emphasis instead on describing entities, with almost incidental information on creating access points." (Maxwell, p.10)

Being designed as a database from the beginning, and with today's computing power and search tools, access is no longer the problem it once was. Furthermore, an entity need only be described once, but can then be linked-to as many times as necessary, rather than repeated in multiple records, as has long been common practice in legacy systems (Chambers [ed.], 2013, p.95). This leads towards making library records available to general search engines, so no one any longer needs to search "the catalogue". To know whether an item of a particular manifestation is on the shelf of a local library, one would just phrase the appropriate search term, including key words in the names of both.

The ultimate closed stack – the library warehouse

It is an open secret that most libraries can, and must, dispose of stock; but legal deposit libraries:

> "are still expected to store most of what they are sent. Digital technology, which was expected to reduce the amount of publication, actually increased it and all legal-deposit libraries were facing problems in the later years of the 20th century in keeping up with the rate of acquisition" (Campbell, p.279).

3 For clarification, a library identifies a *manifestation* by ISBN; an *item* by the barcode or RFID tag adhered to it upon accession. Frické deals with FRBR thus: "With Panizzi, in the 19th century, the library ontology contained three kinds of things: *works*, *editions* and physical *copies*. This centuries old ontology is tied to books. Yet it is clear that many IOs [information objects], or, more generally, 'artistic creations', never appear as books – there are musical symphonies, operas, films, performed plays, and so on. So there needs to be a category to catch this 'medium of expression' of a work. FRBR just calls it *expression*." Frické prefers 'edition' for manifestation and 'copy' for item.

In the first quotation introducing this chapter, the law Jewett refers to is that of copyright, or legal-deposit. As has been shown in this study, such institutions have been the first to develop radical solutions for book storage and bibliographic organisation to cope with the expansion caused by the observance of such laws. Campbell also makes the point that for most of library history books have been stored separately from reading rooms; something that architectural historian Nikolaus Pevsner observed as characterising the 19th century library; likely a reaction to the grand era of reading rooms in the 18th century (*Ibid*., p.302). In the 20th century, legal deposit libraries had to resort to renting warehouse space. In the last five years, both the British Library and the Bodleian Libraries, University of Oxford, have designed and built dedicated facilities to manage their legal-deposit and other storage needs.

The Bodleian's BSF was opened in 2010, comprehensively replacing a variety of storage solutions that had been devised throughout the 20th century. Thanks to the BSF, two of these – the extensive Underground Bookstore (UB) that had linked the Schools Quadrangle to the Radcliffe Camera (built 1909-12), and Giles Gilbert Scott's New Library in the 1940s, have now both been extensively renovated and re-purposed as open stacks and reading rooms.

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> "Space is a common theme since the inception of the library."
> (Michael Williams, Interim Associate Director, Collection Support, Bodleian Libraries)[4]

The Bodleian Libraries Book Storage Facility

What is now referred to as the Old Bodleian started with Duke Humfrey's Library, which was then extended with the Selden and Arts Ends. The quadrangle – into which the Arts End is integrated – was built in 1610 after Bodley's death, to further extend the library and provide teaching rooms and a gallery. Eventually the entire building, except the Divinity School itself, was given over to books, and this remains the case. The neighbouring Radcliffe Camera – built to house Dr John Radcliffe's collections and library – became part of the Bodleian in the early 19th century. In the early 20th century it ran out of space and was extended by two storeys of book stacks under the lawns, known as the UB (Underground Bookstore). Suspended bookcases could be slid into the aisle for access – a very dense form of storage. With this facility Bodleian Libraries could accommodate 1.5-2 million books. The UB is now known as the Gladstone Link and is an undergraduate reading room with books on display.[5]

Almost as soon as the UB was in use work began on the New Bodleian Library building by Giles Gilbert Scott.[6] However, the war delayed its opening until 1946. It had 11 floors of closed bookstacks, three of which were underground and, though it was designed to accommodate 50-100 years of growth it was full after just 25 years. The stacks were not compartmentalised as today's planning laws would require (for example, to prevent the spread of fire) and services such as water pipes also ran through them.

In about 1970 the University inherited the local Nuneham Courtnay estate and progressively built modules for book storage within the walls of the kitchen garden, collectively known as the Book Repository; planning restrictions prevented these buildings from being higher than the garden's walls. Seven modules were built over a period of twenty years, all using roller stacks. After this, further planning permission was refused. By the turn

4 Interviewed by the author for this study, 23rd July, 2015, at the BSF.
5 Many of its original suspended rolling bookcases are still in use (although no longer mobile) on the upper level. The lower level is mostly furnished with modern rolling stacks. Much of the floor between the two levels is the original steel grille design allowing light to pass down.
6 Now the Weston Library, housing Special Collections.

of the millennium, the Bodleian was "bursting at the seams" – all of its libraries were acutely short of space. The next resort was the Deep Store facility at a Cheshire salt mine, which is also used by the National Archives. It is a stable, cool and dry environment, ideal for document storage. The least-accessed materials were stored there, freeing space for the in-demand materials at the central sites. The main thing to go there was, interestingly, scientific journals in print. These were the first to be taken up online so demand for the print versions declined markedly. Two million books were "relegated" there but, as it is a commercial storage site, this was at some cost.

The decision was made to consolidate the Bodleian Libraries' off-site storage, with any upfront capital outlay to be balanced by longer-term savings. This process included the barcoding of Bodleian Libraries book stock, which (unusually late for a large research library) had not previously been done. This barcoding scheme would produce the first reliable and comprehensive inventory of Bodleian Libraries physical holdings.[7] Considered as the only possible city-centre site, The New Bodleian building was quickly deemed unsuitable and several years' work went in to planning a dedicated robotic warehouse on the outskirts of Oxford. This was eventually refused planning permission in 2009 due to the building's height and flood risk at the site. An alternative was quickly needed. Sites outside Oxford were considered at Bicester, Didcot and, finally, Swindon. Land was bought in early 2009 near to the Honda factory and its neighbouring suppliers. Ground was broken in September, seven months after the first plan had fallen through. The BSF project took 51 weeks to complete, opening in October 2010 at a cost of £26 million. It contains 230 kilometres of shelving in racking 11.4 metres high arranged in 31 aisles some 71 metres in length. This was expected to hold about eight million books but is now expected to hold up to 12.5 million due to a better understanding of how many books can fit into the archival-standard cardboard storage trays used. The BSF is wholly owned and operated by the Bodleian Libraries.

The BSF was originally planned for low-use materials (with preservation the priority) but its realised efficiency makes it practical for the supply of medium-use material too. A "victim of their own success," good service has lead to higher demand. "Retrievals are almost double what we expected – massively exceeding expectations."[8] Very Narrow Aisle (VNA) format was chosen over robotic cranes because of the 'low-use' expectations; staff and forklift trucks can be shed, unlike an installed automated system. Currently, staffing is increasing, albeit from a low base. The BSF was designed for a staff of 26; it started with 18 and now has 21. However, this could change and people are employed on fixed-term contracts. Throughout this project the overall expectation was for demand for print materials to reduce. This has not yet happened and Bodleian Libraries is considering biasing its discovery system to encourage the use of online versions over print where they are available, to the end of reducing cost.

The BSF ingestion process

Williams managed 100 full-time people barcoding 15,000 books a day in a process that started before the BSF was ready to ingest items. The Bodleian's library management system's (LMS) catalogue records contain the barcode numbers as metadata. This is the *only* connection between the LMS and the BSF's warehouse management system (WMS).[9] Trays are allocated based on the size of the items they are to contain. The BSF adopted the Bodleian Libraries' Nicholson Classification (by size, A-G, see Appendix B), that dates from the 1880s. Now, as then, and right back to 1602, like-sized materials are stored together for space efficiency. At the BSF the Nicholson Classification "mapped straight on to the trays and gave us a broad understanding of the profile of our collections to determine the pitching of the

7 Barcododing of accessions is now done at the cataloguing stage, before books are sent to the BSF.
8 Interestingly, it takes, on average, one minute (or less) to retrieve an item, but two to replace it.
9 The WMS is designed for library applications, of which the BSF was the first (in VNA format) in the UK; there are other examples in Europe and the US (eg, RECAP, a joint project between Princeton and Harvard, see p.16), using software from the same supplier.

shelving." Though only a subset of Bodleian Libraries collection is subject to the Nicholson Classification, extrapolation has proved to provide an accurate representation of the split, A-G. Other materials have also been sized as part of the ingestion process. Individual items are barcoded; the trays they go into are barcoded, and the shelf locations themselves are barcoded. Items are sorted by size, scanned-in and are loaded into an appropriately-sized tray, which is filled. These are then re-scanned by a second operator to confirm the inventory as any discrepancy could lead to loss of items in the warehouse.[10] Once agreed, the completed trays are loaded on to a "tray-to-shelf" trolley, which is transported by low-level 'stacker' forklift to the VNA truck and loaded onto its forks. VNA forklift trucks are designed to operate in the narrowest possible aisles and are automatically guided (steered or, in practice, kept straight) once in an aisle. Their operator stands in a cab that elevates with the forks, allowing him or her to slide the tray into the appropriate shelf space, or from the shelf onto the truck when retrieving items. The truck fills the aisle's width so cannot turn within it but the operator can reach the racking on either side with equal ease.

The operator chooses where to put trays initially – they have a handheld barcode scanner for recording where tray (for example, of barcode 123) was put away (in shelf position XYZ). After this, tray 123 will always be returned to location XYZ. The WMS can be queried to find vacant positions but this is not yet necessary as they are easy for the operators to find. So, in two important respects, the BSF, while operated as a conventional contemporary high-density warehouse, reinstates two principles common to Bodley's Duke Humfrey of 1602 – permanent shelf locations and shelving by size. In the case of the latter this is, as before, for the more efficient use of space, though prevention of theft was also a factor in 1602, with the quartos and octavos protected in the galleries. In the case of the former, the analogy is more coincidental than instructive. The operator allocates a shelf somewhat in the way a hard disk drive would allocate a sector on the disk for new data. It doesn't matter where it is as long as its position is known.[11] During the original ingestion process, aisles were filled simultaneously to overcome the limitation of only one VNA truck being able to service an aisle at once; ie, the process would have been considerably delayed had the aisles been filled one-by-one. The BSF has an advantage over RECAP in that its aisles are open at each end, allowing truck access and exit without reversing. Seven million items were placed in the 15 months to Jan 2012 by a staff of 80, a much greater rate than achieved with any similar project before. Books arrived on pallets "on an industrial scale."

Michael Williams admits that librarians struggled with the fact that their collections were being physically dispersed and, therefore, rendered unbrowsable, except via the catalogue. But he also points out that they had previously been in closed stacks, so the loss of collocation of a collection was really only to the librarians themselves. Books are ordered through SOLO[12] – the catalogue of the major collections of the libraries of the University of Oxford. There are six 'fetches', or book retrieval periods, each day and two van services to Oxford, meaning an order before 10.30am will be received in the relevant reading room that afternoon. Vans go to a satellite hub where the crates are divided between an outer Oxford route and an inner one. Books arrive and leave in Toteboxes[13] (limited to a maximum of 15 kilograms). The BSF is staffed between 7.00am and 10.00pm. Deliveries average 19,500 items a month, peaking in Hilary term (the beginning of the calendar year). The Bodleian receives all of the legal deposit books it is entitled to but subject librarians are allowed to take what they want for their own collections; the rest is stored at the BSF. Legal deposit receipts plus purchases typically average one thousand new books every day.

The BSF's spare capacity is now being put to good use. 12-14 kilometres of shelving is currently housing items that will be returned to the Weston Library by the end of 2016.

10 Trays are also periodically recalled for audit by the WMS.
11 If the BSF were required to supply high-use items it would make sense for quickly accessible shelf locations to be chosen.
12 Search Oxford Libraries Online – www.solo.bodleian.ox.ac.uk
13 Industrial strength containers with hinged lids.

The refurbished building will hold less than originally expected. Magdalen College is refurbishing its library and has temporarily sent most of its collection (some 68,000 items) to the BSF, a service for which the Bodleian charges. This project is expected to be completed by the end of 2015. In principle, the Bodleian could offer a similar service to other UK libraries.

The BSF building itself consists of four 'chambers': two dedicated to legal-deposit and two to other collections. The BSF operates to the PD 5454:2000 standard for the storage of archival documents. Air temperature is kept to 17.5°C and humidity at 50%. Much money has been saved by widening the original tolerances on these values, and more cooling takes place than heating. An array of solar panels in front of the facility can contribute 12% of electricity requirements. Improvements over planned costs have been achieved by being able to put more items in each tray than expected. As of June 2015 the BSF holds 8.3 million items, which is expected to be 8.5 million by the end of the year.

Michael Williams admits, "We didn't know how many books we had before the barcoding."[14] The main reason for this is that a catalogue record does not necessarily equate to one physical holding, as it is possible for one catalogue entry to represent an item of multiple volumes. The estimate was 6-6.5 million books to go to the BSF but it turned out to be 7.1 million after the barcoding was complete. A planning assumption is that expansion should be enacted when the BSF has only 170,000 tray spaces remaining. On current trends, this is predicted to be in 2022. The BSF at its current extent is expected to be completely full by 2033. Like the Fisher Fine Arts Library seen in the previous chapter[15], the BSF is designed to be easily expanded – for example, the current environmental systems can cope with two more chambers and the plot is 6.88 hectares in area, allowing in principle a vastly greater warehouse than currently exists. Sophisticated sprinkler (localised) and smoke detector systems protect the stock. Preferring wet books to burnt ones, Williams explains that, if the worst happens, wet books are freeze dried to prevent mould. The BSF also offers a "Scan and Deliver" service. Scanning is done on site in a dedicated room using proprietary management software.

The British Library's Additional Storage Building[16]

The British Library's Boston Spa site was inherited as part of the formation of the Library in 1973 and accommodates many of the Library's primary staff and functions, including the Document Supply Centre (BLDSC). This derives from the National Lending Library for Science and Technology, which was sited in Boston Spa due to its central geographical location. Boston Spa is also the site of several British Library storage buildings of different generations. In the case of the ASB, 'Additional' refers to the fact that, unlike the Bodleian's BSF, it was not designed to supersede all of the BL's 'off-site' storage, though it did replace a facility in Woolwich. The British Library has had a long programme of working towards becoming a two-site operation, with a requirement to improve the environmental conditions of much of the stock (in particular, that at Woolwich and Colindale, the original dedicated newspaper store).

The chosen solutions, after much planning, consultancy, modelling, simulation, and experience, are the ASB and the more recent National Newspaper Building (NNB).[17] The ASB is a fully automated high-density storage facility with 262 kilometres of linear shelf capacity

14 Bodleian Libraries announced the accession of its 12 millionth item on 10th November, 2015 (University of Oxford, 2015).

15 Campbell (p.299) also gives the example of Utrecht University Library (2004). "… the structure of the [adjacent] car park has been designed so that it can be extended vertically to provide extra book storage on top." Campbell notes that a floor full of books is up to three times heavier than a floor full of cars.

16 The section derives from an interview of Helen Andrews, Operations Project Manager, British Library, conducted by the author at Boston Spa on 29th September 2015.

17 Andrews stated that the British Library took greater internal control of the NNB project after gaining vital experience planning and running the ASB. She was not directly involved in the development of the ASB but stated that it was largely delivered by external consultants and suppliers.

up to a height of 21 metres with some 140,504 locations, each of which can accommodate two containers. It has seven aisles, each worked by a fully automated 20 metre 'Storage and Retrieval Machine' (SRM).[18] Each SRM has two individually controlled load handling attachments, allowing one container to be removed in order for another to be (re)placed behind it.[19] The interface to the store is via six workstations, with a heavy-duty motorised roller conveyor system connecting to the SRMs through an airlock. Before being transported through the airlock into the void, two profile stations check a container's weight, dimensions and 'fill level'; ie, that it is evenly loaded. There are three sizes of container with a capacity ranging from 93 kilograms to 163 kilograms. These are available in different quantities in proportion to the stock the ASB is designed to accommodate. Able to hold seven million items, despite the 'lower-use' designation for its stock the ASB is capable of a maximum throughput (in/out) of 90 containers an hour.[20]

This stock comprises serials, monographs, music, some rare books, CDs, and vinyl. As with the BSF, the ASB is also used for temporary storage. The replacement for the Colindale newspaper store – the NNB – was opened in January 2015 and, as of late September, some stock is still in the process of being moved out of the ASB into the NNB.

The ASB has a central firewall; 'Void 4' being on the left, 'Void 3' on the right. These numerals refer to the number of aisles on each side of the firewall. The environmental conditions in the ASB and NNB also conform to PD 5454:2000. Oxygen levels are kept low at 14.9% (nitrogen is added) to prevent fire in the airtight voids. It should be impossible to strike a match in the ASB and NNB, precluding the need for a sprinkler system. However, the ASB has the added precaution of the firewall, after librarians expressed concern about having so much stock in one room. The temperature is maintained at 16°C; the humidity 52%. The lack of human presence also means that energy can be saved by leaving the aisles unlit. The SRMs are capable of working in the dark.

Unlike at the BSF the interface between LMS and WMS[21] is not simply one barcode per item. There is a "gateway" or "host interface" (bespoke software) that mediates between requests to the LMS and those it makes on the WMS. The 'British Library On Demand' service is also routed through the gateway. It looks for titles, rather than barcodes so, even if a book is barcoded, that number is not used by the WMS. Workstation operators do not scan book barcodes when filling containers. Instead, the unique identifiers for items of stock are British Library shelfmarks, which are recorded in the LMS's bibliographic records. During the ingestion process the WMS records the shelfmarks for monographs by container. Containers *are* identified by barcode (see photograph in Appendix B). Serials do not have an item-level shelfmark so it is possible that several containers will have to be called out to find a particular issue because the shelfmark for a serial may well be linked to several container barcodes. To supplement and improve this there is regular auditing and metadata is improved/updated on each container that happens to be retrieved. The British Library also has a data quality team for cataloguing that is always working; for example, to find lost items. The WMS for both the ASB and NNB is customised off-the-shelf software (not library specific), but the supplier worked to integrate it with legacy British Library systems.

To service the London reading rooms a van leaves the ASB for St Pancras at 2.00am daily, arriving before 8.00am. The British Library states a 48-hour supply time for such deliveries, which also includes the time needed to find the item and pack it for transport.

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18 Generically known as a stacker crane. See Gattorna (ed.), 1990, pp.206-7; Lindkvist, 1985, p.112.
19 In this 'double-deep' storage, some ease of access is sacrificed for storage density. See Gattorna (ed.), 1990, p.205. The BSF has a similar arrangement, albeit handled manually.
20 An early simulation of the ASB can be viewed at: https://www.youtube.com/watch?v=7DlC6_EcLwg
21 Internally, the British Library refers to its warehouse management system as the 'Warehouse Control System' (WCS).

Do robots dream of eBooks?

The two case studies that are woven throughout this study – those of the institutions now known respectively as the Bodleian Libraries and the British Library – have proven to be rich examples of the pressures on building design and bibliographic organisation that were a consequence of the book flood that washed over the modern period, from 1500 to the present day. This latest chapter, concerned primarily with the computerisation of the catalogue and how that made possible the efficient off-site library warehouses here described, continues to provide many points of similarity as well as some instructive differences.

The chapter *Accommodate* provided historical references to a *magasin*-format library – one in which the shelving is laid out into the room, perpendicular to the longer walls, in order to increase storage capacity. This is a core element of warehouse design, seen at its peak in the BSF as an example of the very narrow aisle, forklift truck-served format, and in the ASB as an example of maximum-density storage served by installed and automatic stacker cranes.[22] The key to good design is finding the solution that costs the least throughout its lifespan, when all relevant factors are considered. Two of the key factors are the cost of space and the cost of time taken to access items and get them where they need to be. "The eventual solution will be a compromise incorporating trade-offs between these conflicting factors" (Oxley, 1994, p.30).[23]

Both of these library warehouses, though generally representative of their type, bring specific considerations that are not typical. Lindkvist confirms what any observer would suspect, that "Crane driven storage systems are expensive" (p.113). However, it must be borne in mind that the British Library's brief for both the ASB and the NNB was to replace stores that could not offer an environment suitable for the perpetual storage of the stock. Meeting such a requirement could only be expensive in comparison with standard warehousing costs. Optimising a facility for safe, perpetual storage led to the low-oxygen environment, which in turn led to automated access. It has also been seen throughout this report how typical the closed stack, or at least staff-only access to books has been over the centuries. This finds its epitome in the NNB, which does not even have a viewing platform and can only be observed via video link.

None of this is to suggest that the method chosen by Bodleian Libraries is inferior. The differences in execution can be explained by differences in circumstances and requirements. The Bodleian, despite being a legal-deposit library of much longer standing than the British Library, nevertheless is not one of the UK's national libraries. In this respect, it is freer to make its own commercial choices when it comes to preservation. Despite the delays caused by unfavourable planning rulings and the acute need for a solution, it chose a site that could accommodate a great degree of expansion and flexibility; unlike that of the ASB, which is enclosed on all sides rather like the original 19th-century bookstacks in Bloomsbury.

The ASB is considerably smaller in floor area than the BSF despite their similar capacities. Forklift trucks require significantly more floor space in which to operate than stacker cranes, but the BSF's plot can afford this.[24] It is true that employing people – in this case specialist forklift truck operators – is expensive, but it is also possible to change staffing levels according to need. In comparison, once a stacker crane is installed, every minute it is idle is a minute in which it is not covering its costs.

It should also be noted that, despite having the most advanced technological solution,

22 Albeit in a warehouse it is typical for shelving to run perpendicular to the shorter walls.

23 This quotation is taken from an article in the trade publication Storage, Handling, Distribution, which was supplied to the author by the BLDSC in the form of a PDF scan of the original, which had been called for the purpose from its home in the ASB.

24 Petroski and Campbell both mention that, when designing bookstacks in the 19th century, despite the availability of steel and glass, allowing great height, storage density was always limited by the floor space required for human access. See Petroski, p.184; Campbell pp.304-7.

the ASB's systems still identify ingested items by a shelfmark scheme that has its origins in the age of steam. To this author's mind that just makes the whole enterprise all the more fascinating.

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This concludes the third chapter concerning the computerisation of the catalogue and the library warehouse. Next, the subject changes to the conclusion of this study, and a brief speculation about the future.

SPECULATE AND CONCLUDE

> *"It is almost as if we were asking that a building be created with structural integrity, yet be capable of accommodating a varied multiplicity of spatial requirements in the course of its existence."*
>
> The role of a machine based authority file in an automated bibliographic system / S. Michael Malinconico, 1975.

In addition to the fact that the two library warehouses in this study hold rare and valuable goods, in terms of process they are doubly atypical, as warehouses, in that any item going out will at some point *come back*. Thus there is no 'turnover' of stock. Helen Andrews commented that, in watching the containers accelerated away into the dark depths of the void, one can easily imagine that some are going in, never to return. The BSF and ASB were planned recently, at a time when it was reasonable to think that the production of printed matter would, in the foreseeable future, decline. The British Library's Pat Oddy, writing in 1996, quoted "A recent poll carried out for the BBC's 'Bookworm' programme [which] discovered that two out of three people believe that books will be obsolete by the year 2010" (p.vii). This was long before the eBook, indeed, right at the beginning of the UK public's introduction to the World Wide Web. Perhaps it was the related excitement that skewed the results. Either way, the expected decline is still expected. As speculated in the introduction to this study, it could well be that the BSF and ASB represent the end of a great period of library expansion in the West, preserving information carriers produced by a technology, and in a format, that changed the world but whose time is up; if not now, at least within the lifespan of those living today.[1]

The next big question, which is already being asked, is which has the greater likelihood of being readable in 500 years' time – the last paper book to be ingested into a library warehouse or its eBook or scanned version, now readily available online but with no mechanism for its preservation? And might it even take an archaeologist to discover the printed edition, as Helen Andrews playfully feared? After all, it has been demonstrated that the library warehouse is dependant for its operation on computer hardware and software, which is itself surely potentially as vulnerable in the longer term as online access to books.

Michael Williams's story about some of the Bodleian's librarians being upset at the dispersal of their collections within the BSF is equally instructive. The catalogue, or LMS/WMS, is now the unifying factor, not the shelf arrangement. Browsing is online, via metadata[2], and storage is freed from the need for collocation. This means that finding is more than ever reliant on metadata and, in the case of the ASB, robots – subject to the algorithm that tells them where to place each tray of books. Fascinatingly, and unlike at the BSF, where once a shelf location for a particular tray is chosen it is expected to be kept in perpetuity, at the ASB the robots should, in time, replace the most accessed trays in the foremost bays. As the photographs in Appendix B show, these are still empty after three years of operation. Perhaps those location-specific British Library shelfmarks have a hold on the books after all.

This study has shown that the successive book floods of the modern era – defined as 1500 to the present day – have significantly changed the way libraries are designed, and the way they work. It has also found continuities, and real similarities between 21st-century and early-modern methods. Barring disasters, the internet will become more and more embedded in daily life. Progress towards a semantic web of distributed data linked by embedded metadata that allows computers to manipulate and reformulate it, not only offers

1 This study has not considered the advance of printing technology *beyond* moveable type up to the digital systems of today, which make it possible for the production of an individual book (ie, print on demand) to be commercially viable. Such technology is of particular value to libraries. The assumption, however, is that, despite the screen-based options for reading available today, printing is easier and cheaper than ever.

2 SOLO has a Browse Search feature that attempts to reproduce the act of looking along a shelf for related works.

the promise of efficient and robust catalogues; it also suggests that cataloguing may finally be truly automated. However, linked data is a way of making information processable. The work of preparing the metadata is likely to remain a human activity for the foreseeable future. But, as the pioneers of card-based excerpting and cataloguing realised, once the initial work is done the possibilities of how that information can be combined and reused expand. Although their readers might not realise it, many webpages today have their content collected automatically thanks to these linked data techniques in a manner very similar to the excerpting and composition techniques described in this study.

Let us hope for an environmentally and technologically sustainable future in which the library buildings that accommodate and perpetuate books are as fluid and dynamic as their organising catalogue systems are stable. After all, it is such buildings and information processing systems that have successfully brought us to this point.

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APPENDIX A -- REFLECTION

I am pleased to have reached this end point of my chosen research project – the completed dissertation – but I have enjoyed the process too. I feel that I have met the objectives I set, certainly on a personal level. That in itself is quite an achievement because even when I submitted the project proposal, which was quite a long time after coming up with the idea, I still did not know if I would be able to combine the subjects I wanted to cover and still examine them in enough depth.

To put this all into context, I arrived at the study of Library Science at the age of 41, twenty years after studying for my first degree; time that I spent working in marketing for the storage and handling industry. I quickly realised the connections between my past and my (possible) future: storage and handling – *libraries do it too*; producing and managing documents – *libraries do it too*. I like connections, especially ones that aren't immediately obvious. While some of my colleagues on the course were ready to leap into the immediate future to work in the digital library, I needed to build some foundations. I couldn't go into a new field without a firm grasp of the basic principles, and the history. This study has been that personal exercise in learning and understanding the key processes in the physical and intellectual development of libraries in the part of the world in which I live and intend to operate. Now I feel like I can walk into a room full of librarians and have something to say. No doubt many of them would have different approaches to the field; perhaps from the perspective of the reader, and how libraries have changed peoples lives. I had to focus on what was of most interest to me. This is why this project is broad in scope and invests so much in understanding what others have studied, before advancing into new territory.

When I visited Michael Williams at the BSF in early summer this year I knew I had made the right choice in studying the early 21st-century library warehouse as the culmination of the processes I had chosen as my subject. It was at once completely familiar – my previous work caused me to visit and write about perhaps 100 newly opened warehouse operations across Europe between 1997 and 2011 – and fascinatingly different. The photographs in Appendix B on the following page say it all – industrial racking stacked with books from one of the greatest libraries in the world. Again, connections.

To be able to look back in time to the intellectual ideas that brought us to this point completed the feeling. The most fascinating thing about early modern intellectuals such as Leibniz is that they were practitioners as much as thinkers; yet some of the things they thought are not tied to the time in which they lived and worked but reach even beyond where (or when) we are today. The history of ideas is not really history when those ideas are just as valid now as when they originated. Connections.

To end with an example, the trade publication Storage Handling Distribution – which I cite in the chapter *Perpetuate*, having received a scan from a paper copy retrieved from the ASB – is one that used to publish some of the case studies I wrote professionally. No doubt some of my words are in one of those dark voids, possibly never to return. That makes me happy.

There is much scope for further research into the design and operation of library warehouses worldwide, but the fact that many of these are semi-commercial enterprises – and particularly their reliance on purely commercial partners such as architects and logistics consultancies – may restrict how much information will be available to the interested scholar in the near-term.

APPENDIX B -- PHOTOGRAPHS

Bodleian Libraries Book Storage Facility

Above: The Nicholson Classification sorter (left) and examples of loaded trays (right). Barcodes are clearly visible on items and trays. *Below left*: A well-stocked aisle. *Below right*: From this angle the loaded racking appears to be almost like a conventional bookcase.

British Library Additional Storage Building

Above left: An SRM waiting for its next job, surrounded by the roller conveyors that feed it. *Above right*: The upper section of the same crane; the ladder is for maintenance. The foremost containers remain empty. *Below left*: A barcoded container stocked with unbarcoded print serials. *Below right upper*: The workstations (one clearly visible bottom-right) outside the voids. *Below right lower*: Roll cages not dissimilar to those used by supermarkets are transported by the daily Boston Spa-St Pancras shuttle vehicle.