SKELETONS OF IRON AND BONE: THE MAKING OF A METAPHOR AND THE ARCHITECTURE OF NATURAL-HISTORY MUSEUMS IN ENGLAND AND FRANCE

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PhD THESIS

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I, ___________________________, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.
This thesis considers the metaphor ‘skeleton’ in architectural language, particularly during the period before 1900 when the term ‘skeleton construction’ was first applied to high-rise buildings. Taking this metaphor as its point of departure, it works to bridge the gap between nineteenth-century conceptual models of architectural thought (particularly regarding neo-Gothic architecture) and a practical and cost-effective material with which to build: iron. It also takes into account the discourses of art, engineering and natural history, within which the metaphor of the skeleton permeated. The skeleton worked as a model for abstract concepts, but it also referred to the invisible entity that supported the living body, as well as the transformed remains of animals such as those displayed in natural-history museums. The thesis investigates the kinship between the animal skeletons and the iron framework of two prominent nineteenth-century natural history museums: the Oxford University Museum of Natural History and the Galerie de Paléontologie et d’Anatomie comparée in Paris. It argues that the interaction between these buildings and the specimens they contain had an important role to play in the establishment of the ‘skeleton’ metaphor in architecture. The transformation of the material of bone into the material of iron is also analysed in architectural discourse, particularly in the writings of John Ruskin and Eugène-Emmanuel Viollet-le-Duc. The thesis also discusses late nineteenth- and early twentieth-century physiological and engineering research into the stability of bone and iron. Following the anthropologist Elizabeth Hallam, it uses the notion of articulation – both a linguistic term and a word to describe assembling bones into a skeleton – to critically engage with the concept of the skeleton in these buildings and the discourses that surround them, thus generating new material conceptions. I propose that this critique of the skeleton is crucial for a re-consideration of nineteenth-century organicism.
**IMPACT STATEMENT**

This thesis makes a substantial contribution to nineteenth-century art and architectural history. Although intensely focused on the materiality of iron and bone, the thesis is inherently interdisciplinary, showcasing new scholarship on museum objects, architecture and display. It examines and reconsiders the status of the skeletal specimen (within the context of its makings as well as its complex (after)life), the museum’s skeleton architecture and the expressive iron ornamentation. Owing to its interdisciplinary nature the thesis has the potential to reach a global research community from diverse specialities and disciplines, including but not limited to art history, architecture (particularly those interested in neo-Gothic architecture, organismic and bioarchitecture/biomimicry), nineteenth-century material culture, history of science (biomechanics, natural history and engineering), history of ‘making’, museum studies and John Ruskin studies. The thesis also demonstrates the relevance of nineteenth-century material and architectural studies to exigent contemporary concerns such as new materialism, vibrant matter, and architectural and material ecologies. I would hope this thesis becomes a methodological model and companion for scholars working in the interdisciplinary vein that is now favoured across the academic faculties and institutions.
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INTRODUCTION

SKELETONS OF IRON AND BONE

ARCHITECTURES OF BONE

In 1831 the skeleton of a blue whale was exhibited at Charing Cross (figure i). Found dead and floating by fishermen somewhere in the North Sea in 1827, it was towed by three boats to the shore of Ostend Harbour on the coast of Belgium, and landed on the sands just before daybreak. What a tremendous sight would have awaited the waking inhabitants of Ostend! Stripped of its 170,000 pounds of rotting flesh and 40,000 pounds of oil, its 95-foot long, 18-foot wide, 70,000-pound skeleton was taken to London amidst a promotional circus, following its highly successful and lucrative exhibition in Paris where, to the delight of the Parisians, it was presented fully articulated in the Place de la Concorde. The savants of the Jardin des Plantes also examined it there, with the comparative anatomist Georges Cuvier proclaiming that ‘this enormous animal must have lived nine or ten centuries’. The interest from prominent natural scientists soon fed into the general enthusiasm for the spectacle, with the show of the dead leviathan’s carcass being advertised with the following epitaph:

[...] being admired by the learned and most distinguished personages of a part of Europe, having been proclaimed, by the Naturalists and Professors of Paris, as the largest in the possession of man.  


2 Georges Cuvier, and the other professors of the Jardin des Plantes in Paris, saw proof of the whale’s great age ‘in the cartilages of the fingers of the hands or side fins, which are perfectly ossified, or converted into bone’. See Percy and Timbs (quoting Cuvier) in The Mirror of Literature, Amusement, and Instruction, p. 105.

A colossal tent was erected in Kings Mews, Charing Cross. This was an area of London that already profited greatly from pleasure seekers who often frequented the streets of Whitehall, Cockspur and the Stand. With a reputation for the most novel of shows and amusements, visitors to the capital were expected to pass through Charing Cross and were therefore likely to have entered the pavilion and seen the Charing Cross Whale, which had been articulated and mounted on large cast iron supports. For a fee of two shillings, a visitor could ‘enter’ the skeleton like a proverbial Jonah. What must visitors have thought when they looked up and beheld the whale’s enormous white rib bones, curving upwards to meet a backbone in the vault of the thorax? Some reports make mention of a twenty-four piece orchestra playing upon an erected platform inside the whale’s ribcage, while visitors sat comfortably in cosy chairs, partaking of refreshments and reading their free copies of numerous natural history publications. In the spirit of the jovial atmosphere that the ‘palace of the Prince of Whales’ evoked, visitors were asked to sign the guest book and invent witty puns and epigrams, such as ‘[w]hy should we be mourned for if killed by the falling of the bones of the whale? We should be be-wailed’.

Eager to feed the public’s appetite for accounts of such jolly novelties and spectaculors, Charles Dickens (1812–1870), who never actually saw the whale when it was exhibited in London, wrote a second-hand account of the exhibition in his popular tuppence-weekly magazine *Household Words* (1850–59). He informed his readers about the possibility of sitting ‘inside the skeleton’ so as to ‘inspect’ the inner world of the whale and to behold the great ribs of the giant cetacean from inside its thoracic

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4 Charing Cross lost its title as an amusement centre following the invention of the music hall, the Variety theatre and the growth of institutional leisure activities. See the University of Sheffield, ‘Shows of London’, *National Fairground and Circus Archive*, 2017 <https://www.sheffield.ac.uk/nfca/researchandarticles/showsoflondon> [accessed 4 April 2017].

Dickens also made mention of another large whale skeleton that was exhibited three-years later in Oxford in 1834:

One hundred and fifty-two children were within its mouth at one time, the roof of which appears like an excavated rock overhead. The children [...] then turned into use by the proprietor of the whale, who wished to measure the capacity of its mouth. Lucky it was for the hundred and fifty-two children that the whale had no longer the power of shutting his jaws together, for what a meal he might have made of them like an ogre of old!⁶

Dickens describes the jawbone populated by children like an interior space and, using the word ‘roof’, analogises it with a building. He views their presence in the whale’s carcass as an occupation of architectural space. Bones make up the internal structure of all vertebral life and were considered to be the body’s architecture. Dickens enters the body through the mouth, an orifice just like a door, which opens and closes, and is a passageway by which things can enter and exit the body. With its domed shape and chalky colour, it is perfectly understandable that the inside of the whale’s cranium would appear to Dickens much like the inside of a cave. Dickens’s graphic, often Gothic imagination heightens his observation of the children entering the whale’s mouth by imaging the jaws shutting as the whale gobbles up one hundred and fifty-two children. Yet the whale is quite obviously dead, and no longer has the power to breathe let alone chew, but the latent animation or potential power of the jaws is still perceived by Dickens through the skeleton’s articulated nature.

Whale jawbones provoked the imagination. They were frequently found in costal whaling towns in the eighteen and nineteenth century, when whaling was at its height. The bones were often made into architectural arches that acted as landmarks for entering the town.⁷ Although bone was not used as a building material per se, the

⁶ With original content ranging from social journalism to short fiction, the highly publicised magazine *Household Works* was launched on 30 March 1850. See the University of Buckingham, ‘Household Words, vol 15, 21 March 1857, p. 275’, *Dickens Journals Online*, 2017 <http://www.djo.org.uk/household-words/volume-xv/page-275.html> [accessed 3 September 2017].

⁷ Nick Redman, in his six-book series titled *Whales’ Bones*, traces a global history of whalebone – the skulls, jaws, ribs, vertebrae, and shoulder blades – as ornament and
natural arch of the whale’s mandible has meant that whalebone arches have been found all across the world. On occasion the whalebone remains pierced by the weapon of its undoing, such as in the whale arch in Bragar on the Isle of Lewis, where the iron harpoon embedded in the bone at the apex of the arch has become somewhat ornamental (figure ii). That the jaw bones were consciously made into a kind of arch(itecture) and were understood as a way of identifying and demarcating geographical space resonates with the idea of the mouth being a portal of some kind and a site of potential transition from an inside to an outside. The link between whale bones and architectural threshold is particularly manifest in Scandinavian languages where the word for whale, hval, means ‘arched’ or ‘vaulted’.  

Dickens also makes mention of whalebone being used domestically for ornamental purposes:

In the garden of a lady at Abingdon the bones of the under-jaw of a very large specimen are placed in the form of an arch, at the end of a gravel-walk. The ivy has grown over them, and they form a very pretty object. In a garden at Clapham we have seen one of the huge dorsal vertebrae converted into a chair by being mounted on three wooden legs; the broad part makes a capital seat, and the projecting spines form the back and sides of the chair.

It is somewhat congruent that that back of the whale, the spine of the dorsal vertebra, was used to help support the back of the human sitting on it. Bones, by way of ornament, furniture (figure iii), scrimshaw from whalers and foragers along the shoreline, or just curious object, were ubiquitous to the nineteenth-century eye.

Another Victorian novelist who experienced the spectacle of a whale skeleton was Herman Melville (1819–1891) who put up in Craven Street in 1849, a stone’s throw from Kings Mews where the Charing Cross skeleton was exhibited eighteen years architecture from the time of the first whalers to the present day. Nicolas Redman, Whales’ Bones of the British Isles (Teddington: Redman Publishing, 2004), and Redman, Whales’ Bones of France, Southern Europe, the Middle East and North Africa (Teddington: Redman Publishing, 2014).


prior. In his seafaring tale of exploration, adventure and costly revenge – *Moby Dick* (1851) – Melville makes mention of an actual sperm whale skeleton that washed up on the shore in Tunstall, East Yorkshire in 1825. Known as the Burton Constable Whale (after the estate where it was exhibited on a wrought-iron frame), Melville included his impressions of the fifty-nine-foot carcass in his novel, and explored the articulated skeleton as both an object and architecture upon which to climb:

Sir Clifford’s whale has been articulated throughout; so that, like a great chest of drawers, you can open and shut him, in all his bony cavities – spread out his ribs like a gigantic fan – and swing all day upon his lower jaw. Locks are to be put upon some of his trap-doors and shutters; and a footman will show round future visitors with a bunch of keys at his side. Sir Clifford thinks of charging two pence for a peep at the whispering gallery in the spinal column; threepence to hear the echo in the hollow of his cerebellum; and sixpence for the unrivalled view from his forehead.10

Like Dickens, Melville perceived the cavities of the skeleton as hollowed spaces analogous to rooms or corridors, the acoustics of the enclosed spaces allowing for voices to travel in whispers and echoes. The articulated bones allowed for manoeuvring the skeleton; for its jaw to swing and its ‘chest’ to open like a wooden chest or trunk, these being bodily metaphors applied to objects with hidden spaces. Parts of the skeleton could be locked and unlocked, like rooms in a house, by the footman who carried the keys to the rooms of the estate. In this way, the skeleton becomes a version of the house within which it is kept, in a mise en abyme of parts that open and close. Melville makes other references to the whale-as-architecture in *Moby Dick*. In the chapter ‘A Bower in the Arsacides’, Ishmael recalls a temple made from the skeleton of a sperm whale. Removed from the fictional shore of Pupella to a nearby glen, the natives preserved the skeleton, placing a sacred flame inside its skull ‘so that the mystic head again sent forth its vapoury spout’.11 Ishmael measures the enormous dimension of the whale’s exterior and enters the carcass-turned-temple,

ornately decorated with carvings and trophies. He also mentions arrow slits carved into the skull. Plants and vines covered the bones, and Ishmael tells of being struck by the Arcadian imagery – of verdant life twinning around death – of ‘Life folded Death; Death trellised Life’.12

Although this last example of bone ‘architecture’ is likely a figment of Melville’s imagination, the fiction would still have resonated with nineteenth-century readers who had also beheld the Charing Cross whale, or any other whale on display at exhibitions or in museums, and who could have physically gotten, like Ishmael ‘beneath the skin of an adult whale’. Melville imagined ribs ‘used for beams whereon to lay footpath bridges over small streams’, and vertebrae piled high to look like ‘Pompey’s Pillar’ or laid ‘like the great knobbled blocks on a Gothic spire, forming solid courses of heavy masonry’.13

These two literary examples demonstrate the degrees to which bones, and the enormous whalebones in particular, fired the Victorian imagination. Both Melville and Dickens encouraged their readers to imagine themselves inhabiting skeletons; to perceive bones as architecture. This has led me to question how the popular imagination of skeletons, as architecture, links with the perception and conceptualisation of nineteen-century iron architecture as ‘skeleton architecture’.

Another exhibition space that Victorians could visit to see whale skeletons, as well as a host of other animal skeletons, was the natural history museum. Many of these museums were ‘built-for-purpose’ in the nineteenth century, meaning they were designed expressly for the display of zoological specimens from all across the world. What I find most remarkable is that some of these museums, with their magnificent iron and glass architecture, actually look like the bones of the skeletons on display. In this way the museum’s iron architecture allows visitors to not only see the skeletons on display, but also to inhabit the skeleton of the building. This kind of visual slippage, between the skeleton of bone and the skeleton on iron, has led me to ask the following questions: how did the word ‘skeleton’ enter architectural discourse; what do such metaphors tell us about the understanding of bone and iron in the past, and what are

12 Melville, Moby Dick, p. 384.
13 Ibid., pp. 386–87.
the implications for this metaphor when articulated in nineteenth-century skeleton architecture? This thesis is the result of my engagement with these questions, and my fresh interpretation of nineteenth-century skeletons of iron and bone. These are by no means contained research questions and I have mitigated their scope by geographically limiting my exploration of the metaphor to England and France.

I have selected two of the most prominent European natural history museums to act as case studies within which to engage and explore the dynamic materiality of iron and bone in the second half of the nineteenth century: the Oxford University Museum of Natural History (OUMNH) and the Galerie de Paléontologie et d’Anatomie comparée in Paris. Both museums, constructed from iron, glass and masonry, were specifically designed for the purpose of displaying spectacular skeletons. I will argue that the intention of the museums’ architects regarding the presentation of the zoological specimens is evident in the design of the exhibition space. Iron and bone, two very distinct materials, are dynamically connected within the museum spaces, as the skeletal specimen and the wider natural world is echoed in the iron structure and the ornamentation of the museums. It is my contention that these two materials, harmoniously articulated in the dry skeletal specimen, are the source of the skeleton metaphor in architecture, and that this relationship, established in the nineteenth century, moves beyond the visual to the conceptual level. I will therefore focus my analysis of the skeleton metaphor within nineteenth-century architectural, engineering and natural history discourse, looking at what contemporary viewers may have seen and understood when discussing or writing about ‘iron’, ‘bone’, and the ‘skeleton’.

I will primarily consider the writings of two nineteenth-century architectural theorists, John Ruskin (1819–1900) and Eugène Emmanuel Viollet-le-Duc (1814–1879). There are several reasons for this selection, the first being that the two men had significant impact on the direction that architecture and architectural discourse took in their respective countries during their lifetime and well beyond. What is more, both wrote prolifically about Gothic architecture, which is particularly important here, as they developed notions of organic architecture in relation to medieval buildings, a view underpinned by the analogies made between architectural and skeletal structures. Last but not least, Ruskin and Viollet-le-Duc discussed the materiality of iron and had extensive, often contradictory views of its use in architecture. Both men were also
naturalists at heart and applied bone and skeleton analogies and metaphors to the world around them, especially when describing the make-up of things.

This thesis is inherently interdisciplinary, and I have therefore taken a multidisciplinary approach, drawing on a diverse body of literature, from art history and architectural history via anthropology to the history of science. In what follows is a discussion of the key authors that have informed my research methodology and output. I have organised this literature in thematic sections although I consider these categories arbitrary as many of the themes overlap.

**RUSKIN**

The art and architectural historian Alina Payne considers the body ‘one of the less addressed topics of modern architecture’.\(^\text{14}\) Payne argues that with the beginnings of industrialisation, the body had been ‘displaced from the centre by the machine’, and she believes there has been no significant inquires made into nineteenth-century interactions between the body and architecture in recent years.\(^\text{15}\) Although I cannot account for the scholarly output in its entirety, I can with confidence state that there is no published literature that addresses John Ruskin’s engagement with the body, outside of Anuradha Chatterjee’s recent book *John Ruskin and the Fabric of Architecture* (London: Routledge, 2017).\(^\text{16}\) With her focus on architectural surface, Chatterjee conceives of Ruskin’s ‘wall veil’ (the surface that divides architectural space, introduced by Ruskin in *The Stones of Venice*, 1851–53) as modelled upon the ‘dressed’ female figure. In her thought-provoking discussion of Venetian architectures in which architectural surfaces become fabrics, Chatterjee argues that Ruskin’s romanticised vision of the architectural body stood in direct challenge to industrialisation, and the soulless nature of iron.

\(^{15}\) Ibid.
Historians and biographers of John Ruskin, from Nicolas Pevsner, via Brian Hanson to, more recently, Lars Spuybroek, have considered his condemnation of certain iron architectures, most importantly the Crystal Palace, as his definitive position on the material, and took it together with his critique of industrialisation in which iron symbolised a kind of soullessness and moral corruption. Indeed one can view Ruskin, through his anathema of industrialised Europe, as attempting to bring the human element back into building construction. He envisaged craftsmen in direct contact with the product of their craft, in effect restoring the kind of humanistic aura, for Ruskin still palpable in medieval buildings, to the industrialised mechanical workforce. Ruskin’s neo-Gothic manifesto, On the Nature of Gothic, would attest to as much. The wrecked British landscape that confronted Ruskin was thematised in his writings through his ethic and aesthetic judgments, where themes of rural nostalgia, the ruin, restoration (his dislike thereof), conditions of labour, and craftsmanship are contrasted with his esteem for the medieval architectures of Venice. Ruskin discussed Gothic buildings as entities in which the materials of construction, the architect and the craftsman came together to form a unified organic structure.

The existing literature has overlooked though that Ruskin also recognised iron as an essential element for all terrestrial life. As an element of blood, iron keeps us alive, and Ruskin hoped to infuse this breath of life into architectures whose very lifespan is marked by processes of oxidisation. The iron in the stone yellows over time, and it is this ‘golden stain of time’ that testifies to the age and ‘life’ of the material and the life of those who raised such edifices. The stone remembers the builders and craftsmen,

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remembers their touch, and they have become a part of it so that those who build never really die. As Ruskin contended: ‘it is in becoming memorial or monumental that a true perfection [in architecture] is attained’.

Iron thus becomes for Ruskin a material with the potential to connect all things at all times. This is iron’s redemption, being part of a material ecology, a circular chain of ‘feeling’ and ‘sympathy’ that works in service of a whole and which is presented quite beautifully in Ruskin’s ‘Law of Help’, and his essay *The Two Paths*, in which the mountains are fed by their own ruin. It is therefore important to recognise from the offset that materials are never so clear-cut in Ruskin’s writings as some authors may have led us to believe.

Raised as an Evangelical Christian, Ruskin’s believed that all things were made by a benevolent Creator. He looked to nature as a kind of scripture and found lessons in the unified beauty of God’s design. Ruskin’s writings often feel like exegetical studies in which the material speaks with a godly voice:

[I]t is impossible for you to take up the most insignificant pebble at your feet, without being able to read, if you like, this curious lesson in it. You look upon it at first as if it were earth only. Nay, it answers, ‘I am not earth – I am earth and air in one; part of that blue heaven which you love, and long for, is already in me; it is all my life – without it I should be nothing, and able for nothing; I could not minister to you, nor nourish you – I should be a cruel and helpless thing; but, because there is, according to my need and place in creation, a kind of soul in me, I have become capable of good, and helpful in the circles of vitality’.

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23 Galatians 3.28: ‘There is no longer Jew or Greek, there is no longer slave or free, there is no longer male and female; for all of you are one’. Also see Jack Denfeld
one thing for Ruskin. Materials have surface and depth; can be helpful and helpless, mundane and magnificent.

In a similar manner, Ruskin also perceived iron as vital, as both organic and inorganic; breathing and static. I will thus take a wider range of Ruskin’s writings into account to provide a more nuanced understanding of his multifaceted views on the materiality of iron. Building on this discussion, this thesis reconsiders the iron architecture of the OUMNH and demonstrates the significance of Ruskin’s ideas for the conception and construction of the building.

Linking Ruskin’s views on iron with his use of the skeleton metaphor, I will argue that the architecture of the museum was conceived as a vital iron skeleton. Although architectural historians such as Carla Yanni, Freddie O’Dwyer and Eve Blau have examined Ruskin’s involvement in the design and execution of the museum building, remarking on the fascinating spatial interplay between cloister garden, cathedral and scientific exhibition space, none have critically engaged with the material of iron and with the link between the building’s structure and the animal specimens. Only one recently published 2016 essay by the architectural historian Nathaniel Robert Walker parallels my own observations regarding the iron architecture which, in both our minds, becomes animated by an understanding of the visual metaphors between glass and skin, iron and bone, and architecture and biology. Walker likens the iron architectural frame to the organic skeleton, and vice versa, and regards the morphological analogy as an ‘interdisciplinary phenomenon’ that evidences the inextricable link between the natural sciences and architecture in the nineteenth century. He describes the architecture of the OUMNH as paleostructure: ‘a


26 Ibid., p. 49.
prehistoric, and indeed pre-human, architectural logic that, when scientifically discovered, analysed, and applied, could tap into the developmental powers of natural history itself, fuelling architectural progress while simultaneously revealing the original ordering genius of the Creator'.

Walker’s argument follows in the footsteps of Philip Steadman’s *The Evolution of Designs* (1979) and Barry Bergdoll’s exceptional essay ‘Of Crystals, Cells and Strata’ (2007) in arguing for a kind of evolutionary architecture in the design of both animals and buildings, particularly Gothic architecture. Walker argues that the architectural iron skeleton emerged from the disciplines of geology and palaeontology as a way of linking the ‘architecture of creation to the architecture of humanity’. The lack of skin and superfluous fat in fossils and bones gave a reductive ingenuous logic to the slender efficient starkness of iron architectures. The wrought iron ornamentation – the tendrils, foliage and flowers – evoke the great tree trunks of the so-called ‘primitive hut’, the imaginary of architecture’s organic origins, taken up during the Enlightenment on the frontispiece of the second edition to Marc-Antoine Laugier’s *Essai sur l’architecture* (1755), discussed in the first chapter of this thesis. The ornament of the OUMNH, argues Walker, recalls the living nature of the *hortus conclusus*: ‘[t]his antediluvian Eden […] teams not with unicorns or nude innocents but with dinosaurs’. Walker’s argument is highly evocative, bringing together contemporary debates regarding ‘deep time’, the geological record, and coal and iron mining with the neo-Gothic iron architecture of the OUMNH, but the author offers little evidence to support it. He discounts the materiality of the metaphor, that is the actual material and structural similarities

27 Ibid., p. 52.
between bone and iron as they were explored during the nineteenth century. Discussing both the metaphorical and material entanglement of iron and bone, my research contributes to literature that considers both biological analogies and metaphors in architecture. It builds on existing literature that explores the linguistic and material exchange between architecture and the natural sciences in the nineteenth century, such as the work of Martin Bressani, Adrian Forty, Barry Bergdoll and Sophie Forgan.31

Sophie Forgan’s research explores the institutional formalisation of architecture and science along with the collaboration of the two disciplines on certain museum projects in London. She also discusses the increased interest in the properties of architectural materials, such as brick, stones and iron, and the extensive, often controversial scientific testing of their load bearing qualities as well as their resistance to crushing.32 Although Forgan does not go into details regarding the testing of materials, she acknowledges the practice and its impact upon the descriptive language employed in the newly emerging branches of natural science and the spaces in which science was displayed. ‘The vocabulary’, Forgan writes, ‘that scientists used about museums also indicated that museum displays shaped the knowledge of a discipline’. Forgan also explores how metaphor, when used to describe architecture for museums of natural history, could reveal the scientific beliefs of those involved in the building of museums. She argues that the naturalist Richard Owen (1804–1892), who successfully advocated for a new natural history museum to be built in London, used the language of ‘phylogeny’ – a language of classification, archetypes and structural relations – to explain the building and its layout. According to Forgan, Owen described the scientific


32 In a particular series of material experiments performed under the aegis of the RIBA in the 1880s, it was discovered that some of the bricklayers falsified their results and used uncontrolled testing environments and parameters. See Forgan, ‘Bricks and Bones: Architecture and Science in Victorian Britain’, pp. 188–90.
museums of the past as ‘extinct’ and spoke of the ‘developmental advances’ in contemporary museum design. In a written version of a speech that Owen gave following the official opening of London’s Natural History Museum, Owen footnoted the historic 1829 debate between the famous French naturalists Georges Cuvier and Geoffroy Saint-Hilaire in which Cuvier regarded the unity of the vertebral body as being like the composition of a house, with the reciprocal arrangement of apartments and rooms. In her own description of the museum’s architecture, Forgan writes that ‘the spine of the great front galleries running along the façade also had a vertebrate, skeletal quality that related well to Cuvier’s reciprocal disposition of parts. Architectural symmetry and design in nature blended together’. Although Forgan’s essay sets out to analyse the phylogenetic metaphors used by Owen, Forgan herself employs architectural metaphors derived from the skeleton to describe the space. This is unsurprising given that the most commonly used metaphors in architecture tend to be bodily metaphors. We all possess a body, and all of us possess a skeleton inside of this body. It is an essential part of human anatomy. If deprived of its skeleton, the body would collapse, fold into itself, melt to the floor and remain immobile. ‘Without it’, as Catherine Ingraham writes, ‘one cannot understand or treat the body […]’. It is the necessary starting point. Bodily metaphors, and especially the metaphor of the skeleton, seem to sit naturally in architectural language, but they should not be taken for granted. On the contrary, they need undoing. As indicated by Forgan’s own metaphorical language, the seemingly obvious nature of the skeleton as an architectural framework has led to it being discounted as an avenue for potential interrogation. Well knowing that it is impossible to not use metaphors, I will try to avoid using the metaphors I am analysing and take the skeleton as a theoretical starting point to address its significance within architectural theory.

33 Following Cuvierian theory, Owen divided the Natural History Museum into two ‘wings’ to represent the two major branches of natural history: extinct and extant species. See ibid., p. 193.
34 Forgan, in ibid., quoting Cuvier: ‘la composition d'une maison, c'est le nombre d'appartemens [sic] ou de chambres qui s'y trouve; et son plan, c'est la disposition réciproque de ces appartemens et de ces chambres’.
35 Ibid.
Jacques Heyman’s 1995 book, *The Stone Skeleton: Structural Engineering of Masonry Architecture*, is a careful scientific interrogation of structural stone Gothic architecture. The titular metaphor of the skeleton to the material of stone evokes thoughts of structure, solidity, stability, strength and permanence. However, the connections between bone and stone’s materiality are far less tenuous: stone itself is often comprised of the bones and shells of marine organisms. The materiality of the stone is not what is at stake for Heyman, as he is more interested in the vertical and horizontal loads and internal thrust maintaining a state of equilibrium. Heyman’s application of the skeleton metaphor is both sensationalist and conventional, provoking thoughts of the medieval ruin and following the loose association of the body–architecture metaphor rather than any consideration of the skeleton’s materiality. The stone ribs of the vault spanning the ceiling of the Gothic church are intended to evoke a cavity, ideas of interiority and the invisible transfer of weights and loads. Heyman uses the skeleton metaphor as a way of envisaging an ideal system of structural support that facilitates the dispersal of multidirectional internal and external forces, such as compression, thrust and shear. Although the stones remain in place, it is not due to their physical inertia but through a maintained state of ‘static equilibrium’. Lars Spuybroek takes a very different position in his recent book *The Sympathy of Things: John Ruskin and the Ecology of Design*, although Spuybroek would perhaps recognise Hayman’s description of static equilibrium. Spuybroek imagines a digital Gothic city composed of architectural designs that follow the writings of Ruskin by affirming the Gothic style as an interpretation of the organic; as a living, ‘foliated’ form that exists in a continuous process of formation.

Whilst Spuybroek does not evoke the skeleton as a paradigm, he presents the rib – a term itself derived from anatomical nomenclature and expressed multifariously in architectural language – as eliminating the division between the structural and ornamental in Gothic architecture. Taking up idea of the ‘abstract line’ developed by Wilhelm Worringer in his *Abstraction and Empathy* (1908) Spuybroek writes: ‘[T]he behaviour of the line however small and thin they are, displays a structural and

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connective logic’, further describing the Gothic line as a ‘living’ line that produces structures. For him, the curving ribs multiply — they grow, intersect, bifurcate, articulate, transform and flow throughout Gothic architecture. The line’s modulation has neither beginning nor end. The line flows, existing in a kind of in-between, too thin to carry weight and too thick to be delicate ornament. It is a rib of ‘active rigidity’, as defined by Ruskin in *The Nature of Gothic*, in which, as Spuybroek remarks, ‘[e]very rib is formed by linear figures in which every point on the line is active’. The line is activated by the beholder of such architectures via foliated organic branching and converging, such as described by Worring’s vitalised Gothic line in which abstraction and empathy merge. The line must first be perceived and then extracted as an ‘entity’ in a process of ‘expansion and delimitation’, accomplished by the viewer’s inner vision and active ‘will’. However, for Spuybroek, the animation of the linear rib moves beyond its activation by the subject to the ‘active form of support and transfer of loads rather than a simple form of resisting forces’. The structure is active, and activity is life. This oxymoron of active rigidity, specified by Ruskin as an expression of Gothic architecture, developed by Worring and later by Spuybroek, could be aptly applied to the skeleton as an entity, itself possessing properties of structural stability whilst retaining flexibility and a potential for animation and growth.

This thesis argues that Ruskin’s take on the natural world and his use of the metaphors of iron, bone and skeleton were key to the establishment of the metaphor of the iron skeleton in architectural theory and to the use of iron frames in architectural practice. Like Nathaniel Walker, my consideration of the OUMNH’s architecture relies heavily upon visual analysis, however, unlike Walker my approach is in conjunction with

41 Ibid., p. 9.
43 Worring, *Abstraction and Empathy*, p. 5.
44 Spuybroek, *The Sympathy of Things*, p. 5.
45 In his thesis, Worring writes that ‘life is activity. But activity is that in which I experience an expenditure of energy. By its nature, this activity is an activity of will’. See Worring, *Abstraction and Empathy*, p. 5.
Ruskin’s appropriation of the skeleton metaphor on which no literature exists outside of this thesis. I argue that the metaphor of the skeleton was a recurring trope in Ruskin’s writings and became a crucial tool when considering the relationship between parts and whole, yet the skeleton as an organic concept within nineteenth-century architecture and architectural discourse has so far been exempt from critical study. That being said, there was one nineteenth-century architect and theorist who explicitly aligned the animal skeleton with iron engineering and the organic frames of Gothic buildings: Viollet-le-Duc.

**Viollet-le-Duc**

Architecture is an expression of thought as well as structure, and the circulating theories, debates, political positions and ideologies from multiple fields and discourses often find their way, physically and conceptually, into the architecture of the day. The work of the naturalist Georges Cuvier, who classified animals based on the evidence of the skeleton, and who theorised a direct relationship between an animal’s form and its function, significantly influenced the philosophies and practice of the celebrated nineteenth-century French architect Eugène Emmanuel Viollet-le-Duc. Architectural historians such as Martin Bressani, Roland Recht and Laurent Baridon have extensively analysed the structural rationalism of Viollet-le-Duc’s designs, his Cuvierian approach, and his influence on modernist architecture. The literature tends to describe Viollet-le-Duc as a rationalist architect, who advocated for the use of contemporary materials and methods in classical and Gothic designs, where a building’s structure and function directs its form. The correct material for the structure should be used regardless of the desired aesthetic, as material honesty and rationality give innate beauty to a building’s form. This being said, Viollet-le-Duc’s architectural philosophy was more nuanced than some historians give him credit for and should not be reduced to a positivist position. Yet the influence of the natural science, particularly

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comparative anatomy and Cuvier’s ‘principle of correlation’ (the ability to conceive the entire skeleton form a single bone), on his architectural reasoning, methods and designs is indisputable, and will be discussed in detail in the third chapter of this thesis.

Viollet-le-Duc’s understanding of the architectural Gothic skeleton was like his understanding of the skeletal system in a living animal. All parts are held in stable equilibrium, what Ruskin termed ‘active rigidity’, and all parts come together in the service of the whole architectural body. This view is made readily apparent in the ten volumes of Viollet-le-Duc’s *Dictionnaire raisonné de l’architecture française du XIe au XVIe siècle* (1869). In volume four, the architect holds that ‘[t]he skeleton of the cathedral is rigid or flexible […] it gives or resists; it seems to be living because it obeys to contrary forces, and its stability is gained only through the equilibrium of these forces, no longer passive but active […] the stone lives, acts, fulfils a function, is never an inert mass’.47 The drawings that accompanied his architectural musings were reminiscent of anatomised bodies seen in anatomical dissectors and treatises. The structural members of the building were taken apart, part-by-part, revealing the intimate structure of the construction material through a kind of dissection. Exploded perspectives of architectural columns isolate the parts of the column in segments, disarticulated but remaining in relation to their articular surfaces, like bones in relation to their joints, showcasing their necessary purpose in maintaining the equilibrium, stability and function of the whole.

When evoking architecture as a living system, Viollet-le-Duc used the word ‘squelette’, and when talking about the structural framework of a building, he employed the terms ‘charpente’ and ‘ossature’, which literally translate as timber frame and bony frame, respectively, although he used both terms interchangeably.

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47 Eugène-Emmanuel Viollet-le-Duc, *Dictionnaire raisonné de l’architecture française du XIe au XVIe siècle*, 10 vols (Paris: A. Morel et Cie, 1869), vol iv, pp. 127 & 164: ‘Tout édifice possède son squelette et ses membranes; il n'est plus qu'une charpente de pierre indépendante du vêtement qui la couvre. Ce squelette est rigide ou flexible, suivant le besoin et la place; il cède ou résiste; il semble posséder une vie, car il obéit à des forces contraires, et son immobilité n'est obtenue qu'au moyen de l'équilibre de ces forces, non point passives, mais agissantes. […] Leur maçonnerie vit, agit, remplit une fonction, n'est jamais une masse inerte et passive.’ Also see on the principles of construction: ‘Nous voyons déjà, à la fin du XIXesiècle, le principe de la voûte d’arête romaine mis de côté’. Les ârcs-doubleaux sont admis comme une force vive, élastique, libre, une ossature sur laquelle repose la voûte proprement dite’.
Such distinctions are crucial for understanding the conceptual transformation of the iron skeleton into a living system of parts. Although, in referring to the skeleton of medieval Gothic buildings, Viollet-le-Duc was considering the materiality of stone, in his contemporary designs and architectures his material of preference was iron. Often equating the engineering of the body, particularly the biomechanics of the skeleton, with the engineering of iron structures, Viollet-le-Duc produced remarkable drawings that show bone and iron working side-by-side in a mechanical system. For Viollet-le-Duc, bone was an ideal building material – graceful, adaptable and strong – and a model material for iron engineers to follow.

In his book *The Evolution of Designs*, Philip Steadman argues that Cuvier treated the animal body like an engineer approaching a machine, arguing that a thing does not necessarily have to be ‘alive’ to be organic. As part of his critique of contemporary design theory, Steadman posits that certain inert physical objects can exist somewhere between the concepts of the living and the dead, the organic and the inorganic. Some buildings, machines and implements are able to express the wholeness, coherence, correlation, integration and organisation of biological organisms. However the architect remains dismissive of biological analogies and metaphors applied to such inert objects. For Steadman, attempting to define the essence of a thing through metaphors derived from nature or biology presents a kind of ontological conceit. Although his argument touches upon the animal skeleton as a structural ‘whole’, whose ‘correlation of parts’ was vital for Cuvier’s practice of comparative anatomy, he limits his exploration of the skeleton to the functional importance of bone as a classification model, as well as its importance in fossil and anatomical reconstruction. He thus moves his critique directly towards the simple yet rational application of the skeleton in architecture, for example in the writings of Viollet-le-Duc. For Steadman, to analogue the supporting architectural framework of a building with the animal skeleton is a ‘naïve expression’ of metaphor. He then moves his argument quickly away from Cuvier to engage with Darwinian concepts as applied to architecture, avoiding a more sustained discussion of comparative anatomy’s relevance for nineteenth-century architectural theory and practice. Bypassing significant fields of enquiry within which the skeleton metaphor played a conceptual or material role, such as in art, geology and engineering, Steadman’s analysis of the skeleton remains one-

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Rather than dismissing metaphors, I argue, it is important to analyse them. Some metaphors can, indeed, be considered as trite; however, as I will demonstrate, the skeleton is a ubiquitous metaphor whose material substrate is important to analyse. I will thus argue for the significance of the skeleton in nineteenth-century organicism in architecture, and the iron skeleton in particular.

In his consideration of the structural skeleton in Viollet-le-Duc’s writings and drawings, Martin Bressani is quick to point out that Viollet-le-Duc, like Alberti, conceived buildings as organic frames and living systems made up of sinew and tendons. He argues that ‘the structural skeleton, enhanced by its ornamental foliation, endows the building with the appearance of organic unity’. Yet Bressani conceives of this unity through functional mimesis, not metaphor. As such I will be building upon Bressani’s work by adding a ‘material’ layer – of iron and bone – to Viollet-le-Duc’s conception of the skeleton as ‘vital architecture’. I will do this by looking at contemporary discourses in the fields of engineering and anatomy so as to bring the materials of iron and bone into dialogue with each other, and with the architectural skeleton.

ORGANICISM AND SKELETONS

Caroline Van Eck’s Organicism in Nineteenth-century Architecture: An Inquiry into its Theoretical and Philosophical Background (1994) was the first book to address the nineteenth century’s preoccupation with styles in relation with the erosion of the Vitruvian model and in correlation with the formulation of organicism in architectural theory. She defined organicism as ‘the metaphorical application to architecture of

\[49\] Georges Cuvier determined the conditions of an animal’s existence from the structure and operation of the skeleton. ‘Correlation of parts’ was the term used by Cuvier to figure the ‘wholeness’ of the animal skeleton. Cuvier believed that he could conceive an entire skeleton form a single bone. See Steadman, ‘The Anatomical Analogy – Engineering structure and the animal skeleton’, in The Evolution of Designs, pp. 31–51.

\[50\] See ‘Introduction’ in Bressani, Architecture and the Historical Imagination.

Van Eck relates late nineteenth- and early twentieth-century skeleton construction to the decline in nineteenth-century organicism in architecture, providing examples in the skyscrapers of John Wellborn Root (1850–1891) and Louis Sullivan (1856–1924) (figure iv). In defining organicism as being ‘based on the concern for the close connection between architecture and living nature’, van Eck describes Sullivan’s skeleton constructions as a collapse in the tenants of nineteenth-century organicist theory. The ‘spell’, van Eck writes, is broken with the development of modernism

Van Eck continues: ‘Organicism is based on the conviction, generally held in artistic theory from antiquity to the end of the nineteenth century, that art should imitate nature, not with the aim of producing perfectly faithful copies but with the aim of creating the illusion of life, of conferring the qualities of living nature upon the products of man, in the hope of effectuating the metamorphosis of dead matter into a living being’. See Caroline van Eck, Organicism in Nineteenth-century Architecture: An Inquiry into its Theoretical and Philosophical Background (Amsterdam: Architectura & Natura Press 1994), p. 18.


Van Eck, Organicism in Nineteenth-century Architecture, pp. 20 & 269–78.
and a move from the plurality of ‘styles’ or ‘types’, and the theory of organic functionality in design towards an inventive, individual ideology of which organic architecture would become the antithesis.\textsuperscript{56} Van Eck describes ‘function’ as the starting point in late-nineteenth-century discussions of organic architecture which argue that architecture should imitate not nature’s forms but her methods.\textsuperscript{57} This interpretation of nineteenth-century organicist theory separates ‘form’ and ‘function’ into discreet criteria. However, in the latter third of the nineteenth century the two terms were often considered as interdependent, culminating in the well-known statement by the organicist architect, Frank Lloyd Wright in 1939: ‘Form follows function? Yes, but more important now \textit{Form and Function are One’}.\textsuperscript{58} Van Eck’s position is that the organicism of the nineteenth century, interpreted through the writings of Ruskin, Gottfried Semper and Viollet-le-Duc, came to an end in the twentieth century with the development of modern ‘space’ relations. The architect and historian Thomas Leslie contends that at the end of the nineteenth century, ‘the importance of strong connections [in skeleton construction] had eclipsed the concern for ideal shapes’, which would support Van Eck’s argument for the decline in organicism.\textsuperscript{59}

Although the notion of a neo-Gothic skeleton aligns itself with a nineteenth-century organicist view of architecture, it is my contention that instead of a ‘collapse in ideology’ with regards to formal organicism in the twentieth century, the skeleton concept persisted as form and functionality began to be understood as conceptually synonymous. The fin de siècle experienced a decline in the notion of architectural ‘purposeful unity’ – an Aristotelian ‘final cause’ theory of unity – and a rise in rational

\textsuperscript{56} Van Eck attributes the development of nineteenth-century scientific organicism to progress in the fields of comparative anatomy, distinguishing ‘type’ and ‘condition of existence’ as a method of imposing an order upon the history of architecture. She describes the path of organicism from Vitruvius to the twentieth century, as a ‘remnant’ of the classic tradition, very different from its modern-day conception represented in the work of Frank Lloyd Wright and Albers & Van Huut. See ibid., pp. 25, 28 & 258–61.

\textsuperscript{57} Ibid., p. 259.


teleological morphology, less in keeping with the organic as an active condition of nature, embodied in architecture through its imitation of natural-life processes, but more as a functional, organic, iron skeleton. The materiality of the structure, so far disregarded in nineteenth-century organicist theory, should also be part of the conversation when it comes to defining or certainly discussing its organic nature, and I have yet to find any literature that addresses the material of iron in organicist theory, other than through its material ‘character’ or ‘sympathy’. The materiality of the skeleton is never quite stable, nor is it fluid in its conceptualisation. It is comprised of ambiguous theoretical boundaries that are continuously being negotiated, metaphorically mediated through the language of material discourses from the disciplines of art, architecture, science and engineering. This thesis will contribute to the literature on nineteenth-century organicism, providing a new perspective by highlighting the significance of the skeleton as an organic concept – both static and animated – that allows for the critical analysis of iron architecture’s articulation.

RE-MEMBERING MATERIALS

This study argues that the materiality of the architectural metaphor of the skeleton becomes nowhere more apparent than in iron architecture of nineteenth-century natural history museums, where the skeletons of bone and iron come together. The architecture of the OUMNH and the Galerie de Paléontologie et d’Anatomie comparée show particular kinship with the specimens displayed, and the set up and display of the collections were part of important discussions in nineteenth-century biology and zoology: Darwin and evolutionary theory in the case of the OUMNH, and Cuvier and the insights and practices of comparative anatomy in the case of the Galerie de Paléontologie et d’Anatomie comparée. Both debates had, as I will show, considerable impact on architectural theory, the notion of evolution and the comparative study of architectural elements. For nineteenth-century zoologists like Cuvier, working with and through skeletons was a viable method of thinking about things such as material, form and use, all of which were key to establishing theories of comparative osteology. These museums of natural history were intended as spaces for knowledge production and learning, but also, I would argue, as spaces for a kind of re-membering, not just of the objects and ‘souvenirs’ of the past, but also the re-membering of a social space, a purpose-built space, with its own architectural and material history and memory.
Bone is a material of memory. Our bones show the physical traces of our lived lives: our age, our habits, our diet, our illnesses and our injuries. Isotopic testing of bone can determine the place of our birth, and evidence of blunt or sharp force trauma can even determine how a person met their end. Bone retains this memory centuries after death and burial. The fragmented history of our lives leave indelibly marks on our bones and bringing these fragments together gives an overall view, a holistic view, of the identity of an individual, which the anthropologist or osteoarchaeologist articulates in their biological report. Iron, too, holds a memory within its very material makeup, a ‘metal memory’ which means that iron, and its alloys, can return to their original form when tested to the point of deformation and failure. When metals are returned to the pre-deformed shape, they are called ‘remembered’ metals.

My intention in disarticulating the word ‘remember’ is to place emphases on the ‘gap’ between things, between something forgotten and something re-membered, and to consider the active, conscious, often-physical aspect of bringing parts or ‘members’ together in objects, ornaments and architectures – of articulation.

**METAPHORS AND THE GAPS IN LANGUAGE AND BONES**

The evolution of language is driven by an appropriation of our analogous memories of the experienced material world in order to communicate new knowledge about the physical and metaphysical world. This produces both an inadequacy and richness of language, as words and their meanings change, intersect and cross over. One method of overcoming this inherent inadequacy is to invent new words. The other is to select a metaphor, an easily recognisable term, and to adroitly project and establish its meaning within a new contextual framework. It is my conjecture that the skeleton was such a projected metaphor, and that this projection took place within the rhetoric of the nineteenth century, throughout multiple fields of discourse. Excluding ship and bridge building, my research makes me confident to state that the skeleton was not

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60 Jay Appleton has discussed the historical problems that have arisen in the discourse of landscapes, paying attention to the confusion that can be generated from an author’s implementation of common adjectives as abstract nouns. See Jay Appleton, *The Experience of Landscape* (Chichester: John Wiley & Sons, 1996), pp. 18–21.
used as an architectural term in the centuries preceding the 1800s. However, the rich metaphorical potential of terms like ‘skeleton’ makes it impossible to trace precisely when the meaning of a particular word was transposed, when, in other words, a skeleton made of bone became a skeleton made of iron and, in due course, steel. I do not propose that the material skeletons of bone and iron were considered to be the same thing. On the contrary, the metaphor is a figure of speech, and looking at the skeleton as a metaphor implies that it is both different from and analogous to the unit made of animal bones. Bodily analogies are a legacy from early-modern ways of thinking about the body and the world as connected, and do not always imply a causal relationship. While looking at the nineteenth-century significations of the skeleton, I will keep this early-modern legacy at play.

Mieke Bal pays particular attention to the discrepancy between words, things and images, and looks closely at the prevalent application of analogies as well as the use of metaphors to familiarise resemblances. ‘[M]etaphoric translation’ Bal writes ‘neutralises foreignness’, something strange becomes familiar, something unknown becomes graspable via the use of analogy and metaphor. This was certainly the case in the nineteenth century, as the many new or radical sciences relied on the familiar for the broader acceptance of ideas. However, there is always a ‘lack’ or ‘surplus’ in the image or object in relation to words, argues Bal, which creates a gap between things – between object and referent – just as in the spaces seen across a page of typed text. In this way, the gap that separates two parts is essential for the production of meaning. Like the spaces between words, the gaps are part of language and enable the possibilities of articulation. The same could be said of articulating skeletons from a pile of bones: the interval between parts provides order and brings apparent wholeness to the chaos of disordered bony material. Although metaphors may act to ‘neutralise foreignness’, Bal reminds us that the gap between words and things always persists and it is important to keep it in mind. Anthropologist Elizabeth Hallam takes up the notion of ‘articulation’ in order to analyse how anatomical knowledge is constructed and ‘articulated’.

The term ‘articulation’ can mean the joining together of bones or skeletal segments; the contact between the upper and lower dentition; a connection with ‘joints’ in an man-made structure; a node in a stem at which another part of the plant attaches; the clarity or quality given to language or elements of speech; the distinct separation of musical notes being played in quick succession, or an expression of the immaterial, the conceptual or the abstract.\(^{63}\) In her essay ‘Articulating Bones’, which served as an epilogue to a special issue on bones of the *Journal of Material Culture* (2010), Hallam addresses the notion of *skeletopoeia* (the technical term for the process of assembling animal bones to form a skeleton). Hallam states that ‘different interactions with bones give rise to different affective materialisations of [these] remains’.\(^{64}\) It is in the process of taking the body apart and re-assembling its cleaned and isolated bones into a constructed skeleton form, that connections between the living and dead body are made. It is these interactions and connections that give rise to different meanings, emotions, animations, materialisations and forms of knowledge. In the living body, articulations are the sites where two bones come together at their articular surface to make, in most cases, a movable joint, and the structure of this joint is directly related to the type and degree of necessary or allowable movement. For example, the elbow joint, being both a trochoid joint and a ginglymoid or hinged joint (a trochleoginglymoid joint), allows for two types of movement: flexion-extension (raising the forearm) and pronation-supination (rotating the forearm). The movement of the joint is facilitated and made smooth by the shape of the condyles on the bones articular surface, the cartilage that caps the bone’s articular surface, the synovial fluid that bathes the joint and acts as a shock absorber, and the bundle of transverse and longitudinal ligaments that stabilise the joint. In short, everything works in consort so as to achieve safe, fluid, multidirectional, pain-free movement.

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In the skeletal specimen, the process of uniting bone with bone, of articulation, allows for a movement and manipulation of the bones, and this movement can be in multiple directions with multiple intentionalities. Although intertwined inextricably with the death of the subject, the specimen continues to harbour the potential to transform within its own spatio-temporal continuum via the process of skeletal articulation. Developing Tim Ingold’s theories of making, Hallam’s methodology provides a different way of thinking about making, and about the articulation of elements to produce new entities, both natural and artificial, an aggregation of animal bones articulated together by human hands. In this way, the skeleton becomes both a tool and an object of investigation. Adapting her methodology for her analysis of the architectural skeleton provides me with a framework within which to interrogate the metaphor, not just by bringing fields closer together but also by engaging with the making of the metaphor and by critically dismantling and re-membering the skeleton.

**DYNAMIC MATERIALS**

My interest in bones initially stems from my training as a forensic anthropologist and my early encounters with the dead. These early interactions with bone or, to be more specific ‘human bone’, have made skeletons part of my quotidian landscape. As suggested by Finish architect Juhani Pallasmaa, ‘as we construct our self-made world, we construct projections and metaphors of our own mindscapes. We dwell in the landscape and the landscape dwells in us.’ As a forensic anthropologist, I intuitively feel the kinship between bones and buildings, joints and architectonics, for what else should I see in architecture but a skeleton: bone articulated to bone just as a column joins to a girder. Unlike the doctor, surgeon or anatomist, who conceive of bones as interior, my understanding of bone has always been one of exteriority. And unlike the palaeontologist, archaeologist or the social anthropologist, for me, they are not the

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remains but the beginnings. My expertise as a forensic anthropologist has informed my readings of the primary sources, particularly in the field of bone physiology. This is especially pertinent in the French context, particularly the writings of Viollet-le-Duc and the naturalist Cuvier, and the links made between bones and elements of buildings.

In the course of my research, I have not been able to identify any literature that directly addresses the material and/or metaphorical relationship between iron and bone and its potential application to ‘skeleton architecture’ in the nineteenth century. Even architectural historians who have engaged with nineteenth-century iron architecture and the ‘iron skeleton’ have not questioned the association of structural elements with bones. The influential architectural historian Sigfried Giedeon, for example, in his classic study *Mechanisation Takes Command* (1948) relied heavily on the logic of iron structure and connects it to the human body. In his discussion of the iron skeleton in nineteenth-century architecture, Giedeon related the rationality of iron assembly to the mechanisation and prosthetisation of the body.  

The nineteenth-century understanding of the skeleton as the body’s framework, a framework that remained even after death, still capable of expressing a former living being’s essence was crucial for its potential to become a metaphor for the architectural iron framework. The skeleton evoked a kind of rational simplicity and purity to a building’s design, structure, form, and function. People, be it articulators or architects, assemble both the animal skeleton and the architectural skeleton, and it is at the points of assemblage, of articulation between one member and another, that choices are made; choices that enable an individual representational critique of any skeleton ever assembled. Skeletons are thus a question of representation, and this is why art and architectural history, especially with their recent focus on materials and materiality, provide an ideal critical framework within which to carry out such a project. In addition, the notion of articulation, developed within the anthropology of making, provides a critical tool with which to interrogate specimen and iron architecture alike. It has also informed my critical reading of archival materials and of nineteenth-century architectural and medical discourses.

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But what is it to write about materials today, materials that are ubiquitous but rarely consciously handled such as bone and iron, by looking at the nineteenth century? Contemporary materialist would advocate for the autonomy of matter, insisting that the material speaks, is active and, to quote Jane Bennett ‘vibrant’ and pulsing with life.\(^{68}\) Materials, particularly materials used in the study of anatomy and natural history such as skeletons, are manipulated through their making (hands-on trial and error, fabrication, testing, and redesign) and through their use and re-presentation.\(^{69}\) Materials also have dynamics of their own, but they are often muted by theorisation, generalisation and personal agenda, or mediated by historical or methodological lenses that try to help focus on the material but instead seem to add distance, like many panes of glass, separating the reader further from the material. I hope to avoid such estrangement by bringing the material as close as criticality will allow. I have become increasingly aware of the debt I owe to my early anatomy, anthropology and forensic training, and the richness of my education, which provided me with a deeper understanding of my own embodied existence, and the essential interdependencies of the mental and physical aspects of daily life. When working with ones hands the boundary between self and object becomes the focus of intent and may, redefine the ‘contour of our consciousness’.\(^{70}\) In Pallasmaa’s view, artworks ‘articulate the boundary between the self and the world, both in the experience of the artist and in that of the viewer/listener/occupant’.\(^{71}\) That does not mean to say that I consider the articulated skeleton as artwork, only that bone is an affective material and handling it requires a certain degree of material understanding, and that the act of making skeletons, particularly non-human or paleontological skeletal specimens, often involves creative decision making and rational guesswork. This is particularly the case

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\(^{69}\) For an analysis of the design, making, handing and manipulation of medical models, including the material’s potential for animation and simulation, see Hallam, ‘Bodies, materials, design: hands-on models in anatomy and surgery, 1920 to now’, in *Designing Bodies: Models of Human Anatomy from Wax to Plastics*, ed. by Elizabeth Hallam (London: The Royal College of Surgeons, 2015), pp. 4–42 (p. 6).


in the days prior to the invention of technologies that allowed for internal imaging of the living body such as x-ray imaging (pre-1900) and the nuanced understanding of biomechanics and bone physiology that such imaging provided. In fact an accurate degree of pelvic tilt in the articulated skeleton was not known until the 1970s, as such knowledge was derived from incorrectly articulated skeletons. Also, once made, skeletons are often articulated into creative poses in an attempt to simulate the stance of living animals. This turns skeletons into entities that can stand in for the living human or animal, and forms the basis of the emotional potential they exert in natural history museums.

For my training in forensic anthropology, the body was broken down for me into 206 component parts that I would identify and put together, a task somewhat easier said than done. Oftentimes bones were fragmented, or there were multiple co-mingled bodies, or a juvenile skeleton was involved, whose bones had barely begun to ossify. In fact, materials such as stone, shell, wood and plastic have often been misidentified as osseous material, and vice versa. If a bone had unusual morphology or was suspect in any way, I would check that its origins were indeed human bone by tapping the bone on the table and listening to the timber of the sound; a muted dull sound or hyperresonance, similar to the sound of ceramic being knocked against a hard surface, indicated human bone. It was a fragmented, multisensory process.

The only way to tackle the human skeleton, to understand the whole so as to achieve cohesive unity and a potential identification of the person, is to break it down into parts and to build it back up again. Unlike a puzzle where you start by looking for the edges followed by blocks of colour, with the skeleton you begin by conceptually segmenting the body into parts. Spatial and temporal cuts are made, and by this I mean you start first with the broad brush strokes, those bones that are easily identifiable such as the appendages – the large limb bones (left and right) of the innominate (pelvis), femur, tibia, fibular, scapular, humerus, radius and ulnar. Then the parts of the axial skeleton are identified – the bone of the head (the cranial bones, the mandible) then the vertebra, sacrum and ribs, followed by all the parts that make up the hands and feet such as the carpals, metacarpals and phalanges, the tarsals and metatarsals. I would then lay out every part on the anatomy table, like setting the table to some kind of macabre feast – instead of a plate it is a pelvis, instead of a cup it is a cranium. The etymological roots
of such words come to mind, as the word skull is derived from the Anglo-Saxon word for cup, pelvis from the Latin for basin (or the Greek for bowl), and patella from dish or pan. It is a meticulous process, a patient process of selecting, touching, lifting, scrutinising, feeling, rotating, documenting and selecting again. The touching of the bone is both mechanical, like the touch used when handling and putting together components for a piece of flat pack furniture, and an intimate, like the light stroke of the soft pads of the fingers required to read braille.

Laid out in the ‘anatomical position’ on the table, the human body appears very flat, dry – dead. I would complete a biological profile form that included an illustration of a skeleton and I would blank out the missing bones (figure v). It is only when you start to articulate parts together that a form emerges. However, the bones are never truly reunited as they once were in the living body. They stay divided, each bony element scrutinised for every particular detail – measured and weighed, photographed; noting the ridges made by muscle attachment and insertion, the shape, texture (granular, nodular, smooth, pitted, striated, billowing), macroporosity, colour, and site of degeneration. Every edge, lip, ridge, notch, protuberance, spicule, fissure, groove, sulcus, suture, symphysis, furrow, fossa, foramen, and fracture were closely examined and recorded so as to aid in identification of an individual by determining the skeleton’s sex, age, stature, ethnic origins, and pathologies.

A great deal of information can be obtained from bone, a piece of hydroxyapatite – a mineral substrate primarily comprised of calcium carbonate – that makes up 15% of our body mass but which informs our lives, and how we choose to live. It will become the last physical traces of the lives that we have led if you know how to read them, or, more precisely, if you know how to articulate them. And if bones are stories waiting to be read, then the forensic anthropologist is the articulator who pulls all the stories together to tell something about the person’s physical life. Piece by piece the body is divided into areas, dissected out, segmented, only to be brought back together in a more ‘complete’ way, a more ‘readable’ way, and during this process a mutual transformation occurs; on the part of the skeleton but also on the part of the articulator as they begin to touch, manipulate, scrutinize and manoeuvre pieces in their own scrabble game, to unravel and then to articulate something. It is impossible not to reflect on the life and death of the person whose very bones are held in my hands. This
person may not have been physically articulated, with wires and hooks penetrating their bones, or mounted on cast iron rods, but they were conceived through a process of assembly – of reassembly and disassembly – with each piece placed in a plastic zip bag, carefully labelled and placed in a box for storage (in cold cases) or for repatriation and burial.

This goes someway in highlighting the very different kinds of articulation that can occur when interacting with different kinds of skeletons. I also consider the process of uniting, or articulating, bones to make skeletons (skeletopoeia) as creative ‘making’, not too far removed from the perspective of the artist or architect when deciding upon their method and materials. ‘All art forms’, Pallasmaa writes, ‘are specific modes of thinking. They represent ways of sensory and embodied thought characteristic to a particular artist medium’\textsuperscript{72}. Yet what is it to think with bones, and extend that kind of thinking into its metaphorical equivalent in architecture, into iron? This kind of material questioning has yet to be written in architectural or material history, although I have looked to art history and anthropology as guides in formulating my approach to the conceptual and material process of making skeletons. In her book \textit{Materiality}, art historian Petra Lange-Berndt proposes the strategy of material complicity by following the material outside of the artist’s ‘medium’, in which the material is ‘only used to \textit{think about} or to \textit{think with}’, into everyday political and social situations.\textsuperscript{73} Lange-Berndt draws attention to the distinction between ‘matter’, rooted in the philosophical tradition in which (gendered) matter strives for the ideal form, and the relatively recent, more concrete term ‘material’.\textsuperscript{74} The material itself might be caught up in the rhetoric of production and commodity, use-value and ‘truth’, particularly in the nineteenth century following industrialisation and the critiques and artistic responses to the materials of mass production. Recognising materials as ‘sticky’ and acknowledging their agency disrupts the anthropocentric and idealist tradition of the humanities, which precluded material-centred studies. Yet, as Lange-Berndt points out, materials were practiced with before they were ever written about.\textsuperscript{75} By intuitively following the material instead of the artist or architect, Lange-Berndt presents a productive discourse

\begin{footnotes}
\item[72] Ibid., p. 19.
\item[74] Ibid., p. 14.
\item[75] Ibid., p. 16.
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that delves into the (after)life of the material. Bone may not have the material ‘stickiness’ of a more malleable substance like wax, as proffered by Georges Didi-Huberman, but the cultural and emotional connotations of human and animal bone are no less adhesive.  

Establishing the skeleton as a material concept – understanding it in both its materiality and artificiality – allows for a new consideration of the numerous ways in which the skeleton was mobilised as a metaphor throughout the nineteenth century. By interrogating the skeleton as material and as a concept I will unravel its various meanings and invocations that lead to its prolific use in nineteenth-century art, architectural and natural-history discourse, and its continued application today.

In writing this thesis I have considered sources not typically studied in architectural history. I have looked at both historic and contemporary studies of the physiology of bones, and I have approached these subjects with the expertise of a forensic anthropologist, as well as analysing them as a discourse. My sensibility for bones and skeletons has enabled me to see the connection between the museum displays and the museum architecture, aspects normally studied in the disparate disciplinary fields of museum studies and architectural history.

THE CHAPTERS

This thesis is divided into three chapters, and begins with an overview of the history of skeleton metaphors – both the bones and the connecting, articulating parts – in European architectural history, and the origins of organic architecture. As Van Eck has pointed out, the term ‘organic’ acquired significance at the close of the eighteenth century, ‘namely of referring to living nature as opposed to dead matter’.  

In the first volume of The Stones of Venice, Ruskin takes his organic and inorganic material perspective from antiquity, disregarding nineteenth-century secular debates and concerns regarding the definition of these categories. He describes Venice along the

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77 Van Eck, Organicism in Nineteenth-century Architecture, p. 47.
tradition of organic rhetoric, as having towers that rise ‘as a branchless forest’. It is true that his examples were typically his favourite structures to be found in Venice and that his tastes favoured the medieval Gothic style, but his arguments were structured so as to be applicable to all forms and styles, for it is the principles not the styles of architectures which were to be followed.

Historians of Ruskin, such as Elizabeth K. Helsinger and Robert Hewison, have produced rich biographies charting the life of this complex, affected, and effecting character, analysing his approach to art and art criticism and the romantic, aesthetic, poetic, literary, religious, and secular influences that surrounded him. As a boy, the hills and mountains of the Alps captivated Ruskin. He wrote numerous poems (which were later published in the collected work, Poems) in which he writes of ‘skeletons’. The skeleton is more than a metaphor in Ruskin’s poems; it is the lines which, although ghostly, are very much present and which form the skeleton of the mountain, and he develops this skeleton concept in his writing on mountains and glaciers. The skeleton can be seen as an essential line, a line abstracted from both the surface and the interior of the mountain, and which signifies the mountain’s form, age and material. The first chapter explores the writings of Ruskin and the influence of the ‘Gothic imagination’ upon a young and impressionable mind. The secular trends for medieval romanticism, beauty and truth, the yearning for the lost, a desire for the wilds of nature, all fed the Gothic aesthetic, which found expression in art as well as architecture. The skeleton would become a leading concept in the search for the neo-Gothic, the new moral style for the nation, whose main proponent would be none other than Ruskin himself. That the skeleton haunted his writings is evident throughout his life, particularly during the middle of the nineteenth century, when he wrote mostly on art and Gothic architecture. The organic nature of the Gothic style lent itself well to metaphor, the grammar with which Ruskin would articulate his ideas on building, craftsmanship and ornament.

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79 For the incisive books regarding the development of Ruskin’s vision of, and sympathy with nature, see Robert Hewison, John Ruskin: The Argument of the Eye (London: Thames and Hudson, 1976), and Elizabeth K. Helsinger, Ruskin and the Art of the Beholder (Cambridge: Harvard University Press, 1982).
The second chapter critically engages with organicist theory and challenges literature that disregards the organic materiality of nineteenth-century iron architecture. It follows Ruskin’s writings through the mid-nineteenth century, culminating in the incarnation of his ideas in the building of the OUMNH, built between 1855–1860. The museum, already controversial at the time of its opening, demonstrates a hybrid of architectural strategies and incorporates both conservative and progressive precepts on natural history. It was an attempt to hold together two apparently incompatible opposites: iron – at the time mostly associated with Crystal Palace, synonymous with technological progress and modern visibility, and the Christian Gothic. This dichotomy of progressiveness and traditionalism was reflected in the attitudes of the personalities overseeing the project, one of who was Ruskin. Taking up the notion of ‘articulation’ as developed by Hallam, as a critical instrument, I analyse the making of the iron skeleton (both metaphorically and literally) and raise the question of what function the concept of the skeleton served in representing and mimicking life, and in attempts to simulate the organic. I argue that the skeleton acts as a unifying metaphor guiding the construction of the museum of Natural History, as the individual architectural elements were blended into a unified whole able to suggest a harmony of nature and technology. Although the association of iron and bone may at first appear strange and rather farfetched, it becomes easily detectable in the museum of natural history. This is demonstrated through the analysis of drawings and the writings of the museum’s various architects and of the comments on the building’s general appearance in which the iron was likened to the exhibited bones. These visual similarities have not been comprehensively discussed in the literature on the museum, yet it is these very similarities that firmly established the material metaphor of iron and bone in architectural discourse. By thinking of articulation as a process in which bones are turned into the conceptual entity of the skeleton, and of iron as a living material that blurs the boundaries between the organic and inorganic, I present another dimension of organicism – one built on and structured by the skeleton. Although many nineteenth-century architectural historians analytically engage with metaphors of nature in their quest for structures that comply with the criteria for ‘organic architecture’, the skeleton metaphor is rarely engaged with critically, if at all. External forms – the visible, growing parts of nature – are often considered as the vital, living and truly organic parts in their form and function. In contrast, I propose that the OUMNH moves beyond the external biomimetics. In order to understand its
organicism we must tackle its (endo)skeleton’s internal structures in their materiality and representational forms.

The third chapter begins with an interrogation of the concept of the skeleton within the writings of the preeminent zoologist Georges Cuvier. Cuvier developed a new discipline of comparative anatomy based on the evidence of skeletons. His approach established identity (of an animal) through difference as he constructed and used animal skeletons in order to compare them. He explained the variations between the skeletons as the result of functional design. If, for example, a less competitive food source was to be found in the branches of tall trees, a longer neck would be an asset, enabling the animal to feed where others were unable. Hence an animal that fed on tall-growing trees would be provided with long legs and necks to facilitate the function.

As the nineteenth-century engineer William Vose Pickett contended, when analogising the beauty of architecture with the works of nature, ‘all are adapted to the wants and necessities of their condition; and in that condition, and for the fulfilment of the uses for which the Great Author of nature designed them, are, from that very fitness and utility, beautiful’ 80 It is an organicist argument of functionality generating ideal natural forms, which would greatly influence architectural theorists in their quest to uncover the origins of style and ornament, in fact the very origins of architecture itself. We can see that the concept of the skeleton, as a tool for unlocking the secrets in functional variation through the expression of certain physical traits (or phenotypes), became a model for the nineteenth-century architect. Gottfried Semper and Viollet-le-Duc were amongst the more famous architects to embrace Cuvier’s comparative methods.

Throughout the chapter, I analyse the concept of the skeleton and the notion of ‘ossature’ (bone structure) in French discourses on architecture and engineering, particularly within the drawings and writings of Viollet-le-Duc. In the last part of the chapter I discuss the architecture of the Galerie de Paléontologie et d’Anatomie comparée in Paris. This museum houses Cuvier’s extensive collection of skeletons for the study of comparative anatomy. The museum’s architect, Ferdinand Dutert, was

responsible for reframing this collection for the 1900 Exposition Universelle and for demonstrating to the world the pioneering role of French scientists in comparative anatomy. I will show that architecture and mounted skeletons closely interact in this museum. The iron wires and supports weave though the natural foramina of the bones, producing a complex interplay between the materiality of the specimen and the articulator’s aim of utilising technology to demonstrate and educate. I argue that this effective interaction of the iron supports with the organic structures in the gallery is especially interesting in light of who designed them – the museum’s architect, Dutert himself. He literally reframed late nineteenth-century osteological knowledge within this museum space. Thus far, the secondary literature on the museum has not considered the architecture and the nature-history display jointly. A thesis by Cédric Crémière, dedicated to the architecture of the Musée national d’histoire naturelle in Paris, discusses the design of the Galerie de Paléontologie et d’Anatomie comparée as an new exhibition space for Cuvier’s collection. It does not address the bones or the skeletons themselves, nor does it provide any analysis of the structural relationship between the skeleton and the iron architecture. In turn, my thesis considers the mutual relationship between both skeleton structures. It also takes into account important related fields notably engineering and biomechanics, and the seminal work conducted at the time in both disciplines on the materials of bone and iron. There was a remarkable exchange between the two disciplinary fields, as engineers and architects received and utilised the work of surgeons and anatomists such as Julius Wolff and his investigation into the pressure resistance of bones. The properties of iron, as permanent and unyielding, were compared with the superficial properties of bone, bone being considered an ideal material in terms of its desirable ratio of lightness against strength.

The skeletons of bone and the skeletons of iron exist together in certain museums of natural history that were built in the nineteenth century. At some point following the common utilisation of iron in secular European architecture (c. 1800) the material distinction between bone and iron became blurred, or even collapsed. The architectural metaphor of the skeleton became, so to speak, naturalised.

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By focusing on the skeleton I hope to open a novel perspective on architectural theory and the architecture of the natural history museum in the nineteenth century. In ‘Organicism Revisited’, van Eck suggests that ‘[t]o understand the persistence of the organic analogy, we need to move beyond the internal perspective of architectural theory or aesthetics I adhered to in Organicism, to develop instead an external, anthropological perspective, which will allow us a more nuanced understanding of the senses in which architecture may be said to live’.82 Taking up this suggestion, this thesis takes a multidisciplinary approach to the analysis of skeletons as organic entities, interrogating their material, conceptual and metaphorical status and application within the discourses of art, architecture, anthropology, anatomy, engineering, geology and zoology.

This thesis proposes that the skeleton was a powerful metaphor and important concept in the nineteenth century, a concept that has to be considered as both an analytical tool and in its materiality. The skeleton was, as I will show, adapted, moulded and transformed by a number of the newly emerging disciplines, and established itself firmly within architectural discourse. This thesis argues that two important European natural history museums of the nineteenth century – the OUMNH and the Galerie de Paléontologie et d’Anatomie comparée in Paris – had an important role to play in the establishment of the notion of the architectural skeleton and serve at the same time to remind us of the materiality of this metaphor.

82 Van Eck, ‘Organicism Revisited: The Desire for the Animation of Inanimate Matter in the 19th Century’, p. 52.
CHAPTER ONE

BONES AND THE TRANSFORMATIVE POTENTIAL OF NATURE AND ARCHITECTURE

TRACING THE BONES OF ARCHITECTURE: BODY AND BUILDING IN ANTIQUITY

Bones’ material association to the skeleton is concrete in that the skeleton is a bodily system, typically made of the mineralised tissue (calcium phosphate and hydroxyapatite) forming hematopoietic bone that supports the body, providing its structure and protecting internal organs. The skeleton is then subdivided into the endoskeleton (found in many vertebrates such as mammals) and the exoskeleton (found in many invertebrates such as arthropods). However, while the word skeleton was introduced into the English language in the sixteenth century and soon became a colloquial term, the use of the latter terms was not recorded until the mid-nineteenth century and remained distinctly within the fields of biology. Bone was often understood in terms of metals, many bones being named from everyday objects primarily made of metal, for example, the xiphoid (sword), fibular (needle) or malleus (hammer). Iron, on the other hand, is a metaphor of the everyday. Likely dating back to the history of language itself, iron has been utilised as a visual metaphor to evoke the hard, the strong, the hot and the cold, the metallic, the destructive, and the mighty. The word as we understand it today takes its root in the Old English term isærn, indicting the metal of iron, or an iron weapon; however, iron as a material was present in most cultures in history and has many etymological roots.

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83 The first recorded mention of the English term ‘skelet’ was in the 1560s and ‘skeleton’ in the 1570s. It was taken from the Modern Latin skeleton, meaning ‘bones, bony framework of the body’, which in turn was derived from the Greek. See Douglas Harper, ‘Skeleton, n.’, Online Etymology Dictionary, 2001 <http://www.etymonline.com/index.php?allowed_in_frame=0&search=skeleton> [accessed 5 June 2017]
84 ‘Iron’, in ibid. <http://www.etymonline.com/index.php?allowed_in_frame=0 &search=iron> [accessed 10 June 2017]. Iron was mentioned in the book of Genesis and was also believed to have been forged by the early Persian and Chinese civilisations. See William Fairbairn, ‘On the Application of Cast-Iron to the...
The trope of the skeleton has recently become a productive field of study within art history, with scholars scrutinising images of skeletons made in the construction and for the dispersal of anatomical knowledge. Illustrated anatomical treatises have been in circulation for centuries, most famously *De humani corporis fabrica libri septem* (1543) by Andreas Vesalius (1514–1564) whose images of skeletons served for anatomical and artistic instruction for more than two centuries. The anatomist based in Padua considered bones as structural, transformational and malleable, full of a subtle yet highly significant potential for animation. He utilised the human skeleton as a teaching aid whilst lecturing at the University of Bologna in 1540, drawing attention to the discrepancies between the Greek physician and philosopher Galen’s (A.D. 129/30–210) descriptions of the human skeleton, which was based on non-human anatomy, and his own constructs. Vesalius prepared and assembled the skeletons himself, describing the intensive preparation process in the *Fabrica*. Once the bones were cleaned and collected, they were brought together – articulated – with iron rods and hooks, and presented in various erect positions and life-like stances. A javelin or scythe was used to support the forearm of the articulated skeleton (figure 1.1). In the *Fabrica*, Vesalius and the draftsmen working for him placed the animated skeletons within ruinous landscapes, the crumbling architecture acting as a visual metaphor for the dead ruined body, the remains of both being their skeletons (although the ruins were not yet named as such), and acting as evidence of their once vital existence.

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87 Prior to the release of the *Fabrica*, Vesalius wrote the *Tabulae*, which was issued in 1538. It had six sheets (19 x 13.5 inches) of woodcuts, the first three of which are depictions of skeletons and are thought to have been made by Vesalius himself. Of the skeletons from the *Fabrica*, Tabulae IV, V and VI were made by Jan van Calcar (c. 1499–1546). See most recently on Vesalius and his anatomical woodcuts Sachiko Kusukawa, *Picturing the Book of Nature: Image, Text, and Argument in Sixteenth-Century Human Anatomy and Medical Botany* (Chicago and London: The University of Chicago Press, 2012), in particular part 3. However, the skeletons were incorrectly articulated, which created errors in anatomical knowledge that persisted well into the twentieth century. See Charles Singer and C. Rabin, *A Prelude to Modern Science: Being a Discussion of the History, Sources and Circumstances of the 'Tabulae Manufacture of Ordnance‘, in The Useful Metals and their Alloys, with their Applications to the Industrial Arts, ed. by John Scoffern (London: Houlston and Wright, 1857), 385–397 (p. 385).
The reconstituted skeleton is also an idealised form, of many parts from different people standing in for the whole body. It was not the singular body that was considered important for anatomical knowledge but the assemblage and transformation of parts from fragmented bones into an upright, growing and moveable structure. Within the discourse of early-modern anatomy, a need for the potentiality of life, of imaginary re- fleshing, of transformation becomes paramount, and this need is reflected in the articulated moving skeleton. And unlike the *memento mori* tradition, in which the bones depicted are reflections of the bones beneath our own skin and flesh, signifiers of the mortality of the body, symbolic of the death we must carry, the reconstituted skeleton is a representation of the living animal. However, one must always keep in mind that a skeleton of bone does not ever really exist in and of itself. Indeed, it is as much a conceptual model as a physical entity, more theoretical and imaginary than real. The established textbook image of the skeleton is derived from what we are encouraged to see when viewing the specimen in the museum – upright, bleached white bones – whilst what is meaningful, often artistic craftsmanship – articulating wires, struts and supports – is routinely ignored and rejected from sight. A true skeleton is really part of a biological system and can never be physically presented, only imaged and represented (via medical technologies such as X-ray imaging) or imagined. The skeleton as a physiological ‘system’ is always carried within you, beneath the flesh of the body, tangible yet invisible. It only exists within the living body, as part of the body’s framework or an endogenous image, and even then the skeletal system is entirely dependent upon its connection with the body’s soft tissues. Skeletons, as entities existing independent of the human body, are a fiction; the successful illusion created by the articulator, an illusion further enhanced when bones are presented as evidentiary fact. They are created and brought into being by the humans that interact with them, as well as the historical collective imagination that continuously replenishes the image of bones brought together as they would be when inside the living creature. Yet, even inside the body, the living skeleton is not the skeleton that would be

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recognised as adhering to a skeleton concept. Its invisibility means we’re alive, its visibility means death.

While the animated skeleton makes a frequent appearance in early-modern anatomical atlases, descriptions of the material qualities of bone are rather sparse. In such discourses, bones were considered as a kind of scaffolding for the discrete hard parts of the animal’s anatomy, and as an essential support for the form and fabric of the body to attach to; for muscle-tendon insertions and for the flexion and extension of ligaments. When the materiality of bone was considered, if at all, it was within the context of the dead body. Bones were the end point of the anatomical dissection, what remained of the body’s eventual ruin, although they were typically the first body parts to be described and illustrated in the anatomist’s treatise. While the muscles were soft and wet, bone was described as hard, cold, dry and earthy. The term ‘skeleton’ itself was derived from the Greek σκελετός, skeletos, meaning something hard and ‘dried up’. Due to its pale, milky white colour in the fresh cadaver, Galen reasoned that

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89 There is as of yet no comprehensive cultural history of bones and bone. Important anthropological essays are however united in the ‘Bones Collective Publication (Special Issue)’ of the Journal of Material Culture, 15 (2010), edited by Cara Krmpotich, Joost Fontein and John Harries. Particularly relevant here is Elizabeth Hallam’s epilogue, ‘Articulating Bones’, a brief sociological and anthropological account of the history of bones via its effective and imaginative materialisations – as relics, familial remains and repatriated body parts – as well as its ability to mutually articulate knowledge about both the living and the dead body. See Hallam, ‘Articulating Bones: An Epilogue’. In his study of the philosophical secularisation and depollution of the cadaver in ancient Greece, Heinrich von Staden notes that in the third century B.C, human bone (osteon anthropou) was considered to be ‘unclean’ and a pollutant. If a bone was discovered in an inhabited area, the community was required to undergo purification. See Heinrich von Staden, ‘The Discovery of the Body: Human Dissection and Its Cultural Contexts in Ancient Greece’, The Yale Journal of Biology and Medicine, 65 (1992), 223–41 (p. 227). For the symbolic dimension of bones and their significance as a material in art since 1945, see Sebastian Hackenschmidt, Knochen. Ein Material der zeitgenössischen Kunst (München: Silke Schreiber, 2014).

90 See Douglas Harper, ‘Skeleton’, Online Etymology Dictionary, 2001 [http://www.etymonline.com/index.php?allowed_in_frame=0&search=skeleton] [accessed 5 June 2017]. Another influential authority in human anatomy was the eleventh-century Iranian physician Avicenna (980–1039). Building upon Galen’s theory of four humours, Avicenna contended that bone facilitated the movement of the body, describing the biomechanics of movement in locations such as the spine and knee joint. He also described bone as having an outer ‘cortical’ bone and an inner marrow cavity, and that marrow counteracts the dryness of bone. See Pedzisai Mazengenyia and Rashid Bhikha, ‘Anatomical concepts of the Musculoskeletal and Peripheral Nervous System as viewed by Avicenna in the Canon of Medicine’, Tibb
bone was composed of solidified fat and semen, a myth that persisted well into the seventeenth century.91

In a Galenic Anatomia from the mid-fifteenth century, today part of the Wellcome Library’s collection, eight coloured anatomical drawings are presented, two of which are designated as the ventral and dorsal view of the human skeleton (figure 1.2). Extending the entire length of each page, and in the supine position (still the standard body layout in contemporary anatomical texts, except for the bent elbows and slightly splayed legs) the bodies are recognisably humanoid although by no means anatomically correct. The dorsal view of the cranium shows denticulated bone made by sagittal and lambdoid cranial suture lines, where the skull plates articulate. In the ventral-view drawing, the ‘face’ is extremely disarming. In place of eye sockets, two red circles burn brightly in a strangely formed skull. The maxilla and mandible bones lack dentition, which gives the skull a comical expression resembling a feline grin. A dark smudge extends at a slight diagonal from head to pelvic region. Pale chalky masses float within, and contrast sharply with the black cavity. These luminous-white bones of the axial skeleton are (inaccurately) mutually related by the inclusion of what appears to be costal cartilage, whilst the appendicular bones are rendered as discrete parts and not as part of a constituted skeletal system.92 They float like individual white

91 For an evaluation of Galen’s life and achievements, see Robert J. Hankinson, ed., The Cambridge Companion to Galen (Cambridge: Cambridge University Press, 2008). In particular see Julius Rocca, ‘Anatomy’, in ibid., pp. 242–62 [doi: doi.org/10.1017/CCOL9780521819541.009]. The notion that bone was composed of semen was still in play as late as 1620, as demonstrated through the lecture notes of John Moir: ‘Bone is ... spermatic, solid, dry, generated out of semen, fat and earth by the power of heat and the innate spirit, so that it is basic to the parts of the body’. The lectures, given in Marischal College, Aberdeen, are a hybrid of Galenic anatomy and Aristotelian philosophy, with continuous references to vital ‘animal’ spirits, reminiscent of Cartesian philosophy. Roger Kenneth French, Anatomical Education in a Scottish University, 1620 – an Annotated Translation of the Lecture Notes of John Moir, Texts in the History of Medicine, 1 (Aberdeen: Equipress, 1975), p. 17.

92 The term ‘system’ is from the Late Latin systema, meaning ‘an arrangement’ and from Greek sistema, meaning an ‘organised whole, a whole compounded of parts’. Its meaning as applied to the animal body as ‘organized whole, sum of the vital processes in an organism’, is thought to have been first recorded in the 1680s. See Douglas Harper, ‘System’, Online Etymology Dictionary (2001) <http://www.etymonline.com/index.php?allowed_in_frame=0&search=system> [accessed 24 June 2017]. Denis C. Phillips examines the increased interest in ‘system theory’ in the early-twentieth century, a philosophical model in which the whole functions
masses within the black Epicurean void. The organic material of articulation, the cartilage, is noticeably absent in the limbs. Necessary to the functioning of the living body, cartilage occupied an ambiguous space in the body, in-between the ‘nature of bones’ and the ‘nature of flesh’. Like bone, it was considered to be cold, hard, dry, and comprised of the ‘coarse part of semen’, but it was also flexible – a necessary property in bone articulation. Galen understood the importance of tendons in moving bone, not quite in a biomechanical conception of levers and pulleys, but as ‘filaments’ [uincula longa] and ‘like a cobweb to the bones beyond the joints’.

In both drawings the bones are strangely shaped, appearing more ape-like than human in their size and form, predominantly in the thighbones. The longest of the long bones in the human body, the femur, is heavy and robust; however, these particular femurs appear shrunken and are incorrectly articulated with the acetabulum of the pelvis. A reason for this unusual bone morphology may be that the bones did not belong to a human. Galen often dissected animals such as pigs and apes. Fresh human cadavers were more difficult to come by and involved circumventing cultural and religious taboos regarding the cutting open of the body, the polluting effect of death and the sanctity of the undesecrated purified corpse. Typical of a Galenic skeleton, the interdependently of its parts, which inspired research in the fields of education, political science, psychology and sociology. See Denis C. Phillips, ‘Organicism in the Late Nineteenth and Early Twentieth Centuries’, *Journal of the History of Ideas*, 31 (1970), 413–32 (p. 427).

93 French, *Anatomical Education in a Scottish University, 1620 – an Annotated Translation of the Lecture Notes of John Moir*, p. 17.


95 Galen, ‘How to study the Skeleton of Men and Apes’ in *On Anatomical Procedures (De Anatomicis Administrationibus)*, p. 4 (Book I, Chapter 2). Also see Heinrich von Staden, ‘The Discovery of the Body: Human Dissection and Its Cultural Contexts in Ancient Greece’, p. 225. Katherine Park challenges the supposed cultural taboo against human dissection in the sixteenth century (taboos supposedly extending back to ancient civilization). Park argues that there was no blanket prohibition of dissection by the Roman Church, an argument supported by the testimonials of sixteenth-century medical men and natural philosophers, who openly performed human dissection, embalming and evisceration. See Katherine Park, ‘Holy Autopsies: Saintly Bodies and Medical Expertise, 1300–1600’, in *The Body in Early Modern Italy*, ed. by Julia L. Hairston and Walter Stephens (Baltimore: John Hopkins University Press, 2010), pp. 61–73; Park, ‘The Criminal
number of bones in the body’s cavity is considerably reduced, indicating that some bones were thought to be more essential to the human form than others, which have become integrated into a new whole. Differentiated by a single faded brown line, the bones of the radius and ulna, as well as the tibia and fibular, have been consolidated into a single mass of bone. The primacy of the vertebral column is indicated through the careful rendering of each segment. Painted an off-white and iodine-brown colour, the backbone is drawn poker straight, each vertebral body stacked upon the next, with a central line or chord running through the length. The backbone’s columnar architecture provides articulation and support for the head, as well as an anchor for the shoulders, ribs and hips. Its retrothoracic and retroabdominal position provides the central axis on which the bilateral symmetry of the body depends. In this state of hyperverticality, the upright attitude of the body is emphasised, reinforcing the difference between the erect stature of Homo sapiens and the curved crouching form of the ape.

The drawings emphasise how tightly the form of the body follows the form of the bones. There is a strange tension between the external form of the body, its morphology, and the internal bones. Perhaps this is because the black space is the shadow of an imagined living body – the skin, flesh and sinews – while the bones are evidence of a dead, dissected, disarticulated animal. In the living body, the bones are felt and not seen. We know they are hard because we can feel the solid strength of our own bones, occupying the deepest hidden spaces of the body. The art and architectural historian Emanuele Lugli has recently argued that images of bones provide a sense of their ambiguous state, as ‘structural yet invisible, reachable yet enfolded’. Indeed, the drawings present the body as an architecture of external form, internal space and essential unyielding structure, with the bones occupying the last architectural position as the whitest, hardest, deepest, the most essential parts. The bones give form and proportion to the body and are integral to the configuration of its parts.

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Galen associated bones with building construction and drew attention to the significance of bones in shaping the body, analogising bones and architectural elements. He suggested that ‘as poles [are] to tents and walls to houses, so are bones to living creatures, for other features naturally take form from them and change with them’.

Bones were seen as giving size and shape to the body. In stating as much, Galen was explicit in communicating the essential nature of bones, with each part contributing to the whole form. The medieval architectural historian Paul Frankl argued that bodily metaphors in architecture allow us to think about structural members as ‘bones’, and wall surfaces that enclose the interior space as ‘muscles’ and ‘skin’.

I agree with this assessment, and yet it is important to note that ‘skeleton’ was not an established concept within Renaissance architectural theory. Its conceptual origins are grounded in the analogies with the animal body in its two-dimensional representational and three-dimensional physical and tactile state. The body became an analogue for architecture and vice versa, with its various parts and members, and its sculptural and spatial articulations. However, this does not mean that architectures were designed to look like living bodies. Indeed, as the architectural historian Joseph

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97 Galen, ‘How to study the Skeletons of Men and Apes’, in On Anatomical Procedures (De Anatomicis Administrationibus), p. 3 (Book I, Chapter 2)

98 This idea was derived from Aristotelian philosophy, implying that bones are necessary in the same way that matter and form is to the essence of the natural body. Everything comes out of the ‘substratum’ and the ‘Form’. See Aristotle, Metaphysics, trans. by Hippocrates G. Apostle (Bloomington: Indiana University Press, 1966), Book vii, sec. 1029a: ‘by matter, I mean for instance bronze; by form, the figure: the composite of the two is the statue’. Also see Aristotle, On the Parts of Animals, vol 1–IV (De partibus animanimalium), trans. by James G. Lennox, Clarendon Aristotle Series, ed. by J. L. Ackrill and Lindsay Judson (Oxford: Oxford University Press, 2001), Book 1, sec. 640a-b 18-27 (pp. 5–6): Air and water are matter for bodies; that is, it is from such things that the ancients constitute the nature of bodies. But if human begins, animals, and their parts exist by nature, one should speak about flesh, bone, blood, and all the uniform parts [...] one should say in virtue of what each of them is such as it is, and in respect of what sort of potential. For it is not enough to say from what things they are constituted, e.g. from fire or earth. It is just as if we were speaking about a bed or any other such thing; we would at least attempt to define the matter of the composite; for a bed is a ‘this-in-that’ or ‘this-such’, so that we would have to mention its configuration as well, and what its visible character is. For the nature in respect of shape is more important than the material nature’.

Rykwert has argued, the idea that the organic ‘body image’ was a theory in classical architecture in misleading, as ‘the body image in antiquity and in “humanist” theory was used as an abstract model – mathematical and functional – for imitation in building, with no plastic, formal implications’.\(^{100}\) The relationship was based on their mutual stability (when balanced) and their supportive and protective function rather than appearance.

Associations between architecture and the human body were not only made in ancient medical texts but also in architectural tracts. They are frequent in the theoretical writings of Vitruvius, which were written in ten volumes in the first decade of the Pax Augusta, c. 30–20, and remain the only architectural treatise to have been passed down from antiquity.\(^{101}\) Continental European architectural history has been modelled on Vitruvius’s *De architectura libri decem*.\(^ {102}\) By imagining buildings through anthropomorphic metaphors, Vitruvius described buildings as bodies and body parts to indicate form, and as a rationale for numbers, measurements and proportions. As such, these metaphors were expressed through the holistic human form as well as through abstracted numerical and geometrical figures.\(^ {103}\) Vitruvius embraced the beauty of balanced proportion that could be found in the human body, and posited that symmetry and ratio were vital for sacred architecture.\(^ {104}\) He described the body as a

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\(^{104}\) Vitruvius, ‘Temples’, in *The Ten Books on Architecture*, Book III, Chapter 1: First Principles of Symmetry, sec. 1, p. 47: ‘The composition of a temple is based on symmetry, whose principles architects should take the greatest care to master. Symmetry derives from proportion, which is called *analogia* [ἀναλογία] in Greek.
being comprised of proportional and commensurate parts, with each member harmoniously relating to the other and contributing to the shape of the whole. Yet the idea of a body of proportional parts brought forth tension and discontent. Firstly, because there is no true symmetry in the human body; secondly, the proportions of the human body vary, both in the singular body and between bodies; and thirdly, because the notion of a body comprised of parts, and the idea of a body that is circumscribed as whole, are diametrically opposed. These conundrums have resulted in numerous and varied interpretations of Vitruvius. However this thesis is concerned solely with the legacy of the skeleton metaphor, and Vitruvius’s potential instigation of its application to classical architectural theory, to which I will now turn.

Vitruvius presented the link between the human body and the architectural body in the language of ratio and proportions. This was taken up in fifteenth-century Italy where architectural proportions became newly theorised and formalised. Vitruvius’s model of the ideal proportions, the theorised figures of *homo ad quadratum* and *homo ad circulum* inspired early modern Italian artists and architects, and is well known from Leonardo da Vinci’s ink drawing (c. 1490) (figure 1.3). The Vitruvian Man, *homo ad proportion*

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107 Ingrid D. Rowland relates the various obstacles and pitfalls faced when translating Vitruvius, suggesting that Vitruvius was not ‘a very good writer’, drawing attention to his ‘clumsy phrasing, his endless sentences, his abrupt digressions, and his congenital failure to use one word when he can use two, especially when they sound alike’. She gives the example of ‘evade’ and ‘avoid’, two words used synonymously throughout Vitruvius’s works. See the ‘Translator’s Preface’, in Vitruvius, *Ten Books on Architecture*, p. XIII.
quadratus, is an athletic male body with classic bodily proportions. In the drawing, a male nude is the central subject of the page, with Leonardo’s own textual notes scrawled above and below the drawing. Straight transverse and orthogonal cuts at the knee, groin, pectorals, clavicles, shoulders and elbows, segment the body into parts, emphasising the proportions and repeated measured ratios to be found in the human body. Each body part or ‘unit’ is a variation or multiple of another body part. There exists a perfect ratio of foot to forearm, hand to leg, head to torso, etc. This drawing explicitly links geometry and architecture with the ideal proportions of the human body, and these ratios were termed ‘sacred’ in keeping with the belief of man being made in God’s image. Inspired by the perfect numerals of Pythagorean and Euclidean geometry, ten and six respectively, Vitruvius segmented the body into units, which he then applied as measurements for architecture. Leonardo’s emphasis on proportion is made clear by his use of a line below the drawing, which appears to have measured increments upon it. One body part in particular, the foot, was a known increment of measurement in architectural design, building construction and beyond. Its position, close to the line of measure, provides both scale and an attempt at a standardised unit of measure. The origins of this metrological measure is provided by Vitruvius:

When they had decided to set up columns in this temple [Ionia’s Panionion Apollo], lacking symmetries for them, and seeking principles by which they might make these columns suitable for bearing loads yet properly attractive to behold,

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112 Eric Fernie draws attention to the controversy surrounding the historical narrative of standardised metrology, especially with regards to the measurement of the foot. See Fernie, ‘Historical Metrology and Architectural History’, pp. 383–99.
they measured a man’s footprint and compared it with his height. When they discovered that for a man, the foot is one-sixth of his height, they applied this ratio to the column, and whatever diameter they selected for the base of the column shaft, they carried its shaft, including the capital, to a height six times that amount. Thus the Doric column came to exhibit the proportion, soundness, and attractiveness of the male body. 

What is important to remember is that the Vitruvian body, even when critiqued as contained, inert, and static, was inspired by the unity and proportions of the ideal living body. Although no direct analogies with bone were made, and the skeleton (as part an essential component of the living body) was not addressed, the Vitruvian body laid the groundwork and became a model for Renaissance architecture. It was a model based on the wholeness and proportions of a well-shaped living man rather than a relationship of semblance. However, Vitruvius’s detailed metaphorical associations with the body also stimulated an anthropomorphic interpretation.

The anthropomorphism of the classical orders that have acted as an impetus for the metaphors aligning the body and the architectural column, such that each has a foot, body (shaft), neck and head (capital), were also discussed by numerous historians of Renaissance architecture. Renaissance theorists imagined architecture to be

anthropomorphic – that architectural parts resembled the human form. The Sienese painter, engineer and architect Francesco di Giorgio Martini (1439–1501), for example, applied the living human form to the shape of the Doric column, often tracing the body within the outline of the shaft, and with the head as the column’s capital.\(^{116}\)

In his *Trattato di architettura civile et militare* (*Saluzzianus Codex*, c. 1470s) Francesco di Giorgio discusses among other things the historical genealogy of architecture in which he includes the drawing of a skeleton, which hovers in the left margin of the sixteenth folio (figure 1.4). It has been described by Emanuele Lugli as follows: ‘Without feet and with his jaw agape, its skull tilting to the left as if lying on an invisible ground, the Saluzzianus skeleton resembles the carcass at the end of a *dance macabre*.\(^{117}\) Despite this symbolic reading that aligns the skeleton with death, Lugli is in no doubt that Francesco di Giorgio was following the Vitruvian pairing of the human body with architecture. Lugli disrupts this relationship by proffering an argument for the presence of the skeleton in relation to the fifteenth-century architects’ quest for a standardised measurement.\(^{118}\) ‘First’, Francesco di Giorgio stipulates, ‘it is necessary to have all the measures and the number of the bones of the human body, from which all the buildings and art of architecture are drawn, and without these measures nothing can be built with art and accuracy’.\(^{119}\) With bone’s primacy in architecture thus established, Lugli offers a unique analysis of bones as the ‘paragon’ of proportion and ‘source’ of all measurement in fifteenth-century architectural theory. He presents the Saluzzianus skeleton as ‘an attempt [by Francesco di Giorgio] to distinguish within the body between proportions and measurements or […] size and scale’, and as evidence of a clear rupture from, and a ‘deliberate twisting’ of Vitruvius.

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\(^{116}\) Pari Riahi, ‘“Ars et Ingenium”: The Embodiment of Imagination in the Architectural Drawings of Francesco di Giorgio Martini’ (unpublished doctoral thesis, McGill University, 2010), argues that these drawings were an essential part of Francesco di Giorgio’s learning process. For examples of anthropomorphic columns drawn by Renaissance architects, see Günther Feuerstein, *Biomorphic Architecture*, pp. 32–39.


\(^{118}\) For a historical analysis of metrology and disputed standards of measurements, see Eric Fernie, ‘Historical Metrology and Architectural History’, pp. 383–99.

who offers a living cutaneous schematic for the dimensional analogies between body and building. Lugli considers the influence of Galen on Francesco di Giorgio’s understanding of anatomy; however, Galen’s writings were about the living body (although he certainly derived his theories partially from the dead body, human and non-human), as was the Vitruvian model – one of living proportions. Lugli is clear in his conception of the skeleton as ‘dead’, defining it as ‘a residue of a body that is no more’. Indeed, my analysis of Francesco di Giorgio’s drawing would support this position. The drawing is of a body beyond death to a point of desiccation and dismemberment, missing both hands and feet. Although anatomically incorrect, certain details have been rendered faithfully such as the dried curling cartridge at the end of each rib. The missing feet are particularly problematic as Vitruvius took his first unit of measurement from the footprint. Lugli is aware of this, interpreting the image as both a product and a solution to the question of systematic standardisation, translating the Renaissance accountant Luca Pacioli (1445–1517) and the specification that the ‘proportions [within the human body] apply to the bones clean of the meat’.

However, although Lugli suggests the possibility of a novel conception of bodily ‘interiority’ in Francesco di Giorgio’s rendering of a skeleton, there is an obvious impediment to such an argument: the skeleton depicted is clearly dead, and as such is presented as a type of exterior through the skeleton as a physical entity, not belonging to or part of a body. To quote Katherine Rowe, the skeleton, partial skeleton, or bone now possesses its own ‘locus of self and agency’. It could just as well be a snail shell or a walnut under discussion rather than a human bone. Bodily interiority is not in play here and, as argued by Renaissance art historian Wolfgang Lotz, would remain disconnected until later in the Italian Renaissance, when both the bodily and architectural interior became demonstrably ‘connected in more than superficial ways with the structures and skins of the exterior’. Francesco di Giorgio’s skeleton departs from the Vitruvian model in another important way. Although composed of

120 Ibid., p. 108.
121 Ibid., p. 106.
122 Ibid., p. 114 (Lugli’s emphasis).
123 Rowe, “God’s handy worke”: Divine Complicity and the Anatomist’s Touch”, p. 287.
various parts of the body, the sum of its parts does not equate to a ‘whole’ body, and therefore the skeleton does not present a body-as-architecture metaphor. Although the Vitruvian model can be partitioned, all of its parts act in service of the whole.

The relationship between part and whole later became a crucial concern for architectural organicism. The term ‘organic’ as such acquired significance at the close of the eighteenth century as a word referring namely ‘to living nature as opposed to dead matter’. According to Denis Diderot’s and Jean le Rond d’Alembert’s Encyclopédie, the term ‘organic’ also referred to organic geometry (the art of describing curves by means of instruments, and in general by a continuous motion), that which belongs to the organ, and part of an ancient music comprising of wind, string and percussion instruments. Caroline van Eck argues that nineteenth-century organicism was based on the theories of classical antiquity that were applied in the Renaissance, and developed into a theory that focused on imitation of an organism’s ‘external appearance’, its apparent ‘methods’ of functioning, and the ‘laws of living nature’. Organicism added a layer of ‘aesthetic, religious or cultural meanings’ to architecture. Dividing organicism into two varieties, van Eck marks their differences:

One [variety] is marked by a concern for a close relation between art and living nature in general, expressed by an imitation of her methods in the construction or ornament. The second, more restricted variety concentrates on organic unity: it aims at achieving in works of art a correspondence and correlation between the parts and the whole which is modelled on the functional correlation of the parts of the living organism.

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125 Phillips, ‘Organicism in the Late Nineteenth and Early Twentieth Centuries’, pp. 413–32; Van Eck, Organicism in Nineteenth-century Architecture, pp. 20 & 64–98.
126 Van Eck, ibid., p. 47.
128 Ibid., p. 37.
129 Ibid., p. 20 (my emphasis).
The second variety is dependent on the first. In this way, architecture from any period in history could be conceptualised, theorised and interpreted using nature as an analytical tool. Nature, in its wider sense, includes the human. In this thesis I offer the skeleton as an organicist concept that adheres to both varieties: as an expression of growth and articulation, imitated in the ‘construction and ornament’, as well as a matrix of corresponding articulating ‘functional’ parts set within a holistic ‘living’ architectural body. One of the key Renaissance theorists was, as is well known, Leon Battista Alberti (1404–1472), and I consider him the first theorist in Western architecture to directly address the skeletal elements in a building’s anatomy. I would also argue that Alberti conceived of these elements as being alive.

Katherine Park, in her essay ‘The Life of the Corpse: Division and Dissection in Late Medieval Europe’, argued that early-modern Italians understood life and death as having a clear division. At death, the soul vacated the husk of the body which remains an ‘inert’, ‘inactive’, ‘inanimate and selfless object’ that serves the interests of the living. She argues that northern Europeans, unlike the Italians, considered the first year after death during the process of decomposition and the reduction of the corpse into its hard tissues – its skeleton – as a ‘crucial liminal period of decomposition when the corpse was most sensitive and vital’. The Italians, on the other hand ‘envisaged physical death as a quick and radical separation of body and soul’. As such, the dead body was treated only as an object of memory and commemoration, which is why, Park argues, public dissection and dismemberment were the severest penalties given to a criminal, and only for the most appalling crimes. This prolonged punishment went beyond the death of the condemned as the public exhibition and desecration of their body was an assault on their family’s honour and the desecration of their memory.


132 Ibid., p. 125.

133 Ibid., p. 131.
Park also utilised Alberti’s own words to further drive home her point. In his third treatise *De re aedificatoria* (1452) – one of history’s most studied treatises on architecture – Alberti, in his chapter ‘On Tombs’, voiced his opinion regarding tomb burials: ‘I think that it is good also to take care of dead bodies for the sake of those which remain alive’. He makes clear that what is done to the body after death serves only the interest of the living. All the dead need from the living is to remember. This means that vitality is more easily comprehended in Alberti’s writings, as there is no liminal space in which things can be interpreted as nearly dead, or almost alive. Therefore, when Alberti used language that spoke to a building’s vitality or living nature, he thought of that building as alive.

Like Vitruvius, Alberti analogised the human body and architecture, and made the former the measure for architectural proportions. In his first artistic treatise *De Pictura* (*On Painting*, 1435), Alberti used three *braccia* – the height of an average man – as the common measure for his perspectival geometry. Alberti mobilised geometry, which he considered the ‘humanisation of space’, to bring the imperfect and morally flawed human being into harmonious accord with the divinely ordered universe. The rhetoric of Alberti was greatly influenced by Vitruvian principles, although in a less revered fashion. Alberti writes:

> […] just as the head, foot, and indeed any member must correspond to each other and to all the rest of the body in an animal, so in a building, and especially a temple, the parts of the whole body must be so composed that they all correspond

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Alberti analogises the living human body with a building and temple. This linkage between the body and architecture, and the underlying unification of the part into the whole is described by van Eck as an ‘organic unity’. The concept of organic unity, which continued to concern architects from the Renaissance well into the nineteenth century, differed from the mathematical principles of universal geometry and perspective as it remained close to nature’s forms and became the precursor to nineteenth-century architectural organicism. Such a notion of unity is vital for establishing the idea of a living holistic skeleton in architecture, in which each member is brought together and unified into an organic whole. Yet how did Alberti conceive of unifying members so as to achieve wholeness in architecture? Unlike in the nineteenth century, when architectural members were connected by unifying architectonics, what I consider to be a form of ‘articulation’, Alberti developed a particular concept that helped him to draw architectural elements together: *concinnitas*. It is a key term in his visual theory and for the appraisal of the visual arts, as well as serving as an expression of architectural unification and beauty.

Albertian rhetoric is immersed in nature’s expressions and shades, adding to an architectural language already enriched and coloured by metaphors from the natural world. The notion of *concinnitas* is regarded by Van Eck as the epicentre of her understanding of the relationship between architecture and nature. Alberti discusses this relationship in *De re aedificatoria*, where he gives *decorum* to pagan architecture and raises sacred architecture to the pinnacle of structural superiority. He was the first to draw a conceptual distinction between a structure and its ornament, a formal divide.
that was to persist within architectural discourse well into the nineteenth century. In anatomical terms, it can be compared with the bony skeleton as the structure, and soft tissues as the ornament. Alberti distinguishes structure from *ornamentum* by identifying what is fixed and inherent in a form, what he calls its structure, and defining any additional element or lustre that provides ‘auxiliary light and complement to beauty’ as ornament. Beauty is an inherent property of a structure and is expressed through *concinnitas*, whilst the ornament ‘has the character of something attached or additional’. Alberti thus establishes a juxtaposition and hierarchy between structure and ornament.

The central Albertian concept of *concinnitas* has proven difficult for historians to translate. Van Eck notes that the term was utilised by Cicero to ‘characterise a style that is “closely knit”, “elegantly joined” or “skilfully put together”, and therefore beautiful or elegant’. Some authors choose to leave the word untranslated, which often proves troublesome. The term connotes skill and foresight of purpose. Nature and architecture have a sympathy toward the other with *concinnitas*, nature’s rule, directing the ‘consonance of parts within a body’ to create a beautiful whole. The building should be joined in a manner of bone and flesh ‘knitted together’ via *concinnitas*. Van Eck proposes that *concinnitas* is ‘not a unity that is modular, based on a common measure and expressed by mathematical proportions; rather it is a unity based on a plan or concept of the whole, that determines the structure of the parts’. *Concinnitas* thus expresses a more holistic view, akin to how one might define organism today, and is in keeping with the Aristotelian concept of ‘purposeful unity’.

Yet the ratios of sacred architecture were principal laws of Renaissance construction, with excellence of form being found in the number (*numerus*), outline (*finitio*) and.

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143 *Concinnitus* is based in the mind and in reason. See ibid., p. 6.
position (collocatio) of component parts. *Concinnitas* operates on a different level; it is vital for any beauty and natural sympathy to exist. *Concinnitas* cannot be described when present, except to declare a structure beautiful and harmoniously joined, yet its absence is keenly felt when a structure is discordant and unsympathetic to its natural environment.

The secondary literature on Albertian theories of ornament and *concinnitas* has so far done little to analyse what kind of living ‘nature’ architecture was meant to imitate, and the analogy, simile and metaphor of bone remains as of yet unexamined. Unlike Francesco di Giorgio, who saw bone as a dead, albeit reliable tool for measuring, Alberti perceived bone as structural and ‘alive’. For him, imitating bone thus means imitating both nature’s manner and methods. In addressing the components of a wall, Alberti identifies the following principle elements:

Some of the principal Parts […] are the Corners of the Wall, and the Pilasters, or Columns, or anything else in their stead set in the Wall to support the Beams and Arches of the Covering; all which are comprised under the Name of *Bones* or *Ribs*. Likewise the *Jambs* on each Side of all Openings partake of the Nature both of Corners and of Columns. Moreover, the Coverings of Openings, that is to say, the Lintels or Transoms, whether strait or arched, are also reckoned among the *Bones*.  

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145 As Van Eck also notes in ‘Organicism Revisited: The Desire for the Animation of Inanimate Matter in the 19th Century’, p. 52.
146 Alberti, ‘That there ought to be Vents left open in thick Walls from the Bottom to the Top; the Difference between the Wall and the Foundation; the principal Parts of the Wall; the three Methods of Walling; the Materials and Form of the first Course or Layer’, in *The Ten Books of Architecture*, The 1755 Leoni Edition, trans. by Edward Owen (New York: Dover Publications), available online <http://archimedes.mpiwberlin.mpg.de/docuserver/images/archimedes/alber_archi_003_en_1785/downloads/alber_archi_003_en_1785.text.pdf> Book III, Chapter 6, pp. 163–4 (my emphasis). In the Rykwert, et al. translation, the *Jambs* are described as ‘lips’: ‘Among the other important, perhaps even more important, parts of the wall are the corners and inherent or additional elements such as piers, columns, and anything else that acts as a column and supports the trusses and roof arches. These all come under the description of bones. So too the *lips* on either side of the openings, which share the characteristics of both corner and column. Also included in the bones are the coverings to the openings, that is, the beams, whether straight or arched: for I call an arch nothing but a curved beam, and what is a beam but a column laid crossways? The zone stretching between these primary parts in referred to approximately as
The bones (*ossium*) of a building are identified as the essential parts, necessary in forming a stable supportive structure. It is also the bones, and the gaps between them, that create the openings such as the doors and windows, allowing for movement between the interior and exterior spaces. The bones operate in multiple directions; there are vertical bones such as ‘Jambs’ (another anatomical term, meaning leg), horizontal bones such as lintels, and curved multidirectional bones such as the ribs.\(^{147}\)

Although the gap between the lintel and floor – the door – offers movement, it is our bodies that move *through* the gap. The gap that I am exploring in this thesis is the gap that potentially gives movement to the architecture itself, the articular gap, and the material transformation as seen in the skeletal articulation of both the specimen (when requiring iron for articulation) and living body (when continuous). Although the material of bone in the living body is discontinuous, it is by no means emancipated as bones are always formed and held within the extracellular matrix, transforming at visibly imperceptible points of differentiation, from cancellous bone to epiphysis to periosteum to articular cartilage to ligaments to cartilage to periosteum, and returning once again bone. It is a communicative and adaptive matrix, composed of the same elements but in varying quantities, with an innate potential to transform into whatever substance the musculoskeletal system needs.\(^{148}\) That Alberti conceived of bone as being part of a living body is evident in his intriguing application of the word ‘bone’ to architecture, and his understanding of its interdependency and communal function:

> The Philosophers have observed, that Nature in forming the Bodies of Animals, always takes care to finish her Work in such a Manner, that the Bones should all *communicate*, and *never be separate* one from the other: So we also should connect the Ribs together, and *fasten them* together well with Nerves and Ligatures; so that the Communication among the Ribs should be *so continued*, that if all the rest of the Structure


failed, the *Frame of the Work* should yet stand firm and strong with all its Parts and Members.\textsuperscript{149}

The bones provide a solid framework to the building, which follows the properties of animal bones as being firm and strong. Associated with the load-bearing component of a structure, the word ‘member’ is also an anatomical metaphor, typically referring to a limb or general part belonging to the body.\textsuperscript{150} In this passage, Alberti directly relates the architectural bones to the bones forged by nature (the bone of the animal), and calls for the architects to imitate nature’s methods in connecting the bones of a structure. By explicitly referring to their communication and interdependency, Alberti identifies bones as being part of a larger system, a skeleton so to speak, of intimate connections. It is an exceptional position to take, as the establishment of bodily systems was a product of Enlightenment natural philosophy.\textsuperscript{151} Within a bodily system bones should never be separate entities but always part of a larger communication network, which implies ‘life’. A detached bone divided is the remnants of something dead. In this way, connecting architectural bones is the beginning of something vital and ‘alive’ in the structure itself.

The notion of fastening ribs (another type of bone) with nerves and ligatures implies that the latter were thought of as being architectural connective flesh, a ligature having the same etymological root as ‘ligament’ (the fibres that connect bone to bone), and being a band, thread or chord that ties things tightly together.\textsuperscript{152} Alberti seems to be


\textsuperscript{150} The anatomical term ‘member’ originates from the fourteenth century. It becomes more ubiquitously applied in the seventeenth century, encompassing any part of a building. See ‘Member, n. and adj.’, in *OED Online* <http://www.oed.com/view/Entry/116296?rskey=nBsSeK&result=1&isAdvanced=false> [accessed 3 August 2017].


\textsuperscript{152} Derived from the fourteenth-century term ‘ligament’, from the Latin *ligamentum*, the tough tissue that connects bones together. See ‘Ligament, n.’, in *OED Online*
searching for textile metaphors to describe the homogenous tissues of the body, yet the textural term ‘tissue’, itself a metaphor stemming from the realms of textiles, had not yet been introduced into medical discourse.\textsuperscript{153} Perhaps this is what Alberti meant by \textit{concinnitas}: the artful knitting or tying together of structural members so as to enable their communication. This conjecture is supported by another passage regarding the bones of vaults:

\begin{quote}
[...] in all Manner of Vaults, let them be of what Kind they will, we ought to \textit{imitate Nature}, who, when she has \textit{knit the Bones, fastens the Flesh} with Nerves, interweaving it every where with \textit{Ligatures} running in Breadth, Length, Height and circularly. This \textit{artful Contexture} is what we ought to imitate in the joining of Stones in Vaults.\textsuperscript{154}
\end{quote}

Alberti presents another direct reference to the ‘imitation of nature’ in the joining together of stones. Material and anatomical metaphors interweave in an elaborate textual visualisation of bodily interiority. In Alberti’s treatise, the connecting capacities of texts and textiles are closely likened. The fabric of the body is weaved together into a contextual whole; the bones have been knitted, and the flesh has been fastened to the bones, with nerves and ligatures running in every direction. Yet stone is the only architectural material being considered. As such we can assume that Alberti is attempting to convey the many different ways and methods for joining the same material, and it is therefore not the material that is important but the manner of its joining together – the ‘artful contexture’ of different materials and surfaces all coming

\textsuperscript{153} Alberti mostly applies the term ‘flesh’ instead of ‘tissue’, the term tissue being introduced c. 1700. See Mechthild Fend, \textit{Fleshing out Surfaces: Skin in French Art and Medicine, 1650–1850}, Rethinking Art’s Histories, ed. by Amelia G. Jones and Marsha Meskimmon (Manchester: Manchester University Press, 2017).

together in the service of the functional whole. The analogous material relationship between bone and stone is implied, as both were considered as earthy materials, and their respective joining produces an organic unity. As such, bone is crucial in establishing Alberti’s theoretical organicist framework.

It is clear from Alberti’s writing on architecture that he understood the value of bone as a potent metaphor and simile, and was careful to distinguish between the two rhetorical forms. He referred to the anatomy of a fish, appealing to his readers’ familiar knowledge – that fish have a backbone that is ‘joined sideways’ – so that one could easily imagine uniting small brick tiles like two halves of a fish.\(^\text{155}\) He also looked at the similarity between the parts of animals and trees:

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\text{The Parts nearest to the Sap are indeed harder and closer than the rest; but those next to the Bark have more binding Nerves, for it is suppos’d, in Trees just as in Animals, the Bark is the Skin, the Parts next under the Bark are the Flesh, and that which encloses the Sap, the Bone}.\(^\text{156}\)
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In this passage, Alberti is discussing the use of timber in architecture. By relating the natural material of wood – with its bark, interior wood, pith and sap – to the natural material of the body – with its skin, flesh, bone and marrow –, Alberti considered not just the structure of a building and its connecting parts as being a living body, but also the material itself.\(^\text{157}\) Bone was recognised as living dynamic matter. In connecting the

\(^{155}\) A fish’s backbone typically possesses vertical dorso-ventral spines and a central backbone rather than a mammal’s lateral processes (ribs) and a dorsally positioned spine. Alberti contended that ‘the Ancients made their Shell either of baked Earth, or of Stone; and where Men’s Feet were not to tread, they made their Tiles sometimes a Foot and a half every Way, cemented with Mortar mixed up with Oil; we also sometimes meet with small Bricks one Inch in Thickness, two in Breadth, and four in Length, join’d Sideways like a Fish’s Backbone’. See Alberti, ‘Of Pavements according to the Opinion of Pliny and Vitruvius, and the Works of the Ancients; and of the proper Seasons for Beginning and Finishing the several Parts of Building’, in \textit{The Ten Books of Architecture}, The 1755 Leoni Edition, Book II, Chapter 16, pp. 210–11.

\(^{156}\) Ibid., ‘Of Trees more summarily and in general’, Book II, Chapter 7, p. 113.

\(^{157}\) The translation of Alberti in Rykwert, et al. is ‘marrow’ instead of ‘sap’: ‘For trees may be likened to animals, their outer bark being their skin, what lies beneath their flesh, what surrounds the marrow, their bones. See Rykwert, et al. translation of Alberti, \textit{On the Art of Building in Ten Books}, p. 46.
material’s imagined interior with the exterior, Alberti envisages another dynamic relation between a microcosm and a macrocosm.

In *De re aedificatoria*, Alberti frequently uses the architectural metaphor of bone. From the frequency of its application, one can adduce that bone was conceived as the body’s framework and that its application in architecture was something of a convention. The skeleton, in contrast, was not an established metaphor, as evidenced by Alberti’s idiosyncratic use of the term in his discussion of a particular stone bridge called ‘Adrian’s Mole’:¹⁵⁸

The Parts of the Bridge are the Piers, the Arches and the Pavement, and also the Street in the Middle for the Passage of Cattle, and the raised Causeways on each Side for the better Sort of Citizens, and the Sides or Rail, and in some Places Houses too, as in that most noble Bridge called Adrian’s Mole, a Work never to be forgotten, the very Skeleton whereof, if I may so call it, I can never behold without a Sort of Reverence and Awe.¹⁵⁹

The manner in which Alberti addresses the bridge as a skeleton (*cadauera*), asking permission from his reader to accept the use of the metaphor, implies that it is not an established term in architecture.¹⁶⁰ That he chose the skeleton metaphor to describe a bridge is remarkable, as the first architectural frameworks that were later more

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¹⁵⁸ There is a reference to Adrian’s Mole in a dictionary of ancient geography: ‘Aelius Pons, now *il Ponte S. Angelo*, a stone bridge at Rome, over the Tyber, which leads to the Burgo and Vatican from the city, along Adrian’s mole, built by the emperor Adrian’. See entry for ‘Aelius Pons’ in Alexander MacBean, *A Dictionary of Ancient Geography: Explaining the Local Appellations in Sacred, Grecian and Roman History* (London: G. Robinson and T. Cadell, 1773).


¹⁶⁰ The term used in the original Latin was not *osseus* (which means ‘skeleton’ of bone) but *cadauera*, which can be translated as ‘skeleton’ but can also mean ‘carcass’, and has been translated as such by Rykwert, et al., in their translation of Alberti, *On the Art of Building in Ten Books*, p. 262: ‘Some bridges even have a roof, like that of Hadrian in Rome, the most splendid of all bridges – a memorable work, by heaven: even the sight of what I might call its *carcass* would fill me with admiration’.
generally termed skeletons were also bridges, more specifically the iron bridges of the industrial period.161

Alberti presented bone as active material in the body, and something that gave energy to architecture. He saw bones as a multifaceted communicating framework and system. He associated bone with the hard, pithy material inside trees; with architectural vaults; with floor tiles, and with a bridge. Van Eck looked to Alberti and his theory of conncinitas as an early manifestation of architectural organicism, and indeed the Renaissance had proved rich in organic metaphor, particularly of the body as a microcosm and as a metaphor of function.162 Yet organicism has proved an unstable framework for the analysis of Renaissance architectural theory due to the imprecision and anachronist use of terms such as ‘nature’, ‘organic’ and ‘life’, to name but a few.163 Architectural historian Vittoria Di Palma warns that, ‘[t]here is no single organic metaphor that architecture can turn to, since the notion of “organic” implies both very different things at different historical moments, and also substantially different things within one historical moment’.164 However Di Palma argues that it is exactly this imprecision that has made the organic a fertile concept for interrogation, and I would agree with her position. Alberti conceived bones as active and alive in the manner that animals and trees are alive, and bone worked for him as a unifying concept. Though not referring to the ‘organic’ explicitly, he established an early form of architectural organicism. For my following discussion of organicism in the late-eighteenth and nineteenth century, it is important to consider the architectural heritage of Vitruvius

161 The term was chiefly applied to suspension bridges in the early nineteenth century due to their rigidity and light structure. See William Vose Pickett, New Forms in Architecture, pp. 24–28. See also Olaus Henrici, Skeleton Structures: Especially in their Application to the Building of Steel and Iron Bridges (New York: D. van Nostrand, 1867).


163 Rykwert, in ‘Organic and Mechanical’, p. 18, wrote that there was ‘no identifiable organic theory of architecture (based on a direct appeal to nature, at any rate to the nature that biology and chemistry study) that can be usefully summarised. Yet the constant appeal to the notion of the organism, particularly as it relates to the body image in architecture, seems to be important’.

and Alberti, and the role of Renaissance architects in establishing bone as an architectural metaphor.

THE ORGANIC IN ARCHITECTURE: LANGUAGE AND IMAGE

Organicism has been recognised as a key concept of nineteenth-century architecture and many architectural historians concerned with this period analytically engage with metaphors of nature in their quest for structures that comply with the criteria for ‘organic architecture’. The use of the term skeleton, however, is rarely engaged with explicitly and in any detail. External forms – the visible, growing parts of nature – are often considered as the vital, living and truly organic parts in their form and function. I propose a method of moving beyond the external biomimetics and towards the endoskeleton’s internal structures through its representational forms. It seems that historians of organicism have taken the notion of the ‘architectural skeleton’ for granted and overlooked that this designation for a functional part of a building could be part of the organicist rhetoric. It may be that the long shadow of modernity has eclipsed the organic provenance of the term, a shadow perhaps cast by a twentieth-century view of functionalism in design theory. Architectural historian Philip Steadman attempted to bridge this gap between the internal and external via a ‘biological analogy’, as opposed to an organic analogy, the use of the word ‘biology’ immediately rooting his research within nineteenth-century parameters and enabling an analysis of the functional and physiological elements in building construction.

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Yet the naturalistic decorous splendour as seen in ancient architectures does not quite fit Steadman’s anachronistic terminology, and has been whitewashed over and solidified under the category of religious decoration.

Historians of architecture, such as van Eck, have argued that the history of an organicist approach is as old as architecture itself. This view is based on the assumption that the first human dwellings were formed out of the natural world, natural formations of rock providing protection from the elements, large trees and their foliage granting shelter from inclement weather. Since Vitruvius it was assumed that architectural principals should ultimately derive from the basic needs of early humans, who used the natural world and the materials of which it is comprised to survive and prosper. One of the most important followers of this Vitruvian idea, and an influential eighteenth-century theorist of neoclassical architecture, was the Jesuit priest Marc-Antoine Laugier (1713–69). Laugier’s works are considered representative of the evolution of ideas during the Enlightenment, and are characteristic of the ‘hesitation’ that was beginning to appear among intellectuals in the middle of the eighteenth century: torn between justifying the classical and universal orders of the past and the progress of critical reason, logic and enlightened thought. Although not an architect himself, Laugier made a significant contribution to architectural and aesthetic theory, and to the formation of the classicist style in France and later across Europe. However, Laugier is often singled out for one theory in particular – the Primitive Hut. In his popular 1753 Essai sur l’architecture, Laugier traced all architecture to the model of the simple hut. He identified the essential elements of basic architectural construction for human habitation – the column, the entablature and the pediment – and rejected any part that was ‘confusing and bizarre’. Like Vitruvius and Alberti before him,

167 Although Laugier was a follower of Vitruvius, he was critical of Vitruvius’s writings. Vitruvius only taught ‘what was practiced in his time […]’. Always avoiding the depths of theory, he takes us along the road of practice and more than once we go astray’. See Wolfgang Herrmann and Anni Herrmann’s translation of Laugier, An Essay on Architecture, p. 2.


169 Laugier, Essai sur l’architecture. For a critical appraisal of Laugier’s influence in eighteenth- and nineteenth-century France, see Wolfgang Herrmann, Laugier and Eighteenth-century French Theory (London: A. Zwemmer, 1962), pp. 5 & 173–202. For a comprehensive discussion on the immaterial origins of architecture, such as the primitive hut, through disegno (both the design and the drawing forth of ideas) from classical architecture to modernism and Ludwig Mies van der Rohe’s ‘prototypes’,
Laugier believed in the structural unity and integration of parts, and that a building should be constructed in such a way that the removal of any one part would lead to discord and distortion. He thereby developed three aesthetic concepts: vérité, simplicité, and naturalisme. This aesthetic departure from the principles of Baroque and Rococo architecture, along with his rethinking of the structural logic of the primitive hut, has led to Laugier being described as one of the first ‘modernists’ of architecture.170

Be that as it may, Laugier questioned established theories and practices in architecture and broke with Vitruvian ideals in many ways. The most radical break was from the metaphysical view of the classical orders. For Laugier the role of the column was purely functional. The Doric, Ionic and Corinthian orders should not be utilised to express stories from the past, or to symbolise a kind beauty now considered as antiquated.171 For Laugier, architecture should not conform to a system of numbers and proportions that hold symbolic or sacred meaning. In the wake of several revolutions that had brought marked changes to the belief systems and societal norms in France, Laugier instigated a kind of architectural reformation by rejecting Renaissance models and Vitruvian principles.172 Instead he took an enlightened perspective based in spiritual and philosophical ‘reason’, and presented architecture as something more akin to a natural law grounded in reason.173 Praising the simplicity of Greek architecture he reduced the essential elements of all architecture to what Barry Bergdoll describes as the ‘upright column, spanning entablature and protective sloping roof’.174 These were the elements taken directly from nature. All else – the wall, doors,

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172 Ibid., p. xv of the preface: ‘Il n’y a plus de progress à espérer dans les arts, si tout se borne à imiter les choses faites; la critique nécessaire à leur perfection ne peut avoir lieu, qu’auvant qu’on aura des règles fondées, non sur ce qui est, mais sur ce qui doit être’.
173 Reason was considered to be the highest human value. See Laugier, Essai sur l’architecture, p. XXXIII of the preface and p. 8 of the introduction.
windows, etc. – were, for Laugier, the product of civilization. In a way, revisiting the primitive hut was a way of starting afresh; of looking back to a time free of the pollution caused by civilisation.\footnote{Kuletin Ćulafić, in ‘Marc-Antoine Laugier’s Aesthetic Postulates of Architectural Theory’, p. 50, links Laugier’s primitive hut, and the idea of purifying civilization, with Rousseau’s ‘noble savage’.}

Breaking with Vitruvian theory and a hundred years of tradition in the French Academy of Architecture made Laugier a controversial albeit popular figure, with many critiquing his simplistic approach or accusing him of attempting to stunt their artistic creativity. Yet the accessibility of Laugier’s language and prose, his writing style and rhetoric, and the popularity of his ideas led to the translation of his essay into several European languages, with a ‘revised, corrected and expanded’ second edition published only two years later.\footnote{The new edition is ‘revue, corrigée et augmentée, avec un dictionnaire des termes, et des planches qui en facilitent l’explication’. See Preface to Laugier’s \textit{Essai sur l’architecture} (2nd edn). For an analysis of the long-term effect that this representation of the primitive hut would have on architecture, see Lavine, ‘Laugier’s Prototypical Hut, Soufflot’s Sainte-Geneviève, and the Enlightenment Theory of Representation’.}

The frontispiece added to the second edition of Laugier’s \textit{Essai sur l’architecture} of 1755 features an allegorical engraving by Charles Eisen (1720–1778) (figure 1.5). In the scene a woman sits in profile, draped in voluminous material. She is the personification of architecture, as indicated by the mathematical instruments – the setsquare and proportional compass – in her left hand. She sits on a fallen pillar, suggestive of ancient architectural remains. Her elbow rests on a fragment of an entablature, identifiable from the dentil processes of the triglyph element. Her foot also rests behind a partially buried column capital or foot (although its location near the foot of the woman would infer the latter). In the right foreground is another capital with volute detailing, and in front of this capital is another column with flute and filet detailing, that extends beyond the picture plane. Plants and grasses grow over the scattered debris, implying that time has passed since the stone structure fell and that nature has already begun the process of reclamation and submergence. The woman is turned towards the figure of a cherub, the angels that protected the garden of Eden, directing its attention to a grove of four trees. Although slightly gnarled, the trees grow...
straight, their branches forming an enclosed canopy overhead. Larger branches of equal length have been placed in the treetops; four placed horizontally, forming a large square enclosure (the entablature), whilst numerous branches have been raised forty-five degrees to connect at a central apex, creating a triangular pitched roof, or pediment. The scene depicts all the necessary elements of ‘noble’ architecture – the perpendicular column, entablature and pediment – and that ‘nothing else need be added to make the work perfect’. However, in actuality Laugier’s tree-columns were not grown directly from the earth but were dead fallen branches, selected for purpose: ‘Some fallen branches in the forest are the right material for his purpose; he [primitive man] chooses four of the strongest, raises them upright and arranges them in a square’. In this way, nature provided the inspiration and the materials for human habitation but not the actual habitat. As such, the ideal architecture presented in the allegory is only ever to be built, not actually found. The radical departure of the image from the text has led some architectural historians to question the provenance of Laugier’s frontispiece – one of the most iconic images in architectural history – as the scene in no way reflects Laugier’s description of the primitive hut. Architectural historian Fabio Restrepo Hernández argues that Eisen never intended to engrave Laugier’s primitive hut. Instead, he suggests, the image was intended as an allegory for the annunciation, with the growing organic ‘temple’ and tree-columns acting as a metaphor for Christ’s body. The stone fragments are temple ruins that symbolise the church of the past, and the organic temple being ‘announced’ by the women and cherub symbolises the future Christian Church.

Whichever way the image is interpreted, Laugier’s allegory draws attention to the relationship between humans and nature. The architecture of the ‘primitive hut’ or the ‘Vitruvian hut’ presented two kinds of nature – an environmental nature (of the earth, the trees and of other growing things), and human nature (of people finding and constructing dwellings by clearing spaces, cutting and collecting branches, and enclosing spaces). As such, the architecture is a form of mediation between the human and its natural environment, which follows the enlightenment idea of ‘natural

cognition’, the basic fundamental truth that there was ‘a mutual basis of the world and religion which was to be found in “natural religion” that was present in every man’s heart’. The architecture also highlights human weakness – human beings may be part of nature but they also need to be protected from its ravages, and their survival depends on the harnessing of nature through architecture.

The allegory presents the historical legacy of architecture as a crumbling ruin. By pointing to the trees, with their strong trunks and open structure, Laugier attempted to bring conceptual clarity to the simple beauty of nature’s design. The noble and virtuous architecture is to be found in the necessary components to a structure (the column, entablature and pediment), which he termed ‘les parties essentielles’. All else is excess and undermines the classical principles of the primitive hut. He called these non-essential parts ‘les parties introduites par besoin’, such as walls, windows and doors, and ‘les parties ajoutées par caprice’, which were considered as anything useless or redundant. Although critical of Albertian principles relating to the inherent subjectivity of beauty and proportion, one fundamental principle was preserved by Laugier: ‘architecture as in all other arts […] are founded on simple nature, and nature’s process clearly indicates its rules’. Like Alberti before him, Laugier drew attention to the simple yet essential weight-bearing elements of architecture that provide the structural form: ‘It is the wall that causes all superfluous weight, it is the wall again that deprives architecture of all its grace […] The less it appears, the more beautiful the building will be; and when it does not appear at all, that building will be perfect’. Eisen’s allegory frontispiece for Laugier’s treatise made visible the abstract concept of architecture embodying an intrinsic naturalism. Laugier’s argument was for a return to the simplicity of the hut, yet it is not an architecture built with bones but with trees.

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181 Jonathan Hill, The Architecture of Ruins: Past, Present and Future (London: Routledge, 2019), pp. 82–84: Writing in regards to sixteenth century and eighteenth-century revival of Palladio, Hill argues that ‘as the building was analogous to the body, the ruin was associated with dismemberment, decline and decay, and was not a significant design theme’.
183 Herrmann’s translation of Laugier, An Essay on Architecture, p. 11.
184 Ibid., p. 38.
However, he failed in his attempt to fully align his architectural metaphors with a growing arboreal nature, as he could not circumvent the established architectural vocabulary entirely. The columns were still the ‘legs of a building’, and spiral columns are to architecture ‘what the bandy legs of a cripple are to the human body’. He also used the term ‘member’ to describe the parts of a building. Laugier’s disregard for the Albertian conception of bone could be due to his focus on the integration of the classical orders into the notion of structure, as the classical orders had been discussed only in relation to the ornamental in French architectural theory for at least the sixty years prior to Laugier’s work.

In tracing the genealogy of the architectural column from Alberti to Gottfried Semper, Harry Francis Mallgrave argued that the architectural column presented an ‘imaginative verticality’, which extends beyond its resemblance to a tree. The column’s verticality is akin to the to the towering mountains, the upright stance of a human, the lift and support of our limbs – all symbols that add erect potency to the imagined column –, and that the connection between its image and its referent is achieved through the application of mimetic devices, such as decorous foliage on the capital ‘head’ that expresses the ‘convincing metaphorical process’ of dynamism and ambiguity. Although an intriguing psychological interpretation, Laugier’s writings do not adhere to Mallgrave’s argument. Laugier’s focus was on the traditions of building, in recalling the essentials of building construction, and he made the imitation of nature the founding element of building work. He held that ‘by imitating the natural process, art was born’ and, for him, the Corinthian order was the most overt architectural example of this. Laugier praises the Corinthian order as being ‘the greatest, the most majestic and most sublime architectural creation’, adding that it ‘has perfect grace and great splendour’. He describes the capital as if being the product of natural growth: ‘The acanthus leaf has by nature the contour and curves which suit the leaves of the Corinthian capital. This plant grows tender stalks among its leaves.

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186 Ibid., p. 29.
189 Ibid., pp. 51–52.
which convey quite naturally the caulicoles of the capital and which these caulicoles with their extensions into volutes originally represented’. Subsequently, he recounts the story of the spontaneous ‘finding’ of the Corinthian order as initially told by Vitruvius. It is a mythical tale of love, loss and remembrance, and of nature captured and transformed. Although the origins of this myth remain unknown, it was Laugier who established the Greek temple as the first architectural element that applied structural reasoning to the laws of nature. The acanthus leaves adorning their capitals may identify Greek columns as Corinthian, but Laugier noted that they taper towards the summit as plants also do, and their forms are dependent upon their structural material and the load that they must carry. The column may represent naturalistic forms, but the function of nature was also imitated. In this way, Laugier presented the slender ornamental column, based on organic forms, as functional architecture.

The trend in eighteenth-century France was to build in the style of classical antiquity: Greek or Roman. The orders of architecture had been re-categorised and further subdivided, and were being emulated in the building practices of Western Europe. It was desired that the style of a civic building was to reflect the ethos of the age of its construction, be it Greek democracy or the Roman republic. Although a neoclassicist, Laugier also held Gothic architecture in high regard as he considered Gothic churches ‘the most acceptable’ of post-classical architecture. Yet this was not always the case. In his 1755 Essai sur l’architecture, Laugier related the numerous faults he had perceived in the Gothic style. He found the flying buttress ‘distasteful’ and remarked on the excessive heaviness of medieval churches, offering them as the ‘lasting proof of the barbarism which filled a period of more than ten centuries’. However, he also believed that the French Gothic churches were ‘the most acceptable’ of medieval

190 Ibid., pp. 52–53.
191 A maidservant placed a basket of goblets, ripe fruit and acanthus flowers at the funeral monument for of her young mistress. The servant covered the basket with a tile so that it would remain fixed to the monument. In the spring, an acanthus plant grew from the earth. With the weighted basket placed upon its central stem, the vines, leaves and flowers grew up the sides and formed the curves of volutes. It was noted by Callimachus (a stone mason) to be such a pleasing arrangement, that he modelled the Corinthian columns on the grouping and forms, the votive basket with its floral tribute transformed into stone. See Vitruvius, ‘On the Corinthian Capital’, The Ten Books on Architecture, Book IV, Chapter 1, sec. 9 & 10.
192 Herrmann’s translation of Laugier, An Essay on Architecture, p. 100.
193 Ibid., p. 40.
architectures, and his opinion of the style improved as he began to separate the structure from its ornament.  

A mass of grotesque ornament spoils them, and yet we are awed by a certain air of greatness and majesty. Here we find ease and gracefulness; they only lack simplicity and naturalness. We have rightly renounced the follies of Gothic (l'architecture modern) and have returned to the antique, but it seems we have lost good taste [vrai goût] on the way.

Laugier seems torn between the merits of Gothic architecture (its greatness, majesty, gracefulness, simplicity and naturalness) and what he considers to be its faults (its grotesque follies of ornament). Naming the Gothic as ‘a style of building that lasts’, Laugier also united the Gothic style with the Gothic spirit of the craftsmen who built such edifices and carved each stone. In this way, the Gothic was both an aesthetic and a method of building, and Laugier hoped that ‘architects would adopt the spirit of this ridiculous style and study the astonishing workmanship of this way of building where nothing gives way although everything is extremely fine’.

Laugier thus proposed a synthesis of Greco-gothic construction, one modelled in classical trabeation and the other modelled in medieval arcuation. Advocating a kind of return to ‘origins’ in architecture, Laugier proposed that the emulation of branching trees could lead to an improved architecture, a proposition supposedly implemented in the redesign for the church of St Nicholas, Leipzig (c. 1784), by the architect Johann Friedrich Dauthe (1746–1816). In a similar manner to the acanthus that grows upwards, with tender stalks and leafy capital, the church of St Nicholas has fluted shafts capped with a profusion of verdant leafy shoots, which grow upwards into the

194 Ibid., p. 100.
195 Ibid.
196 Ibid., p. 75.
198 Herrmann, Laugier and Eighteenth-century French Theory, p. 186; with regards to the decoration of Gothic churches, see Laugier’s Observations sur l’Architecture. Also see Bergdoll, European Architecture 1750–1890, p. 14.
geometrical forms of the transept vaults (figure 1.6). Laugier appreciated the continuous variation of ‘all geometrical figure, from the triangle to the circle’, which enhance the compositional aesthetics of a building. The delicate chiselling of the stonework was intended to evoke the ‘untrammeled grandeur’ of the Gothic, which Laugier so admired, whilst maintaining an undeniable link to the Corinthian capital. However, Laugier may have taken issue with the monocoloured pale green paint applied to the columns. He advocated the blending of different shades, especially shades of green, so as to produce a chiaroscuro effect ‘as fascinating as a beautiful painting’.

Another example is the architect Jacques-Germain Soufflot (1713–1780), who travelled to Paestrum in 1750 to study the remains of Roman temples. Soufflot, like Laugier, championed a synthesis of Greek and Gothic forms to generate a kind of evolved hybridised style. The recent find of the Corinthian columns in the ancient site of Balbec (today in Lebanon) were reimagined and adapted in the ecclesiastical and profane architecture of Europe. These ruins were replicated by Soufflot in the church of Ste. Geneviève, c. 1757–1789, later repurposed and renamed as the Panthéon, where the columns were modelled from the newly discovered, although baseless, Doric of Paestum (in the crypts) and the Corinthian of Balbec (in the nave and portico). Ancient organic motifs were to influence the appraisal of structure and ornament, permeating a distinction that had remained relatively unchallenged since Vitruvius.

There is a remarkable lightness to the stone vaulting and columns in the Panthéon, infusing the interior space of this classical-style building with a Gothic atmosphere or

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202 The newly excavated seats of ancient civilisations, such as Pompeii Herculaneum and Paestum, uncovered architectural treasures in the form of civil structures, sculptures and decorative motifs. Artists and architects travelled to these sites, such as the Italian draftsman Giovanni Battista Piranesi (1720–1778), who produced a series of monumental drawings at the archaeological site of Paestum in 1777, which were engraved and widely distributed throughout Britain and France in the late eighteenth century. Such images of Doric ruins proved highly influential to the French decorative arts, painting and architecture. See Allan Braham, *The Architecture of the French Enlightenment* (London: Thames and Hudson, 1980), pp. 64–66.
‘spirit’. This was due to the insertion of wrought iron cramps and bands, which remain completely hidden by the stone masonry but are responsible for uniting the structure and maintaining structural integrity (figure 1.7). The iron enabled the columns and point supports that hold the weight of the roof vaults to be reduced to their minimum mass and could therefore become slimmer in form. These adaptations concerning size and volume would evolve with the development of iron as a structural and developable architectural material, creating novel rational structures of monumental expression.

Laugier's writings were highly influential for French neoclassical and Revolutionary architecture, and Soufflot was a devoted disciple. With the help of his friend Jean-Rodolphe Perronet (1708–1794), the celebrated engineer and bridge designer, Soufflot designed a new system of iron-reinforced masonry that served as ‘an armature for lightweight spatial and structural effects’, merging ecclesiastical philosophies regarding sacred building with ideas of human reason and scientific achievement. The use of iron enabled Soufflot to achieve the eclecticism of a light Gothic aesthetic with classical styling. These reinforced-iron structures will be discussed further in Chapter Three with regards to the engineering of iron for colossal architecture.

According to Laugier’s neoclassical aesthetics, which equally endorsed the lightness and grace of Gothic churches, architects should ‘keep to the simple and the natural’, because ‘it is the only road to beauty’. His triad of beauty, truth and nature was to be embraced and reinterpreted well into the nineteenth century. Perhaps the most renowned advocate for the implementation of these virtues was John Ruskin in his vigorous promotion for a Gothic revival in Britain. Ruskin, considered to be a sage of the Victorian era and a prominent influencer of artistic taste, publically promoted the

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204 Laugier was widely read during his lifetime. His intellect and architectural tastes were praised by the highly influential Abbé Leblanc, advisor to Madame de Pompadour, and Madame de Pompadour’s brother, the Marquis de Marigny (the Directeur des Bâtiments). See Herrmann, Laugier and Eighteenth-century French Theory, pp. 15 & 18.


Gothic style and the ‘spirit’ with which Gothic structures were raised. As an art and architectural enthusiast, who also read French, it is likely that Ruskin was familiar with Laugier’s essays on architecture (although Ruskin makes no mention of Laugier in his published works). Although certain aspects of their approach differ, particularly regarding Laugier’s philosophy of enlightenment urbanisation, there are striking similarities between the two men’s consideration of the structural unity of architectural parts (which is reminiscent of Ruskin’s ‘Law of Help’, which will be discussed later on in the chapter) and in their appraisal of Gothic architecture. Laugier respected the grandeur and airy atmosphere that pervaded Gothic buildings, praising their gracefulness, simplicity and naturalness, although he looked less favourably upon the grotesque ornamental excesses. Ruskin also included naturalism as an essential tenet of the Gothic; however, unlike Laugier, he saw the abundant natural forms expressed through Gothic ornament as organic forms that represented the entirety of nature, which included the dark, savage, excessive and grotesque. Although these ornamental excesses were abhorrent to Laugier, Ruskin takes a similar stance to Alberti by arguing for the synthesis of ornament and structure. He does this by uniting the Albertian ‘bones’ of the structure with the ‘skeletons’ taken from nature.

ORGANICISM AND THE ENERGY IN NATURE: JOHN RUSKIN

John Ruskin, the nineteenth-century social critic, historian, draughtsman and patron of the arts, held that connections with the divine were made possible through natural forms, and stressed that nature was not to be confined to the decoration but should embody the entirety of a structure. For Ruskin, structure and ornament were one and the same, the two categories merging in a unified and ‘organic’ whole. For Van Eck

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208 Laugier considered the city of Paris to be a stagnant place with narrow streets, ‘miserable avenues’, and poorly built dwellings. He believed that destroying the old buildings and infrastructure would make the ‘ideal’ city (an open and rational space) and would improve both the aesthetics and hygiene of city. See Laugier, *Essai sur l'architecture*, 1755, p. 209–21. Laugier’s position would be realised by Hausmann a century later. See Alexis de Hillerin, ‘La recherche du beau ideal dans l’*Essai sur l’architecture* de l’abbé Laugier’, p. 427.
this position is the essence of organicism. In Ruskin’s own account, drawing provided a means of seeing the ‘composition’ of nature. In the following sections, I will analyse a selection of Ruskin’s drawings in which I perceive a composition of organic ‘wholeness’ or articular unity, as I consider his drawing as a cognitive process from which sprung the ‘skeleton’, an abstract line that Ruskin would consider as ‘aweeful’. I will then discuss the significance of the skeleton metaphor in Ruskin’s writings and of its subsequent effects in the mid- to late-nineteenth century. I will argue that the term ‘skeleton’ became for Ruskin a means for seeing the structure of nature.

The skeleton metaphor was introduced as part of Ruskin’s particular observational and perceptive power. The literary critic and art historian Elizabeth K. Helsinger argues that, for Ruskin, ‘the metaphors express visual information important to the painter-topographer in the form of a strong distinctive impression, a central thought that is the mark of imaginative vision’. Yet the metaphor of the skeleton gave more than a strong impression, and it was less imaginative that other poetic metaphors and ‘pathetic fallacies’ employed by writers and poets. The term ‘skeleton’ invokes the very essence of a thing; the very lines of its make-up, the essence of its structure. I contend that Ruskin utilised the skeleton as a metaphor in unifying the natural world with the man-made, the ornament with the structure. It is a theory of construction that has yet to be proposed nor discussed within art-historical discourse. I argue that the skeleton is a highly significant metaphor as it becomes a term for addressing structures in nature – from the human or animal body to plants and rock formations. In fact, as I

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209 The first type of organicism is ‘a close relation between art and living nature’. The second type is an ‘organic unity’ into a conceptual whole. See Van Eck, *Organicism in Nineteenth-century Architecture*, p. 20.  
210 Helsinger, *Ruskin and the Art of the Beholder*, p. 32.  
211 Ruskin’s ‘pathetic fallacy’ can be summarised as poetic fancy, or emotional distortion introduced in the description of the appearance of things: ‘All violent feelings have the same effect. They produce in us a falseness in all our impressions of external things, which I would generally characterize as the “pathetic fallacy”’. See Ruskin, *The Complete Works*, v, p. 205. Ruskin takes the poet Coleridge as an example: ‘The one red leaf, the last of its clan; that dances as often as dance it can’. Ruskin explains that Coleridge fancies that the leaf has a life and a will of its own. Yet a dying leaf is powerless – it does not choose to ‘dance’. There is also the contradistinct substitution of death with merriment, and the wind with music (*The Complete Works*, v, pp. 206–7). Also see George P. Landow, ‘Ruskin and Allegory’, in *Aesthetic and Critical Theory of John Ruskin* (Princeton: Princeton University Press, 1971), pp. 321–457 (pp. 378–87).
will argue, the metaphor becomes a framework for seeing organic entities in a particular way.

*The Complete Works of John Ruskin* were published posthumously (1901) in thirty-nine volumes, comprising of his books, hundreds of papers and lectures along with thousands of drawings, letters and other *Ruskiniana*. His most renowned compendium on art and artists was *Modern Painters*, initially published in five volumes from 1845 to 1860, and his most celebrated treatises on architecture were *The Seven Lamps of Architecture* (1849) and *The Stones of Venice*, which first appeared in three volumes over 1851–1853. In the ensemble of his *Complete Works* Ruskin uses the word ‘skeleton’ more than a hundred times. He applied the word in a variety of ways, both in the literal-anatomical and in the metaphorical sense, and across a range of subjects from rocks and mountains via natural history to architecture and from botany to ornament. Yet the story of Ruskin’s skeletons begins in his youth with his perception of the fundamental lines in nature; the forms that make up the topography of the earth, and the lines of growth in a tree. By Ruskin’s own account, it was through the act of observing and drawing forms from nature that he was able to perceive the lines from which nature was composed.

In the second volume of his autobiographical work *Præterita* (1886–89), Ruskin recalls a moment in 1842 when, as a young adult, he was travelling in Switzerland. Whilst journeying through Fontainebleau he attempted to draw an Aspen tree. In later life Ruskin recollected the significance of this moment for having changed his perception:

Languidly, but not idly, I began to draw; and as I drew, the languor passed away: the beautiful lines insisted on being traced, – without weariness. More and more beautiful they became, as each rose out of the rest, and took its place in the air. With wonder increasing every instant, I saw that they ‘composed’ themselves, by finer laws than any known of men. At last the tree was there, and everything that I had thought before about trees, nowhere.212

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Ruskin was following the lines of growth and these lines informed the eventual shape of the tree. This passage provides many clues concerning Ruskin’s vision of nature, not just how he perceives its wondrous beauty but also its unfathomable depths, as beyond the laws of men, inferring that nature is a composition with intelligently composed rhythms and harmonies. It is suggested by the Ruskin scholar Alan Davis that this moment heralds the start of Ruskin’s quest for an organic vision in both art and architecture, for it is in the process of drawing that his perceptions were sharpened and his method of drawing shifted from the picturesque to the naturalistic – forms taken from nature without a preconceived notion of how they should be reimagined. However we should remain sceptical of this narrative. *Præterita* was the last work that Ruskin had published. Suffering from long and recurring bouts of ill heath, he was looking back on his youth through a lens coloured by forty-five years of life experience, transitioning from a relatively unknown novice in art theory to a celebrated sage. It was a period (from the mid- to late-nineteenth century) that included dramatic scientific and technological advances, such as Darwinism and the invention of mechanical photography. Davis seems uncritical of Ruskin’s autobiography. Ruskin does not acknowledge a sharp shift from the picturesque to the naturalistic as he still engaged with the picturesque in *Modern Painters*, in both artist practice and theory. However, I do think that Ruskin favoured information from nature over the impression of a picturesque landscape, that his conception of nature was translated through his perception of natural forms, and that his drawing process, as well as his use of language (particularly metaphor) was his mode of translation.

Although the original drawing to which the description pertains has not yet been identified, we can attempt to understand Ruskin’s thought processes by applying the aforementioned passage by Ruskin to his 1845 drawing of a tree (figure 1.8). The drawing was made in pencil and black ink on a large sheet on blue paper. The scene appears to be more of a woodland coppice than of a particular tree. The centre of the drawing possesses the darkest swaths of colour and the more concentrated lines, which resemble the roots or branches of a gnarled and twisted tree. The darkness is almost menacing – a strange beast could be emerging from the centre rather than harmless branches. The lines make up the various tree forms, yet it is the shading with dark ink that solidifies and situates the lines in space. It appears that Ruskin began the

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drawing in the centre of the sheet of paper, in the place where the tree grows from the rock. Working upwards, following the curved ‘composed’ lines of tree growth, the rock seems to anchor and shape the thicket’s life. The botanist and Ruskin scholar David Ingram commends Ruskin’s observational technique, adducing the time of year to be autumn and the trees to be a silver birch and an ash or rowan.  

Davis describes the drawing as an unfinished sketch – rough and imperfect – all attributes of ‘savageness’. He also considers it disordered, unstructured and experimental – identifiers of ‘changefulness’. This is Davis’s attempt at linking Ruskin’s drawing process with his organic perception of the Gothic style, which includes the qualities of savageness and changefulness, as I shall discuss later in more detail. I suppose the image could be interpreted as a metaphor for how the first Gothic architecture was built, from nature twisting around stone. And indeed I agree with Davis in regards to the incomplete nature of the drawing, but I would not suppose it rough or unstructured just because it is unfinished. I perceive a delicacy in the application of ink, and intentionality to the composition. The drawing is organic but not in the way Davis describes. I perceive in the drawing the process of organic growth, like a seed that has begun to germinate, latent but with the potential for life. Generative energy seems to be drawn from the attentiveness of the drawing process itself, until we are presented with something that has composed itself into the living network of a tree.

In his analysis of Ruskin’s drawings of natural phenomena, Paul H. Walton interprets Ruskin’s conception of nature as the ‘visible signs of an impulse that moves everywhere, in accordance with the divine law […]. Ruskin now saw this vital current widespread, so that to his eyes, nature was no longer a more or less haphazard collection of forms, waiting to be transformed by the artist into images of ideal harmony, but a living organism shaped from within by forces that imposed a common

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harmonious visual rhythm on rock, and cloud, and wave’. Rhythms and forces; impulses and movements; Ruskin’s organic vision or ‘truth’ was nature in motion, never suspended, sometimes imperceptibly slow, sometimes fleetingly fast but always in rhythmic motion. It was these rhythms that produced the lines and patterns in nature that Ruskin searched for. He candidly acknowledged that his drawings would never be the picturesque compositions of other artists, such as those made by his travelling companion, James Duffield Harding, during his 1845 European tour, but his drawings could become far more valuable. In a letter to his father, Ruskin referred to the sketches he had made in his notebook: ‘[M]ine are always ugly, for I consider my sketch only as a written note of certain facts, and those I put down in the rudest and clearest way as many as possible. Harding's all for impression – mine all for information’.

Ruskin’s process of drawing from nature proved to be vital for transforming his art, whilst also acting as an experiential aesthetic over an intellectual, and allowed him to see things that remained otherwise invisible. This was a view that Ruskin would continue to extol in his role as a lecturer in Fine Art at the University of Oxford. In an 1861 lecture titled ‘Trees and Twigs’, Ruskin presented the growth of the tree as a reflection of the divine order and as a model for the good and moral growth of architecture and society. He would direct his students to look at the way the trees and leaves grew in order to help them understand the laws, rhythms and harmony of organic growth. Davis contends that through Ruskin’s studies of nature, his visual perception turned into a holistic appreciation of nature’s forms and he began to realise that it was less the detail of an image or object that was important but the way the image/object grew into a unified whole to become more than mere surface. However, there is a sententious side to this argument that Davis appears to have overlooked. Andrew Leng contends that from 1860 onwards, trees were of particular significance for Ruskin. Leng argues that Modern Painters vol. v, more especially the chapter titled

216 Paul H. Walton was unable to identify the particular drawing of the tree that Ruskin described in Præterita. His analysis is based on other drawings of plants and trees that were undertaken around the same time. See Paul H. Walton, The Drawings of John Ruskin (Hacker: New York, 1985), p. 60.
218 Ruskin, ‘On Leaf Beauty’ and ‘A Lecture on “Tree Twigs” (Delivered at the Royal Institution, April 19, 1861)’ in Modern Painters vol v, taken from The Complete Works, vii, pp. 13–130 and 467–478.
‘The Origin of Wood’, was a response to the secularisation of society and a coded re-writng of Charles Darwin’s *On the Origin of Species*, first published in 1859.\(^1\) Darwin used a metaphorical tree – a dendrogram – as a device for visually presenting the shared origins of life on earth, and life’s continuous struggle for existence. Nature was a temperamental and ferocious beast, ‘red in tooth and claw’, fighting for survival.\(^2\) Ruskin believed that Darwin had declared war on nature, which he considered to be an unpardonable act of hubris, and thereby challenged and appropriated the tree of life for himself. He presented numerous sketches and schematics of trees, marvelling at their botanical geometry and composition, and referring to the intelligent nature of their design. Yet by seeking to counter what he considered to be Darwin’s conceit at every opportunity, Ruskin’s polemical discourse inadvertently complied with a Darwinian framework.\(^3\) Davis analysis of Ruskin’s drawings and diagrams of trees, c. 1860, takes none of this into account and yet, as Leng argues, contextualising Ruskin with scientific discourse adds insight into Ruskin’s arguments.

In 1860, the year after the publication of *Origins*, Ruskin released the last volume of *Modern Painters*. In the chapter ‘The Law of Help’, Ruskin presented the ‘last and the most important part of our subject’, that subject being art and its relation to ‘God and man’.\(^4\) One could conceive of ‘The Law of Help’ as the study of relations such as the relations between ‘material or formal invention’ – the technical composition, the arrangements of lines, forms, colours – as well as the relations between ‘expressional or spiritual invention’. Expressional or spiritual invention is harder to define, but

\(^1\) Andrew Leng, ‘Ruskin’s Rewriting of Darwin’, *Prose Studies*, 30(2008), 64–90 [doi: 10.1080/01440350801939526]


Ruskin identified it as the ‘delight’ felt from art, where the viewer ‘rejoices’ in the arrangement, composition and the sense of completion and wholeness. This sense of wholeness takes into account the making ‘process’ that lurks behind every composition, arrangement and assemblage in art. It is not an additive as such; it cannot be conjured into the art, but it is understood by Ruskin as the complicated relation between a medium and craftsman, and, as I perceived in the drawing *Tree Studies*, an energy born from its creator. As Ruskin wrote, ‘to create anything in reality is to put life into it. A poet [maker], or creator, is therefore a person who puts things together, not as a watchmaker steel, or a shoemaker leather, but who puts life into them’.  

In this way pictures are still and not still, and the material, composition, lines, colours, forms, sense of completion and ‘process’ lend a vital yet inexplicable animation to the artwork.

Ruskin’s theory of composition is also applicable to nature (as perceived by Ruskin on his way to Fontainebleau when he drew the Aspen tree) and in architecture. Composition, from the Old French *componere*, means ‘to put together’, and is a guiding principle for Ruskin in his art and architectural criticism. In his own words, ‘[e]very great work stands alone. Yet there are certain elementary laws of arrangement’.  

Ruskin defines it himself as the ‘help of everything […] by everything else’ in order to approach ‘completeness’. It includes the action of putting things together – the process – through formation or construction. The notion of ‘help’ means to assist, to make easier, or to be of use, and is applied not just to the assemblage as a whole, but to the parts and their relations or sympathies with each other. For Ruskin, inanimate homogenous substances such as rocks or clouds do not ‘help’ each other, as a removal of one part will not injure the whole. They are helpless or ‘lifeless’, and far removed from an ecology of relations. However, ‘hurt or remove any portion of the sap, bark, or pith, the rest is injured’. The plant is animate and ‘helpful’, and ‘the power which causes several portions of the plant to help each other, we call life’.  

The intensity of that life is directly proportional to the intensity of helpfulness, and the dependence of each part on rest, so that ‘we may take away the branch of a tree without much harm to it; but not the animal’s limb’.  

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223 Ibid., p. 215.  
224 Ibid., p. 204.  
225 Ibid., p. 205.  
226 Ibid.
Ruskin perceives in the animal relate to its dynamism, energy and life force? Or does ‘intensity’ relate to its precarious nature as it battles for survival? In a potential response to Darwinian pessimism, Ruskin considered help as part of the divine nature in all things, and that life is in action, in a process of ‘helpful’ becomings. He rejected the idea of nature as a battleground. Instead, nature was composed by the ‘Helpful one’ or ‘the Holy one’, meaning God and life giver, and is therefore governed by ‘The Law of Help’, the law of life. For Ruskin, the ‘anarchy and competition’ of Darwinian natural selection followed ‘the laws of death’.227

I conceive of the processes, sensation and feelings that Ruskin described in ‘The Law of Help’ as *articulations* between parts or members, bringing things together and allowing them to achieve their potential by uniting and animating them. This is especially profound when Ruskin defines help as ‘life’, and death as helplessness and ‘separation’.228 In a similar way, the art historian Jeremy Melius describes the sense of relations between parts, or the ‘relationships’ perceived in artworks, as ‘chains of feeling’ in which a hierarchy of affection can be discerned and linked through chain-like connections. And although such feelings seem ‘enchained’ at first, the chains can potentially break apart to reform into other articulations, and this potential for breaking apart and reassembly gives generative dynamism to the artwork. The realm of possibilities remains open, which gives a kind of ‘elastic rationality’ to the artwork.229

I interpret Ruskin’s watercolour *The Walls of Lucerne* (c. 1866) as ‘articular’ in nature. In the past it has been considered to be ‘among the most successful of Ruskin’s attempts to represent his perceptions of the organic unity of nature’ (figure 1.9).230 Yet there is very little ‘nature’ present as the subject of the watercolour is a human built wall. The sky is awash with varying intensities of blue and grey, the colour more intense and denser around the central wall turret. There is an awkwardness or imprecision in perspective, moving from the central turret to the right of the scene. It is unclear if the wall is horizontally straight or if it is receding. The size of the wall crenulations remain the same, which would indicate that the wall is being viewed and

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228 Ibid., p. 207.
229 Jeremy Melius, Lecture on ‘Ruskin and the Art of Relations’, *Tomás Harris Lectures*, 25 October 2018 (University College London).
drawn straight-on, and that the wall is dipping downwards instead of receding, with the merlon caps of the crenulations having been made at an oblique angle. Added to this is the optical effect caused by the sudden change in tone and colour gradation, from sepia brown to a brilliant white, with soft pastel blues and grey. This chromatic shift creates a visual tension, both pulling the wall forward in the lighter areas and pushing it back in the darker sepia-brown areas.

Although most observers would judge the watercolour as unfinished, Alan Davis considers the work as complete in its organic purpose. He describes the drawing’s unity, ‘linking points’, wholeness, and ‘dynamics of growth’, to suggest that Ruskin’s process in creating the drawing is as organic and the nature it depicts.\textsuperscript{231} However there are points of contention, the first being the type of growth inferred. Is it animal, rhizomal or floral? Is it a physical growth, like the widening of a river, or a psychic maturation? Organism’s grow differently at every stage of their development. Growth also infers a kind of movement or transformation, of generation or degeneration. How is this imagined? The second point of contention regards the dynamics of growth. Assessing the direction, rate or magnitude of this perceived growth is challenging, unlike in Ruskin’s drawing of a tree (figure 1.8), which has a clear epicentre from which Ruskin worked outwards. The Walls of Lucerne is composed very differently. A large portion of the page – the lower right quadrant – is bare of line or colour. The composition is rather haphazard, without purposeful centrality or vanishing points. Although Davis’s language and visual analysis is imprecise, I do detect a kind of growth from the left of the watercolour to the right, in the progressive articulation of (wall) units into a whole like the individual vertebrae of the backbone being articulated together, one on top of the other. The Walls of Lucerne is the backbone of the watercolour, the essential structural line that follows the earth’s topography.

Another drawing that I consider expressive of Ruskin’s composed vision of nature is his drawing of trees titled Trees and Rocks, c. 1845 (figure 1.10). It is a drawing full of energy in both the penmanship, with its twisted dark lines, and in the rapid application of wash. These washes of brown and grey provide depth and solidity to the observed natural forms. Tall, upright conifers are drawn in the middle and distant hills. David Ingram has praised Ruskin’s observational skills, managing to identify an

\textsuperscript{231} Ibid., p. 6.
evergreen silver fur, a Norway spruce and a deciduous European larch, with wood sorrel in the foreground.\footnote{Ingram, ‘Trees and Rocks: Ruskin's Botanical Drawings’ [n.d], Ruskin Library and Research Centre <http://www.lancaster.ac.uk/users/ruskinlib/Flora/1996P1566.html> [accessed 10 March 2017]}

The intensely curved black branches of the tree in the centre look as if they have been bowed into shape by the continuous blowing of a strong easterly wind. The trees and shrubs are composed of repetitive curved lines juxtaposed against the sky, with hills and more trees in the background. These lines are repeated in the rocks covering the lower left of the drawing. The lines of nature echo throughout every part of the composition. It is reminiscent of Alberti’s concept of beauty – of a connection between parts and the unification of lines into a whole. Each line seems connected in a way that is ‘helpful’ to the composition of the whole, and in manner that animates the image.

Ruskin consistently looked for the lines in nature, remarking that an observer of nature must seize upon ‘every outline and colour’.\footnote{Helsinger, Ruskin and the Art of the Beholder, pp. 24–5. Also see Ruskin, The Complete Works, III, pp. 258 & 253.} Just at the process of drawing sharpened Ruskin’s perceptions, he began to see in the natural forms and formations that he was observing and subsequently drawing a kind of repetition of line and shape; the expression of similar patterns within various natural phenomena. He expressed these lines in a drawing he titled Abstract Lines, printed in 1851 in The Stones of Venice vol. 1 (figure 1.11). Various lines curl, twirl and float across the page. Some lines are jagged, like the topography of broken rocks or mountains, whilst others are supple and sinewy. Some of the lines are continuous, whilst others bifurcate or branch repeatedly. These were Ruskin’s lines of nature. In great cloud formations billowing through mountainous regions, Ruskin saw the waves of the sea breaking against jagged rocks. The clouds not only looked like waves in his drawings and watercolours, they were waves. In his verbal accounts he also saw, for example, cresting waves in the façade of St. Mark’s in Venice.\footnote{Ruskin, The Stones of Venice vol 1 (3 vols), taken from The Complete Works, IX.} Such a resemblance of form linking natural phenomena and architecture can be discerned in many of Ruskin’s sketches made during his European tours. The process of drawing not only fostered associations between natural forms – it also enabled Ruskin to develop the descriptive potential of metaphors in his writings, as he freely applied metaphors to nature, art and architecture. Ruskin was an
exceptionally influential writer and art critic, and his organic metaphors were quickly absorbed into the descriptive and critical language of the day.235 His influence is still felt today in the language of art and architectural discourse to the effect that certain words, tones and inflections of language can be termed ‘Ruskinian’. 236

Elizabeth K. Helsinger contends that Ruskin gave motion to the landscapes he described through the use of constant and multiple verbs and verb forms so that ‘every element seems to vibrate or, more exactly, to shimmer and scintillate in a dance of light’.237 Certain metaphors dominate throughout Ruskin’s works, particularly in his diaries and in Modern Painters. These metaphors provide the manifestation of ‘inner energy’ to the objects in nature, such as fire, rock, and the sea – all elements possessed of energy.238 Ruskin detected the living power or force felt in all things, and made no sharp division between animate and inanimate nature. Light and colour mark the presence of energy, be it energy expended through growth or energy exhausted through decay. However, Helsinger does not list the skeleton metaphor amongst them, which I consider an oversight on her part.

For Ruskin, the engagement with the art of his contemporary Joseph Mallord William Turner (1775–1851), allowed for an exploration of the resemblances between animate and inanimate nature, and to simultaneously argue for the organic nature of painting. He sang Turner’s praises in the first volume of Modern Painters and would continue to do so for the remainder of his life, constructing a portfolio of ekphrastic organic metaphor for use in his critical writings. Numerous historians such as Mark Frost and Stephen Kite have discussed Ruskin’s application of organic metaphor.239 The


236 One such Ruskinian writer is the art historian Kenneth Rexroth, who wrote the following regarding J.M.W Turner: ‘Turner painted, at least in his maturity, dynamic saturated space, all the force if which were organically related like the strains and stresses, vacuoles, vortices, and pseudopods which make up the living process of an amoeba. Even in the heroic paintings, Ulysses is a scrawl of colour, Polyphemus a cloud’. See Kenneth Rexroth’s essay ‘Turner: Painting as an Organism of Light’, in Bird in the Bush: Obvious Essays (New York: New Directions, 1959).

237 Helsinger, Ruskin and the Art of the Beholder, p. 31.

238 Ibid., pp. 31–32.

239 Ruskin’s Modern Painters vol I, taken from The Complete Works, III. See Mark Frost, ‘The Everyday Marvels of Rust and Moss: John Ruskin and the Ecology of the
architect and historian Stephen Kite utilised linguistics as a framework for his appraisal of Ruskin’s oeuvre, stating that ‘as buildings are to be read, texts are built’. Kite, building upon the writings of Elizabeth Helsinger, explores the rich and formulaic use of analogy and metaphor by Ruskin in his description of building, architecture and architectonics, claiming that the city is a ‘space where buildings are analogised as texts’. Kite associates the metaphors of text and language with architecture. Both books and buildings require reading and structuring, and both are constructed to possess ‘tectonic and spatial character’. Kite describes how Ruskin began to draw in the same manner that children learn to read, stating that for Ruskin ‘word building becomes picturesque image building’. However, Kite fails consider the restrictive framework that the text imposes upon the image, nor does he address the deviant nature of both words and materials, which cannot always be controlled. I concur with Davis, who argues that Ruskin’s landscapes were heavily influenced by the works of Turner in their abolition of an ordered indexical surface to a visual sublime and noble line. Davis illustrates this point with a series of Ruskin’s own sketches in which he draws lines from a range of natural phenomena such as mountainous verges, arbores branches, a willow leaf and other such flora. Quoting Ruskin, Davis writes that ‘such natural lines “are expressive of action or force of some kind” and it is this character that breathes life into artistic design’. 

Ruskin dwelt upon the idea of the line capturing the essential form of the object/subject throughout his life. He seized upon these lines, naming them the ‘aweful lines’, which are to be extracted from whatever form is being contemplated. These are the lines that show the history of an object, as well as its present course and its futurity. They are lines of action:

Try always, whenever you look at a form, to see the lines in it which have had power over its past fate and will have power

240 Ibid., p. 418 (Kite’s emphasis).
241 Helsinger, Ruskin and the Art of the Beholder, p. 212: ‘[Ruskin] formulates for himself a critical identity to which reading is central’.
242 Ibid., p. 419.
243 Davis, Ruskin’s Organic Vision, p. 9, quoting Ruskin in The Stones of Venice vol 1, taken from The Complete Works, ix, Chapter 9, p. 267.
over its futurity. Those are its aweful lines; see that you seize on those, whatever else you miss. 244

In a botanical sketch by Ruskin titled *Study of a Lettuce Thistle*, 1854 (figure 1.12), two spiky leaves with their associated stalks are depicted. The ink sketch is likely an observation from living nature, the lack of artistic finesse and detail indicative of rapid study, and a patchy blue wash of ink indicating an outdoor location. Sharp undulating U-shaped lines fill the bottom of the page, their spiky forms like that of the thistle leaves above. At the bottom of the page, in the lower margin, is a scrawl of text in Ruskin’s hand: ‘Everything depends on *this* action.’ I assume that Ruskin was referring to the action of drawing and, in particular, to the repetitive tick-like lines to the side of the sketch that echo the tick-shaped edges on the prickly leaf. The lines of growth and the characteristic spiny edges of the leaf pattern – the form – are the result of action. Ruskin’s method of capturing this action is evident in the thin, sharp and decisive outline of the leaf. In *Study of a Lettuce Thistle*, the drawing process is the action, and the repetition of tick-like lines re-enact and become analogue to the growth in nature.

It would be easy to assume that by *action* Ruskin also meant function, a term heavily discussed within secular writings on natural philosophy (and later in physiology, the science of function in living systems) and which would bring together the writings of Ruskin with contemporary science; however, action has a very particular meaning separate to function. Functions were mechanical and utilitarian; action implied life and force, growth and time. The ‘aweful lines’ of the lettuce thistle are lines of action, and it is these lines that must be extracted from nature for the essence of form to be captured.

244 Ruskin, *The Stones of Venice* vol i, in ibid., ‘Sketching from Nature’, ii, Chapter 15, p. 91. For the use of abstract lines in decoration, and the transference of natural contours to architecture, see ibid., iv, p. 266–70. For the abstraction of mountain lines, see ibid., vi, pp. 335 & 339–40. For the governing lines in trees, see ibid., xv, pp. 91–6 & 116.
LINE, ABSTRACTION, ORNAMENT

Metaphors are, of course, always an integral part of language. What is specific about Ruskin’s use of metaphor is the way he employs it to draw connections between the natural world on the one hand and art and architecture on the other. Mark Frost argues that ‘Ruskin did indeed attempt to ally conceptions of environment drawn from Christianity, Romanticism, and science, but these were incapable of stable conjunction’.

Yet he looks at Ruskin’s works through the lens of a very specific interpretation of Ruskin’s organicism and puts little emphasis on the language as such. This language can be constructive or destructive to their argument and is thus interpreted as being a mere rhetorical device. The instability of nineteenth-century investigations of nature begged for some sort of unifying essential theory within disparate fields of interrogation. Ruskin’s determination to uncover ‘a natural realm, complete, coherent and unbroken’, resulted in his frequent application of metaphor, which could act as a unifying device in the simplest of terms.

He needed a metaphor which conveyed the essence of nature but which was also not fixed in a concrete homonymic form, thus enabling the genesis of a variety of conceptual forms and an application within a variety of fields of interrogation. He needed a skeleton.

The skeleton as being indicative of the ‘bare outline’ is reported to have been first recorded c. 1600, which is where such terms as ‘skeleton crew’ (1778) and ‘skeleton key’ derive their meaning. As such, the skeleton as being what is essential entered into the conceptual, metaphysical realm and became the paradigm for extracting the essential components to any system of thought – real or imagined – from which something can be built upon. With the skeleton as a metaphor, Ruskin was able to unite natural phenomena and artifice by reducing everything down to an essential line, in a manner similar to William Gilpin (1724–1804) in his search for the lines of the picturesque, William Hogarth (1697–1764) with his ‘line of beauty’, and Edmund Burke (1729–1797) in his lines of sublimity. Ruskin had certainly read Hogarth and was likely familiar with the work of Gilpin and Burke (although their published contributions were absent from the inventory of Ruskin’s library). Ruskin took the

246 Ibid., p. 10.
skeleton as a recognised anatomical and abstracted noun and metaphor, and reduced it to a line.\textsuperscript{248}

In Ruskin’s work, the essential line was both real and conceptual. By conceptual I mean that the visual recognition attributed to the metaphor has become eroded and can at times be lost, for the very thing that identifies the noun – the three-dimensional articulated bones – has become a two-dimensional line that may be continuous or that may intersect with other lines. The skeleton in its linear form – the abstracted essential line – was also described by Ruskin as the governing line (in regard to arboreal forms) and the ‘aweful line’ of landscape, perhaps drawing inspiration from Gilpin and Burke and the sublime \textit{horrou} of mountains.\textsuperscript{249} Ruskin believed that in identifying form, be it natural or man-made, the aweful lines must be seized upon so that the essence of form – what is essential to the form – can be grasped. The most beautiful lines, Ruskin asserted, are those found in nature, ‘their universal property being that of ever-varying curvature in the most subtle and subdued transitions, with peculiar expressions for motion, elasticity, or dependence’.\textsuperscript{250} Such expressions are reminiscent of Hogarth’s line that ‘waves’ (the wavy and the serpentine line) and Burke’s lines of beauty.\textsuperscript{251}

In relation to ornament, Ruskin looked firmly to nature for recognition and inspiration in design. All forms should be taken from nature, representative of her beauty and

\begin{footnotes}
\footnotetext[249]{Edmund Burke, \textit{On the Sublime and Beautiful} (Boston: The Harvard Classics, 1909–14), and William Gilpin, \textit{Observations relative chiefly to the Picturesque Beauty, made in the year 1772 on several parts of England; particularly the mountains and lakes of Cumberland and Westmoreland}, i (London: Blamire, 1786), p. 191.}
\footnotetext[250]{Ruskin, \textit{The Stones of Venice} vol i, taken from \textit{The Complete Works}, ix, Chapter 9, p. 267.}
\footnotetext[251]{William Hogarth dubbed this the line of beauty and the line of grace. See Hogarth, \textit{The Analysis of Beauty: Written with a View of Fixing the Fluctuating Ideas of Taste} (London: Samuel Bagster, 1753).}
\end{footnotes}
variation. The sculptures and carvings should not necessarily attempt a mimetic representation of nature’s morphology, but should embody the abstract beauty of natural forms, and be executed in the spirit of true craftsmanship. For Ruskin, this was a Gothic trait. In *The Stones of Venice* vol i, Ruskin writes that all noble ornament is ‘the expression of Man’s delight in God’s work’. Anything else taken from outside of nature is ‘painful’ and ‘base’. He continues along the same vein throughout, stating that the material of ornament is everything God has created, material being both physical and inspirational. When addressing Gothic archivols, in terms of the lintel, Ruskin contends that there ‘is no organism to direct its ornament […]. But the arch head has a natural organism’. The term ‘organism’ seems to refer to an energy that Ruskin perceives within the structural elements of the Gothic architecture. He infers that this energy is required for ornament, and that the straight-lined lintel is somehow deficient. Yet the Gothic arch – two serpentine lines that converge to a point – possesses a natural energy. It appears that curved lines, resembling lines from nature, possess energy whilst straight lines do not. One could imagine this line of tension in the arch of a bridge. The stones of the arch are locked into place by the keystone at its apex, which holds all the stones in place. Without the keystone, the other stones in the arch will fall. It is the forces within the stone, and the forces that the stone is capable of withstanding that drives the form of the structure, which is why the Gothic arch is so often compared to the shape of a growing leaf whose morphology is determined by internal and external forces.

In *The Stones of Venice*, Ruskin describes the ‘lines’ of nature, providing an example in the form of a leaf with its veins and spiral-growth patterns marking ‘the forces of growth and expansion’. Ruskin perceives such forces as lines. These lines can then be extracted from the leaf and become represented within ornamental carvings and abstract patterns. He refers to this type of abstraction as ‘noble’ and ‘truthful’. Ruskin’s assumption of a truthful natural aesthetics proved highly influential in the second half of the nineteenth century. In particular, the members of the Pre-Raphaelite brotherhood were desirous for a return to the beauty and truth of nature. Inspired by stories from the bible, the prose of William Shakespeare and the poetry of Alfred Lord Tennyson,

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253 Ibid., p. 389.
254 Ibid., p. 268.
these artists attempted to paint moral narratives of a chivalrous nature, subject matter that was exceedingly popular amongst the romantics of Victorian society. The supple and sinuous lines of trees and flowers were brought together with the succession of young and beautiful women, the epitome of Victorian loveliness and femininity.255

What is so interesting here is that Ruskin, in his quest for organic unity and the awful lines of nature, seized upon the most essential lines. These essential lines were often abstractions of the morphological ‘outline’ of natural entities or landscapes, such as leaf forms and jagged mountainscapes. Other times, these lines singled out the inner parts of the form that indicate directional growth, structure and survival, such as the veins in leaves and the spirals of shells. It was only from the essential lines that the true form of nature could be abstracted and represented on a page, carved into a stone or hammered into iron. I contend that it was from these very lines – lines that originated from an organic nature – that Ruskin conceived and developed his skeletons. Ruskin first began to perceive such skeleton lines in his initial critical appraisal of art works and architectures.

RUSKIN’S SKELETONS

In the first volume of The Stones of Venice, Ruskin looked back to the ruins of Venice in an attempt to save the Gothic legacy for England. Ruskin describes Venice along the grand tradition of metaphorical rhetoric. It has towers that rise ‘as a branchless forest’.256 Its architectures are fascinating to Ruskin as they consist of an amalgamation of styles. The location of Venice as the central port with links to the northern continent, the south of Italy and Byzantium, situated the city at a crossroads. It was Ruskin’s


opinion that the distinct Roman, Lombard and Byzantine cultures broke like waves upon the stones of Venice, creating buildings in a fusion of styles and a variety colour palettes.\(^{257}\) While appreciating the diversity of Venetian architecture, Ruskin favoured the Gothic style and takes most of his examples from this period. However, his arguments were structured so as to be applicable to all forms, as he looked for the principles not the styles of architectures.

The first chapter is titled ‘The Quarry’. Stephen Kite suggests that this chapter title refers to both a literal and a metaphorical quarry. It provides the material (literature, art history, architecture, classics, etc.) from which Ruskin mined and constructed his understanding of Venetian architecture, more especially that of Gothic architecture. Kite suggests that this chapter sets up the linguistic building blocks for constructing the entirety of *The Stones of Venice*.\(^{258}\) This chapter draws upon architectural theory and begins by introducing two of the classical orders – Doric and Corinthian – and their derivative forms. The subsequent chapters, heavily illustrated with Ruskin’s own sketches, describe in enormous detail the multiple parts and forms that make up a building. Some chapters are dedicated to the individual architectural elements such as ‘the wall base’, ‘the shaft’, ‘the capital’, ‘the arch line’ and so forth.

Ruskin is swift to reassure the reader that his evaluation of Venetian architecture is not necessarily the definitive answer to the questions of what components constitute good or bad architecture. There are bound to be alternative perspectives and interpretations, just as, he says ‘Zoologists often disagree in their descriptions of a curve of a shell or the plumage of a bird’.\(^{259}\) The fact that Ruskin uses this analogy with Zoology is telling. He was well informed of recent debates and breakthroughs in such fields as Comparative Anatomy, Zoology, Paleontology, Geology and Botany, as is evidenced by the contents of his personal library and his correspondences with leading figures in

\(^{257}\) ‘I would endeavour to trace the lines of this image [of Venetian architecture] before it be for ever lost, and to record, as far as I may, the warning which seems to me to be uttered by every one of the fast-gaining waves, that beat, like passing bells, against the Stones of Venice’. See Ruskin, *The Stones of Venice* vol i, taken from *The Complete Works*, ix, Chapter 1, Sec. 1.


\(^{259}\) Ruskin, *The Stones of Venice* vol i, taken from *The Complete Works*, ix, Chapter 1.
science, such as the zoologist and palaeontologist Richard Owen, who made important contributions to comparative anatomy, and the geologist Charles Lyell (who Ruskin had also met). An amateur naturalist himself, Ruskin would later write his own treatise on birds (Love’s Meinie), flora (Proserpina) and mountains (‘Of Mountain Beauty’ in Modern Painters vol IV) becoming a recognised and respected voice in Ornithology and Geology. Ruskin carried Georges Cuvier’s Le Règne Animal with him whilst traveling through Italy, being perhaps more sympathetic with Cuvier’s Catastrophe theory over the secular debates regarding Lamarckian evolution due to his Evangelical beliefs. Cuvier’s rhetoric is noticeable in his many descriptions, and in his use of biological terminology and metaphor.

Ruskin’s first reference to the bones of the building appears in The Stones of Venice and his chapter on the shaft:

It must be evident to the reader at a glance, that the real serviceableness of any of these grouped arrangements must depend on the relative shortness of the shafts, and that, when the whole pier is so lofty that its minor members become mere reeds or rods of stone, those minor members can no longer be charged with any considerable weight. And the fact is, that in the most complicated Gothic arrangements, when the pier is tall and its satellites stand clear of it, no real work is given them to do, and they might all be removed without endangering the building. They are merely the expression of a great consistent

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260 Richard Owen is considered most famous for his naming the dinosaurs ‘terrible lizards’. In 1858 Ruskin acquired a copy of Richard Owen’s Monograph on the Fossil Reptilia of the London Clay and of the Bracklesham and the Territory Beds (London: Paleontological Society, 1849).

261 See Edward Griffiths, et al., edition of Georges Cuvier, The Animal Kingdom - arranged in conformity with its organisation, by the Baron Cuvier with additional descriptions of all the species named, and of many not before noticed by Edward Griffiths and others (London: William Clowes, 1827); Also see Ruskin, Modern Painters vol II, taken from The Complete Works, IV, p. 95, which contains Ruskin’s description of radiated animals and zoophytes. Ruskin quotes Cuvier in many of his works and this has been discussed by Mark Frost in his 2005 thesis ‘The Law of Help: John Ruskin’s Ecological Vision, 1843–1886’. Frost looks to Cuvier’s ‘Laws of Organic Economy’ in his dissection of Genesis: ‘The form of a tooth leads to the form of the condyle, that of the scapula to that of the nails [ ... ] Similarly, the nails, the scapula, the condyle, the femur, each separately reveal the tooth or each other; and by beginning from each of them the thoughtful professor of the laws of organic economy can reconstruct the entire animal.’, See Frost, “‘The Law of Help’: John Ruskin’s Ecological Vision, 1843–1886” (unpublished doctoral thesis, University of Southampton, 2005), p. 127.
system, and are in architecture what is often found in animal anatomy – a bone, or process of a bone, useless, under the ordained circumstances of its life, to the particular animal in which it is found, and slightly developed, but yet distinctly existent, and representing, for the sake of absolute consistency, the same bone in its appointed, and generally useful place, either in the skeletons of all animals, or in the genus to which the animal itself belongs.⁶²

Deciphering this passage is a challenge. Ruskin is referring to animal bones in particular but he conceives them quite differently to Alberti, who considers the bones of architecture as the essential elements. Ruskin considers some bones, and processes or projections of bone, as useless. By this he means that a shaft of bone may on occasion be as redundant as a process of bone, yet its structural redundancy is not of import as the bone still contributes to the overall expression of a whole system. By referring to the ‘ordained circumstances of its life’, Ruskin aligns God with nature, or more specifically with an animal’s environment. Ordained circumstances imply devine purpose, and as such there is purpose in all bones, even those considered redundant. There must be a reason for their presence in the body, even though we do not know what that reason may be.

It is an interesting idea, quite reminiscent of Cuvier’s theory of comparative anatomy in which the bones of every animal are formed for their function. Cuvier would argue that every bone has a function, whatever that may be – even the coccyx (the tail bone) in humans is a site for muscle attachment and aids in stabilising the pelvic floor. I believe that Ruskin is alluding to the variation of types, both within and external to a species. For example, a rudimentary tail is useless in a human but essential for balance in a monkey. However, Ruskin is careful not to connect the human with the animal. While such a comparison between anatomy and architectural columns is not new as such, Ruskin is, as far as I can see, the first to utilise it in this functional albeit redundant fashion. There is another link to be made with Gothic architecture, as

⁶² Ruskin, in The Stones of Venice vol 1, taken from The Complete Works, IX, Chapter 8, Section 21: The Shaft (my emphasis).
redundancy, for Ruskin, is an essential tenet of Gothic architecture and the skeleton as an architectural model leaves room for this kind of redundancy.

As previously mentioned, Vitruvius himself recorded the portions of the base and capitals of piers as being equal to the proportions of the head with the foot, and this proportionality continued in the nomenclature of the architectural columns ‘because the base of the column is also called the foot and the capital is also called a head’. Ruskin’s analogy of bone with the architectural shaft occurs again in Chapter Eleven, where the voussoirs of the buildings’ arches are compared to animal vertebrae. However, the link is made here via visual rather than functional resemblance based on the shape and striations of the polychromatic arch. It was not until The Stones of Venice vol II that Ruskin began to see bone as expressing more than architectural resemblance or redundancy.

Ruskin’s essay On the Nature of Gothic Architecture, published in The Stones of Venice vol II, is dedicated to the character of the Gothic style. Ruskin singles out its distinct nature, naming it one of ‘external forms and internal elements’.

For Ruskin, Gothic architecture is comprised of both internal elements (elements from builders; richness, fancifulness, love of variety), and external forms (pointed arches, vaulted roofs); of ‘mental expression’ and ‘material form’. Both characters are needed for Gothic architecture, ‘their union in certain measures’, in the same way that certain molecules are comprised of a number of atoms. Here Ruskin lists the expressions or elements of Gothic architecture, in order of importance, as savageness; changefulness; naturalism; grotesqueness; rigidity, and redundancy. The first thing to note from this list of Gothic regulations is that the architecture is addressed as a whole, not separated by the Albertian principles of structure and decoration. All aspects of a building should embody the Gothic aesthetic. Secondly, the idea of redundancy is directly advocated as an element of the structure, again breaking with the Albertian tradition. And lastly, that these Gothic expressions are not limited to the structure itself but should be embodied by the builders and craftsmen who erect the structure. Ruskin adapts these Gothic principles and devises characteristics for a Gothic ‘spirit’; rudeness; a love of

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change; love of nature; disturbed imagination; obstinacy, and generosity. One or two of these elements, when absent from a building, will not substantially reduce its ‘gothicness’, but the elements need to be considered according to their levels of importance, such as they are listed above, and that substantial reduction or absence of the top three (savageness, changefulness and naturalism) would seriously jeopardise their Gothic ‘life’. As Ruskin writes: ‘pointed arches do not constitute Gothic, nor vaulted roofs, nor flying buttresses, nor grotesque sculptures; but all or some of these things, and many other things with them, when they come together so as to have life’. In this way, the Gothic building is raised above the mundane and classical to the level of art created by artists. The Gothic spirit has the potential to transform a lifeless structure into a living building. It is the appearance of life through the action of the ‘Gothic spirit’, which defines Ruskin’s Gothic.

Ruskin discussed buildings like they were living organisms, yet his conception of the Gothic included the idea of madness as the craftsmen are also to be considered as part of the Gothic architecture. This generates another dimension to the life of the structure, and increases the tensions between life and death, of creation and destruction. Yet this idea, of bringing life to an immobile structure, comes to an unavoidable impasse when confronted with biological definitions that make movement a condition of life. This poses a particular problem since Ruskin makes ‘rigidity’ a key element of the Gothic style. However, he is aware of this metaphysical conundrum and opens the possibility of an animation of the rigidity of Gothic architecture, using the oxymoron ‘active rigidity’ to address ‘the peculiar energy which gives tension to movement’.

Ruskin continues by stating that this rigidity is ‘a stiffness analogous to that of the bones of a limb, or fibres of a tree, a […] communication of force from part to part’. Here is the first direct reference to bone, in direct relation to his Gothic ideals. Its content is remarkably Albertian, particularly when he refers to the communication

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265 Ibid., p. 182.
266 Cuvier argued that movement was a condition of life. See E. Blyth, et al., translation of Cuvier, The Animal Kingdom, Arranged According to its Organisation by Baron Georges Cuvier (London: William Clowes, 1827), p. 16.
267 ‘Active rigidity’ is defined in Ruskin’s ‘The Nature of Gothic’ as the fifth of his six tenets of Gothic architecture. See The Stones of Venice vol II, taken from The Complete Works, x, p. 239.
268 Ibid. Also see Pevsner, Ruskin and Viollet-le-Duc, p. 24.
between parts. Like Alberti, Ruskin analogised architecture with trees, fibres, limbs and bone. He also considered architecture as an ‘organism’ of energy. By aligning bone with force and stiffness, Ruskin reaffirms bone as an agent of ‘active rigidity’. Bones may be stiff, but when part of a living organism they allow for its movements. The energy that Ruskin perceives in architecture is something that I would describe as a potential for movement, which builds up in the points of structural articulation. Taking together all of his recorded references to bone, Ruskin sees bone as part of the system that supports and energises the architectural organism and, most importantly, bone is animated.

This long-established trope of the architecture–body metaphor can be found, to some degree, in every nineteenth-century anatomical treatise that discusses bones and the skeleton. For example, the frontispiece for George Witt’s *Compendium on Osteology* from 1833 (figure 1.13) presents a kind of Promethean mason, chiselling away at a rock to reveal the skeleton, and invoking ideas of craftsmanship, architecture and sculpture, as well as the material associations of bone with stone.269 This image can be interpreted as the craftsman ‘creating’ from stone in the Ruskinian sense, but at the same time the stone is determining the structure being revealed. The tools in the hands of the craftsman-turned-anatomist are positioned at the metaphorical surface between mind and matter, as mental from is impressed on material substrate. The skeleton is presented upright, fully articulated and whole. The association with Promethean creation is overt, the creator giving ‘life’ and vitality to its creation just as Ruskin discussed in ‘The Law of Help’. There is also a connection to the materiality of rock, which may hide secret vital forces within its mundane exterior. Added to which is the knowledge that fossil hunting was a much-enjoyed Victorian pastime and major paleontological discoveries were commonplace in the nineteenth century. The connection between geology, anatomy and architecture is thus made all the more profound in the image.

An illustrative example of the skeleton being perceived in architecture can be found in Alfred Bartholomew’s *Specifications for Practical Architecture* from 1846, although

The skeleton metaphor is not mentioned within Bartholomew’s architectural treatise (figure 1.14). The ‘living’ skeleton is figured as a buttress supporting the Gothic edifice with its ‘arms’, weight and angle of its ‘body’ situated in such a way as to transfer forces from the building proper to the ground. The skeletons upright form and ‘bracing’ stance fit neatly into the architectural members of a flying buttresses, which is composed of an architectural arch and pier, and is designed to transmit lateral forces between the wall and the pier. This image brings attention to the internal and external forces acting upon architecture, and how the thin bony arms of the buttress are all that is required to achieve architectural equilibrium. Although this image in no way visualises the ‘active rigidity’ that Ruskin perceived in the Gothic line and in Gothic vaults, it does equate the natural-built world to the human-built world in an intriguing, almost embodied way. The skeleton not only supports the building but has become a necessary part of the architecture and is viewed as the ideal form to fulfil that particular function.

Returning once again to the organic skeleton, Ruskin also drew parallels between bone and the fibres of a tree. The tree constituted an ideal form for Ruskin, and he sketched and pondered upon it repeatedly, either in reference to his own drawings or regarding trees in the works of others, as will become clear in the proceeding text.

While Ruskin compares the bones of a limb and the fibres of a tree in his notes on Gothic architecture, he pushes this association in a poem in which the tree is likened to a skeleton:

Many a branch and bough is bending
O’er the grey rocks, grim impending.
Danced the leaves on the bent twigs high,
Skeleton like on the evening sky.

The poem is highly reminiscent of Ruskin’s first true observation and drawing of a tree from 1845. One can imagine the dark lines of the branches being traced upwards,

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following the lines of growth; twisted, gnarled, and reaching, buffeted in the evening breeze, their dark skeleton a menacing moving silhouette against the twilight sky. Along with the grim grey rocks and the fading daylight, the skeleton works as a potent symbol for death as well as for animation.

Ruskin also takes up the traditional imagery of the ‘cult of the macabre’ with the skeleton as a personification of death, which was mobilised in many early-modern anatomical illustrations. He also uses this imagery when describing architectural ruins and evokes a derelict house in Venice as follows: ‘Well; take the next house. We remember that too; it was mouldering inch by inch into the canal, and the bricks had fallen away from its shattered marble shafts, and left them white and skeleton-like’.  

In both the poem and this description of a ruinous building Ruskin’s uses the notion of the skeleton as a simile, and not a metaphor. What the comparison of the poem and the text on Venetian architecture demonstrates is that Ruskin employed such rhetorical devices consciously. It is evidence of his acute awareness of descriptive language, and that he knew perfectly well, in this case, the difference between something being like a skeleton and something being a skeleton. A notable example of the application of ‘skeleton’ as a metaphor is found in Ruskin’s scathing critique of the work Salvatore Rosa (1615–1673) in the third volume of Modern Painters. Ruskin saw Rosa’s painting Landscape with Baptism in the Jordan (c. 1650) (figure 1.15) when exhibited in Florence, just before it was purchased by the National Gallery of Ireland in 1854. Ruskin took particular issue with the trees that occupy the right two-thirds of the canvas. The medial plane, the traditional centre of the picture plane, is occupied by the prominent arch of a tree trunk while the human figures (and with them the narrative that the painting’s title refers to) are sequestered to the lower-left corner of the frame. In his account Ruskin writes that ‘even when the skeleton look of branches is justifiable or desirable, there is no occasion for any violation of natural laws’, likening the forms to the ‘wing bones of a pterodactyl’.  Although Ruskin employs these osteological terms to express his dislike of Rosa’s painting, the skeleton metaphor has positive connotation when applied to living ‘animated’ system, such as the Gothic. These trees appear dead, and the use of the skeleton metaphor is strictly along the lines

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272 Ruskin, Modern Painters vol i, taken from The Complete Works, III, p. 255.
273 Ibid., p. 582.
of memento mori imagery. Yet Ruskin also finds displeasing the way Rosa represents nature. Helsinger argues that his critique of Rosa was an attempt at distancing himself from his readership by attacking the publics preferred artists (such as Claude, Salvatore Rosa and Gaspar Poussin) and that these attacks were deliberately exaggerated.  

Ruskin’s critique continues in Chapter Three, ‘Of Imagination penetrative’, with another painting by Rosa’s from the Guadagni Palace, *The Baptism of Christ* (c. 1655), where he writes that ‘the first — the showing of Christ — consists chiefly of a huge and wild group of skeleton trees which occupy the centre of the picture, and struggle about the sky’.  

This critique is continued in a comparison with another of Rosa’s works, *The Temptation of Saint Anthony* (figure 1.16), where he likens the trees to the skeletal monstrosity of the tempting demon, writing that ‘the skeleton branches of the trees like limbs of the Tempting Demon of the St. Anthony’. The bones are rather bird-like. The viewer can discern the individual bones and joints of the rudimentary ‘wing’ bones and the stick-like legs, made all the more monstrous by the impossible articulation and hybridity.

Ruskin frequently associates trees and bones, but it is in his account of Rosa's painted trees that the skeleton comes into play as a metaphor for trees with little leafage and that it is, in this case, a negative account of a badly rendered and hostile nature.

A further example of a skeleton extracted from nature can be found in volume four of *Modern Painters*. Ruskin writes that ‘the fairer forms of earthly things are by them [darkness] subdued and disguised, the round and muscular growth of the forest trunks is sunk into skeleton lines of quiet shade’. In this instance, Ruskin presents the skeleton line as the lines of the tree when shrouded in darkness, something closer to a shadowy platonic form than to a material substance. Ruskin’s skeleton metaphor is

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274 Helsinger, *Ruskin and the Art of the Beholder*, p. 16.
277 Ibid., p. 266.
278 Ibid. See *Modern Painters* vol IV, in ibid., VI, p. 80 (my emphasis).
now being used to describe conceptual lines in nature. For Ruskin, the skeleton, now bereft of the materiality of bones finds its form being imagined in numerous other ways, its ‘lines’ now freed from substance and implanted into the cracks and crevices of rocks and glaciers, again likened to a pterodactyl’s wing, and in the topological surface of mountainous landscape. Another such instance of applying the skeleton line was in Ruskin’s description of Turner’s *The Goddess of Discord Choosing the Apple of Contention in the Garden of the Hesperides* (1811) (figure 1.17). In this painting, the dragon Ladon seems to be made of the rock upon which it stands guard making it difficult to judge where the rock ends and the dragon begins. Its camouflaged colouring highlights this effect. Its strange rocky vertebrae echo the mountain crags in the distance and are brought into stark relief against the whiteness of the clouds. It is unlike any other secular depictions of dragons. Like one of Richard Owen’s ‘terrible lizards’, Turner imagines a realistic anatomical skeleton within a mythical creature, giving the impression of an antediluvian monster petrified in rock. Ruskin, a prominent champion of Turner’s work, also noticed this feature of the painting and made his own sketch of the detail, entitled *Quivi Trovammo* or *The dragon from Turner’s Garden of the Hesperides* (figure 1.18). In the last volume of *Modern Painters*, Ruskin describes the dragon as being ‘crowned with fire, and with the wings of the bat’. Helsinger proposes that Ruskin interpreted Turner’s image as being a social critique of industrialised Britain, as ‘an emblem of consuming as opposed to productive labour, a destructive deity – the perversion of Carlylean work-as-worship which has usurped all other faiths in contemporary England’. It is true that Ruskin and Thomas Carlyle corresponded for many years, right up until Carlyle’s death in 1881. The two social critics were staunch in their derision of industrial Britain’s dark satanic mills and the loss of England’s green and pleasant lands. Helsinger interprets Ruskin’s sketch of the dragon as symbolic of industrialisation, in which the dragon seems to exist in a plume of smoke of its own making and has become even more skeletonised, particularly in the spine, wings and head region. The lines of the ribs and the spinal ridges are even more emphasised by the rock upon which it perches, the cross-hatched lines of the pencil accentuating the furrows in the rock and the ridges of the dragon’s articulated bones. In his analysis of Turner’s *Garden of the Hesperides*, Ruskin notes the visual

279 Ibid., pp. 381–82.
resemblance of the dragon’s form with glacial rock, a likeness ‘so nearly perfect, that I know no published engraving of the upper part of the Glacier des Bois, when it first breaks over the rock towards the Source of the Arveron, so like it as this dragon’s shoulders.’ He continues:

[T]he strange unity of vertebrated action, and of a true bony contour, infinitely varied in every vertebra, with his glacial outline – together with the adoption of the head of the Ganges crocodile, the fish-eater, to show his sea descent (and this in the year 1806, when hardly a single fossil saurian skeleton existed within Turner’s reach), renders the whole conception one of the most curious exertions of the imaginative intellect with which I am acquainted in the arts.  

The conflation of the ‘bony contour’ and ‘glacial outline’ is taken even further by Ruskin in his essay Of the Inferior Mountains, where he directly refers to ‘the mountain anatomy’ in the ‘great skeleton lines of rock’. He writes that such outlines ‘are always concave; that is to say, all distant ranges of rocky mountain approximate more or less to a series of concave curves, meeting in peaks, like a range of posts with chains hanging between’. Such language paints a vivid picture – one of vertical posts connected by chains – and is similar to the language the twentieth-century zoologist D’Arcy Thompson would later employ for describing iron and steel suspension bridges. A chain, usually a metallic artefact made of individual links, is used here as a simile for the strong yet simple parabolic line created by the hanging chain. The addition of links effects the gradient of the slope making it deeper, just as erosion on the mountain makes the terrain steeper. The application of imagery relating to man-made, engineered objects to the mountains is of interest here, because it is unusual for Ruskin to call upon the man-made when describing nature, as he tends to find

282 Ruskin, ‘Of the inferior mountains’ in ibid., III, pp. 457–58. Ruskin refers to the horizontal and perpendicular lines of geological rock formation: ‘consequently, the great skeleton lines of rock outline are always concave; that is to say, all distant ranges of rocky mountain approximate more or less to a series of concave curves, meeting in peaks, like a range of posts with chains hanging between’. In a way, Ruskin is describing a great suspension bridge with the suspension chains hanging between the iron pillars.
inspiration for his colourful rhetoric solely in natural forms. Why not a drooping vine, a thread of spider silk, or a braided rope for a metaphor?

Ruskin’s description of the chain and posts could be considered as his method of associating everyday forms, such as chained fences, with images more foreign to his British readership, like the crags of the Alps. That being said, the image of the hanging chain had been frequently employed since the seventeenth century in relation to the mechanics of architectural vaulting, the geometry and design of the arch, and in the calculation of the mechanical-load paths of materials under axial compression. It is Robert Hooke (1635–1703), with his proposed physical laws or ‘inventions’, who is credited with producing the first published account of such building mechanics in his law of elasticity; however, Hooke’s law took the form of an anagram and was only to be translated posthumously in 1705 by Richard Waller, the secretary of the Royal Society. The translated anagram was as follows: Ut pendet continuum flexile, sic stabit configuum rigidum inversum.284

The Latin translates as ‘As hangs the flexible line, so but inverted will stand the rigid arch’, for the chain is a form free from bending and of pure tension whilst the equivalent arch is a form of pure compression. Giovanni Poleni would later in 1748 illustrate this account of the parabola as a ‘hanging chain’ and the ‘inverted rigid catenary arch’.285 Hooke’s law of inversion creates interesting imagery when one examines its architectural application alongside Ruskin’s writings. This architectural feature of the chain and arch is further related to the natural world through the design of architectural ‘shells’; three-dimensional matrixes of hanging-chains (meridional and hoop chains) connected at nodes and, when inverted, create the geometrical model for the compression-only arch. Such shells include the cone, spherical dome and raised oculus-centred dome. Structural ‘ribs’, to aid in the dispersal of bending stresses, commonly support such architectural vaulting.

285 Giovanni Poleni, Memorie istoriche della gran cupola del Tempio Vaticano (Stamperia Seminario, 1748).
Turner’s Garden of the Hesperides connects rocks to bones in a fusion of mystic animal and stone that coalesces the divide between organic and inorganic, real and mystical. When Ruskin went to view that painting in the Turner Gallery at Marlborough House, he was inspired to write the following:

I am very anxious to get this picture hung in better light, in order that the expression of the dragon’s head may be well seen, and all the mighty articulations of his body, rolling in great iron waves, a cataract of coiling strength and crashing armour, down among the mountain rents. Fancy him moving, and the roaring of the ground under his rings; the grinding down of the rocks by his toothed whorls; the skeleton glacier of him in thunderous march, and the ashes of the hills rising round him like smoke, and encompassing him like a curtain!286

Turner’s dragon becomes a machine with regards to the fear inspired by the unknown, the mythological dragon acting as symbolic of the ‘thunderous march’ of industrialisation. There is an obvious material conflation here; with the articulation of the body and the iron, the iron and water, the mountain glacier and skeleton. As Ruskin’s language captures the imagination, the skeleton form of the dragon introduces the reader to a material of everyday life – iron. However, although her analysis of Turner’s dragon of iron and smoke aligns with Ruskin’s critique of industrialisation (discussed in greater detail in Chapter Two), Helsinger’s symbolic analysis is not entirely convincing as it overlooks a very obvious interpretation of the ‘great iron waves’ that form the dragon’s backbone. Skeletons of animals and the material of iron conflated in more literally ways, for iron was the material of skeletal articulation, the metal wires and hooks uniting bone with bone. Turner’s dragon resembles an articulated paleontological specimen in the British Museum, its petrified immobilisation a result of rigid skeletal articulation.

Ruskin did draw skeletons, although he made many contradictory statements about anatomical dissection. He condemned the practice of dissection as being ‘destructive to our sense of organic power and beauty’ and taught his students to observe and draw

286 See Ruskin’s notes on the Turner Gallery at Marlborough House, 1856, taken from The Complete Works, XIII, p. 118.
only from living nature, yet he would himself study animal anatomy.²⁸⁷ Such contradictions are rife in Ruskin’s works. However, I suppose all his statements could be condensed into a simple truth: that nature should be observed accurately and that life should be reinforced over death although, to paraphrase Ruskin, the two are forever intertwined for what is life put a progress towards death.²⁸⁸ Ruskin’s opinions on anatomy and dissection have been the topic of much discussion by historians.²⁸⁹ In terms of the application of anatomy and natural history to Ruskin’s appraisal of art and architecture, one can draw upon his numerous drawings of animals, not surprisingly considering he wrote Love’s Meinie, a book dedicated to his love of birds.²⁹⁰

At various times during the 1870s, Ruskin would travel to the British Museum in London to draw from the Natural History collection. He reported that the prominent British zoologist Richard Owen paced the halls and did not have much time for conversation.²⁹¹ There are recorded sketches of animal bones made by Ruskin, such as a Pelican’s head and skull, a head and skull of a goatsucker, a bearded vulture, and a chough’s skull which details its ‘short noses into long’ in a similar manner to that of

²⁸⁷ Ruskin, Modern Painters vol II, taken from The Complete Works, iv, p. 155. Also see Letter to Dean Liddle (dated 1 Dec 1878) in ibid., xxii, p. 519: ‘Man is intended to observe with his eyes, and mind; not with microscope and knife’.
²⁸⁸ Ibid., t, p. 474: ‘When you say a growing thing, therefore, you mean something advancing towards death’.
²⁹⁰ In the introduction to Love’s Meinie, the editor E.T Cook wrote the following: ‘He wished his pupils to look at birds and to love them, rather than to dissect or shoot them; to study their colours, their motions, their habits, rather than their anatomy; to study them alive and as they are, not dead and as they may once have been. This was his standpoint towards natural history generally.’ See Ruskin, The Complete Works, XXI.
²⁹¹ Owen began his career as a curator at the Hunterian Museum in the Royal College of Surgeons. He worked there for twenty-nine years before becoming the superintendent for the Natural History collection at British Museum in 1856. Following a successful campaign for a new museum to house the expanding collection, Owen became the first director of the new British Museum (of Natural History), which opened in 1881 in South Kensington. See Paul Lawrence Farber, Finding Order in Nature: The Naturalist Tradition from Linnaeus to E. O. Wilson, Introductory Studies in the History of Science, ed. by Mott T. Greene and Sharon Kingsland (Baltimore: The Johns Hopkins University Press, 2000), pp. 44–45.
Darwin’s finches, detailing the natural selection of beak length. However, Ruskin was by no means Darwinian in his outlook. In short, Darwin’s theory was a theory of adaptation in that small changes in initial conditions for life can have amplified effects. The expression of form is environmentally dependent and the most favourable expression for an animal’s particular environment will be selected. The evolution of species is thus based on selected traits that are natural (pressures exerted by nature) and sexual (pressures of selecting mates that can produce live, healthy offspring with a survival advantage). The idea of life as a struggle for survival, a competition, as a predator-prey relationship that strives to seek the advantage and that death was the outcome in every instance, painted for Ruskin a bleak picture of nature and creation. He therefore remained at loggerheads with Darwin, especially regarding the idea of sexual selection, from the 1860s until the end of his life; however, Ruskin did concede that interspecies variation did occurred, although he was not convinced of the impetus being the drives of pure survival.

Ruskin’s sketch of *Skull and head of a bearded vulture* (figure 1.19) provides insight into Ruskin’s perception of the animal skeleton as an object of osteological study. In the lower left of the picture is the frontal view of a vulture’s head, probably taken from a taxidermied specimen. The eye sockets contain glassy orbs and the strong linear shading under its beak indicates dark plumage. The central drawing is of the profiled view of the head of an articulated vulture skeleton. Its bony beak, cranium, orbits and cervical bones are faithfully observed. A curious straight line, what appears to be a straight bar, runs from the jaw area to the lower beak. This is the mode of its articulation. The variation in shading and highlights indicates its metallic nature. In observing the skeleton specimen, Ruskin included the iron of articulation necessary for keeping the animal’s bones together as a unified entity, although only the vulture’s head is captured in the drawing. This unification is essential for the semblance of life and for a unified morphology. Like the bones in architecture that Ruskin described, the iron bar in the bird’s jaw has the potential to be active – the iron allows for animation.
THE BONES OF CONTENTION

Architecture for Ruskin went beyond the Vitruvian and Albertian metaphors of proportional bodies and cohesive parts. He engaged with Gothic architecture as a style, an expression of an era, and he engaged with the craftsmen and masons that built them. They were the embodiment of the Gothic spirit. The Gothic architecture was animated by its bones, which Ruskin considered as being imbued with a kind of natural energy. Ruskin perceived this energy as active rigidity.

Ruskin’s poetic prowess is rife in his writings, with the skeleton and the bone as simile and metaphor a reoccurring trope in his works. He abstracted lines from architecture, trees and rocks, seeing them as ‘skeleton lines’. The rocks general topography – the surface line – was also thought of as a skeleton line. This contour follows the visible landscape, creating the forms of the peaks and valleys that identify and divide mountainous regions and the land’s borders. The skeleton is also perceived as a physical entity within the museum, but it is an entity of hybridity, composed as iron and bone.

The notion of organicism is generally only used as a critical tool with which to view and engage with architecture; however, van Eck presents organicism as a philosophy of architectural design, identifying and examining the ‘traces’ of organicist philosophies in the designs of selected building through the writings of architectural scholars. Three of these architectural theorists are regarded today as being the great architectural minds of the nineteenth century: Viollet-le-Duc, Gottfried Semper and John Ruskin. In her book van Eck does discuss one architectural example where the discourse of organicism actually effected the construction of a building: the Oxford University Museum of Natural History. The museum was designed and built with a Ruskinian and organicist (namely Gothic) critique in mind and displays a purposeful ideology which I will discuss further in Chapter Two. What follows will be an analysis of the skeletons within the Oxford Museum, and how the material of bone and the material of iron relate within the space of natural history.
CHAPTER TWO

SKELETONS IN THE OXFORD UNIVERSITY MUSEUM OF NATURAL HISTORY

The skeleton is an anatomical construct as well as an architectural metaphor. The connection between the two is far from arbitrary, and it is most pertinent and visible in nineteenth-century anatomy and natural history museums. In a number of these buildings, the selection of iron as a construction material was a conscious choice reflected upon in relation to the material properties of the skeletal specimens contained within the ferrous framework. There are a few such museums, purpose built in their day, which have remained (more or less) in their original appearance and use. One of them is the Oxford University Museum of Natural History (OUMNH) which I will discuss in this chapter. I will demonstrate that the iron frame of this museum was explicitly referred to as ‘skeleton’. I will further argue that the idea of the building being a skeleton, the parts of which are harmoniously connected, facilitated the perception of the architecture as an organic whole. I will mobilise Elizabeth Hallam’s concept of articulation (as set forth in the introduction) and trace the making of the metaphor of the skeleton in the process that led to the OUMNH in order to critically challenge the supposed organicism of the building. I will do so by analysing the discourses and visual material (plans and sketches) around the planning and building of the museum and its display as well as the actual architecture.

The alignment of the anatomical skeleton with the architectural frame also connects the materials iron and bone. Although this association of metal and bodily matter may at first appear counterintuitive, it becomes easily detectable in the drawings and writings of the museum’s various architects and of those who commented on the building’s general appearance, likening the iron to the exhibited bones. The convergence is not merely based on visual resemblance, but also grounded in a perceived material kinship between iron and bone. In order to demonstrate this, I will discuss John Ruskin’s interpretation of the material iron in building construction, particularly in relation to Gothic architecture. Following up from my previous chapter,
I will highlight his validation of iron as ‘organic’, with a kind of tactile naturalism, and the potential of the material for a neo-Gothic aesthetic. In his consideration of iron, we see Ruskin coming to terms with the use of the industrial material in architecture. His conception of the material as organic was highly relevant for the OUMNH, as Ruskin was able to align the museum’s structure with the spirit of nature and of the Gothic. This reinterpretation of iron challenges the canonic narratives of architectural history as well as museum studies, and could prompt a reassessment and reinterpretation of mid- to late-nineteenth century iron architectures in Britain and France. This reassessment should start with those building’s where the relationship between interior and exterior skeleton is closest: the museums of anatomy and natural history.

MID-NINETEENTH-CENTURY IRON ARCHITECTURE

Mid-nineteenth-century Britain arguably produced the most novel and innovative iron architectures, from London’s structural wrought-iron market halls of Smithfield, Leadenhall, Islington and Covent Garden via the shopping arcades of the West End (Burlington) to Crystal Palace. The new iron railways terminated in grand iron and glass railway sheds, such as the terminus at Kings Cross (1852), Euston and Paddington (1854).292 In 1850, when conceiving his design of Paddington station, the engineer Isambard Kingdom Brunel (1806–1859) elaborated on his choice of metal for the building of train stations:

I am going to design, in a great hurry, a station after my own fancy […] with engineering roofs etc., etc. It is at Paddington, in a cutting, and admitting of no exterior, all interior and all roofed in […] Now such a thing will be entirely metal as to all the general forms, arrangements and design; it almost of necessity becomes an Engineering Work, but, to be honest, even if it were not, it is a branch of architecture of which I am fond, and, of course, believe myself to be fully competent for,

but for detail of ornamentation I neither have time nor knowledge, and with all my confidence in my own ability I have never any objection to advice and assistance even in the department which I keep to myself, namely the general design. Now, in this building which, entre nous, will be one of the largest of its class, I want to carry out, strictly and fully, all those correct notions of the use of metal which I believe you and I share (except that I should carry them still farther than you).

This passage by Brunel was written months before the completion of architect and horticulturist Joseph Paxton’s (1803–1865) spectacular Crystal Palace for the Great Exhibition of 1851. Paxton’s design has since become symbolic of nineteenth-century iron and glass construction in Britain, because it was, unlike the slightly earlier railway stations, the first not to be masked by a masonry façade. The masonry fronts of train sheds protected the structure against the weather and often added decorative elements. Also, the taller the iron skeleton, the wider its base needed to be so as to withstand the greater compressive weights. The increased surface area would be adversely affected by wind pressures, although, at this time, no one had worked out exactly to what extent. With external masonry walls ornamented in various styles, the innovations in iron engineering were hidden. The structural elements were veiled, not glorified. The iron was truly the framework, the skeleton, intended to remain unseen like the bone buried in flesh. It was covered by a masonry façade, deemed aesthetically more appealing. The iron was used solely as a load-bearing and supportive material, concealed whenever possible until London’s Great Exhibition of 1851, an event that brought forth the revelation of a new aesthetic in Paxton’s Crystal Palace (figure 2.1). Probably the most famous (or infamous) British iron and glass skeleton, Crystal Palace was the first spectacular utilisation of iron and glass for style as well as for merit, and would forever change the way architecture would be perceived. The structure was of a scale never before seen in Britain, being 1,848 feet long and 408 feet wide. It was comprised

of 6,500 prefabricated cast iron columns, pillars and beams, and enclosed 90,000 square feet of glazing. Built in repeated units (designed in accordance with the specified dimensions for the glass panes), it took nine months to construct in Hyde Park before being opened by Queen Victoria on May 1\textsuperscript{st} 1851. In 1852, following the exhibition, it was dismantled, shipped and re-assemble in Sydenham in 1854. This new Crystal Palace was larger, Paxton having added a barrel-vault transept on each end of the naïve. The palace was tragically destroyed by fire in 1936, its iron skeleton being the only parts to survive its cremation (figure 2.2).

Envisioned to demonstrate the strength, skill and inventiveness of Britain's industries to the world, the Great Exhibition of 1851 gave rise to many more world exhibitions over the following decades. Its largest venue, the Crystal Palace was to become, depending on the political point of view, the embodiment of technological progress, or of a capitalist, proletarianised Britain dominated by mechanical production. It was at total odds with the ethics of Ruskin’s Gothic-revivalism. Ruskin was pushing for a new ‘British’ style to fill the void created by industrial processes, churning out cheap imitations of historical styles for the facades of nineteenth-century buildings, a deception which he could not countenance. In 1858 he wrote:

\begin{quote}
We desire (A) to make art large and publicly beneficial, instead of small and privately engrossed or secluded; (B) to make art fixed instead of portable, associating it with local character and historical memory; (C) to make art expressive instead of curious, valuable for its suggestions and teachings, more than for the mode of its manufacture.
\end{quote}

Instead of the generic, un-ornamented architecture of the Crystal Palace, he favoured a specific style that was ‘expressive’ and in touch with historic traditions. He advocated the ‘truth’ of the style manifested in a building’s stones being sourced from

\footnotesize{\begin{itemize}
\item \textsuperscript{297} Barry Bergdoll, \textit{European Architecture 1750–1890}, pp. 208–9, described the Crystal Place as a ‘monument to emerging consumer capitalism’.
\end{itemize}}
the region within which it is built, the buildings fabric hewn by true craftsman, and the adornments directly representative of nature. For him, such truths were to be found in the Gothic style.  

We can begin to see that the enormous use of cast iron in the frame of Crystal Palace would be a point of contention for Ruskin due to its industrial associations as well as its perspectival, repetitive, and prefabricated nature, not to mention its lack of colour and ornament (although certain sections were ornately painted in primary colours, with patterns designed by Owen Jones (1809–1874). The attention of the viewer would have been drawn to the soldered, welded and riveted iron joints of construction, and the glazing obscuring the building’s form, blurring the boundaries between the inside and the outside, aspects that would later be praised by modernists such as Le Corbusier.

In his thesis on *Ruskin and Gothic Skin*, Phillip Harris takes a phenomenological approach and comes to the conclusion that Ruskin’s architectural writings were ‘all about bodily judgments […], diagnosed from a metaphorical language, [and] all about skin’. Harrison believes that Ruskin saw Crystal Palace as a new version of the Renaissance’s mathematical approach to architecture, which overemphasised proportion and perspective. For Ruskin, Renaissance architecture was detached from the body and removed, according to Harrison, the ‘boundaries between depth and surface’. While I agree with Harrison’s account of Ruskin’s view of Gothic architecture as ‘bodily’, I would challenge his focus on surface. It is not surprising that a dermatologist turned art historian would be interested in a building’s skin. He argues that Ruskin could not condone the Crystal Palace due to its lack of adornment and ornament. Ruskin, Harrison writes, ‘regarded its exterior surface as a dematerialised

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wall veil. The wall veil (flesh) had been dissolved to reveal the iron columns (bones). However, it is not fair to claim that Ruskin had no consideration for structure and depth. For Ruskin, every line had mass, and ornament was as integral to architecture as structure.

Harrison’s thesis only runs skin deep, and the materiality of the building; the density of the walls; the mass of the structure and its interior, are not sufficiently addressed. Drawing connections between the line of landscape and the surface of Gothic structures, Harrison supposes that ‘[t]he skin of Gothic buildings, the Gothic skin, was treated by Ruskin as a textual landscape, with the growth of its stones treated like living cells: building blocks subject to order and disorder, diagnosed at the surface as an aesthetic state’. To support his argument, Harrison takes a phrase from Ruskin’s notes to the Old Water-colour Society, made in 1858, and contends that ‘Ruskin took delight in the “the skin rather than the make-up of things” with an appreciation of aesthetics, rather than a structural or architectonic view of buildings’. However, this quote of Ruskin’s is far removed from its context, which is in fact a negative criticism of Carl Haag’s watercolour On the Sabine Hills (c. 1856) (figure 2.3), in which Haag favours the skin of the limestone over its substance:

I believe the same things are the matter with it [On the Sabine Hills], only in a far less painful degree, which destroys so much of the value of Carl Haag’s figure pieces; namely, a delight in texture rather than in forms or undulations of surface—or (in rougher words) in the skin rather than the make of things; further, a delight in violent contrasts of colour rather than in finely invented harmonies of it (the same thing as the endeavour of a composer to get effect by passages of flute and harp after drum and trumpet, instead of by real invention of successions in chords); and lastly and chiefly, a tendency to stage sentiment rather than life sentiment, making him insist always more on costume than expression—nay, in fact, always see costume first.

302 Harrison, ‘Ruskin and Gothic Skin’, p. 312.
303 Ibid., p. 11
305 Ibid.
In contrast to Harrison’s imprecise representation of Ruskin as being infatuated with the superficial, I would put forward a view of Ruskin as someone who is looking for the organic growth, the ‘make of things’ and the wholeness of art. In terms of architecture, this includes its many surfaces, masses, spaces and everything in-between.

Ruskin called architecture a ‘distinctively political art’. His view of Crystal Palace was, as is well known, part of his critique of industrialisation and its mode of production. In his vision for the OUMNH, he aspired to bring the human element back into building construction. He wanted the craftsman to be in direct contact with the product of his craft; in effect, he hoped to bring the ethos of medieval building back into the industrialised workforce. Architectural historian Brian Hanson argues that Ruskin’s insights on moral and political building practices were primed by over a century of previous architectural scholarship, which he drew upon in order ‘to relate the politics of the building to the politics of the world-at-large.’ At this time in the mid-nineteenth century, Ruskin believed the battle for a national building style had reached a moral crisis, prompting him to make caustic remarks with regard to the ferrovitrious structure of Crystal Palace:

For three hundred years, the art of architecture has been the subject of the most curious investigation; its principles have been discussed with all earnestness and acuteness; its models in all countries and of all ages have been examined with scrupulous care, and imitated with unsparing expenditure. And of all this refinement of inquiry, – this lofty search after the ideal, – this subtlety of investigation and sumptuousness of practice, – the great result, the admirable and long-expected conclusion is, that in the centre of the 19th century, we suppose ourselves to have invented a new style of architecture, when we have magnified a conservatory.

307 Hanson, *Architects and the "Building World" from Chambers to Ruskin*, p. 9.
308 Ruskin thought that a structure for the exhibition of global cultures was superfluous when suffering a crisis of British culture at home. A stable style would unite aesthetics and, in turn, unite the British people, creating culture or “re-imaging” culture. See Ruskin, ‘ARTIII: Architecture – The opening of Crystal Palace, 1854’, in *The Complete Works*, XII, Chapter 6, pp. 417–32.
Such remarks still carry weight with present-day Ruskin scholars. Biographers and architectural historians continue to conclude from Ruskin’s critique of the Crystal Palace that he was a staunch opponent of iron as a material. However, even when seen through Ruskin’s criteria there were merits to Joseph Paxton’s great greenhouse; there was no falsity to its innovative and geometrical structure. In fact, the iron and glass signified a kind of architectural morality. The morality of architecture, articulated in the mid-nineteenth century by Ruskin’s *Lamp of Truth* through the aphorism ‘all practical laws are the exponents of moral ones’, bestowed a genuineness – a realness to ‘correct’ architecture, conferring upon it a substantial truth. Still, Ruskin was vehemently opposed to the way iron was used in the architecture, arguing that ‘morality’ bypasses the iron of the modern edifices. He was not alone in this opinion and iron was considered by many to be ‘insubstantial’ compared to masonry, and therefore inappropriate for civic buildings. The iron framework was thus generally concealed by masonry fronts, even in rather functional buildings such as the great train sheds of Britain.

The Great Exhibition of 1851 and its transparent architecture of display brought the products of the foundries and factories into the clear light of day, in full view of the social classes, illuminating the process of production. This perhaps should have lessened Ruskin’s displeasure and he conceded: ‘the value of every work of art is exactly in the ratio of the quantity of humanity which has been put into it […] The quantity of bodily industry which that Crystal Palace expresses is very great. So far it is good’. Yet Ruskin could never countenance the iron architectures saturating the London skyline with the red iron blood of the workers, who had raised such glorified

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310 Ruskin, *The Seven Lamps of Architecture*, taken from *The Complete Works*. Of railways and stations, Ruskin contended that ‘no one would travel in that manner who could help it’ (*The Lamp of Beauty*, p. 159), and ‘better to bury gold in the embankments than to put it in ornament in the stations’ (ibid., p. 160). He also argued that ‘the iron roofs and pillars of our railway stations […] are not architecture at all’ (*The Lamp of Truth*, p. 67), and that ‘the moment that iron in the least degree takes the place of stone […] the building ceases […] to be true architecture’ (ibid., p. 68).

edifices and which would later, in 1853, saturate the earth at Crystal Palace in Sydenham. Since the first great human-built structures, death and colossal-building construction had walked hand-in-hand, and Crystal Palace was no exception. Indeed, after the 1936 fire, images of the ruin of Crystal Palace (figure 2.4) seem all the more potent for their associations with the skeleton, death and destruction.

At the 1851 Great Exhibition over 100,000 objects were displayed including animal sculptures and objects of natural history. The sculptor, naturalist and director of the fossil department at Sydenham (now Crystal Palace park), Benjamin Waterhouse Hawkins (1807–1894), known today mainly for his 33 life-sized reconstructions of extinct ‘antedeluvian creatures’ for spectacular display within the South London park’s grounds, also designed and sculpted showpieces for the ‘industrial design’ segment of the Great Exhibition. One of these objects, an iron doorpost in the shape of a cat is

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312 Ruskin was a firm advocate for the honest, solid and safe principles of Gothic construction. Regarding death on the construction site, see The Stones of Venice vol II, taken from The Complete Works, x, pp. 313–14: ‘There is hardly a week passes without some catastrophe brought about by the base principle of modern building; […] some fungous wall of nascent rottenness that a thunder-shower soaks down with its workmen into a heap of slime and death. […] when the cheap work, and contract work, and stucco and plaster work, and bad iron work, and all the other expedients of modern rivalry, vanity, and dishonesty, begin to show themselves for what they are’. For an account of accidents and deaths resulting from a failure of cast-iron beams in factories, mills and large buildings in the early- to mid-nineteenth century, see William Vose Pickett ‘On the Application of Cast and Wrought-Iron to Architecture and Building’, in The Useful Metals and their Alloys, with their Applications to the Industrial Arts, ed. by John Scoffern (London: Houlston and Wright, 1857), 410–41 (p. 416). For the tragic accident at Sydenham, which resulted in the loss of twelve workmen, see Jeffrey A. Auercbach, The Great Exhibition of 1851: A Nation on Display (New Haven: Yale University Press, 1999), p. 200. Also see Steve Grindlay, ‘Frightful Accident at Crystal Palace’, Sydenham and Forest Hill Local History, 14 March 2009 <http://sydenhamforesthillhistory.blogspot.co.uk/2009/03/navvies-grave.html> [accessed 14 February 2017]. Also see Grimaldo-Grigsby, Colossal, pp. 11, 15 & 54–55. In her discussion of the building of the Suez canal in the mid-nineteenth century, Darcy Grimaldo-Grigsby draws attention to engineers and industrialists tallying the cost of human lives against the projected profits: ‘In this “humanistic” narrative, engineers understood there were choices, some cost more money and time than others, but human suffering or conditions of labour were seldom deemed critical variables in their ruthless calculations’ (p. 11) and ‘only the abolition of what the British called “slavery” [corvée] led to modern mechanisation’ (p. 55).


314 The British Zoologist John Edward Gray (1800–1875) described the creatures as a ‘crowning humbug’ and ‘gross delusion’. See Valerie Bramwell and Robert M. Peck,
of particular interest here. Commissioned by the Coalbrookdale Company, ‘who brought elegant, iron-made household items to the homes of a growing, affluent middle class’, Hawkins utilised his knowledge in the casting of iron to create the animal doorposter.\textsuperscript{315} A sketch for the expedient sculpture shows the feline in the process of a grooming regime (figure 2.5). The neck ribbon indicates domesticity and the attitude is one of leisurely labour. The sketch outlines the form of the cat and pays particular attention to the internal weighted-iron structure (figure 2.6). The iron takes the curved path of the animal’s spine, the vertebral column being the ideal position for such a weighted apparatus as it follows the body’s centre of gravity, preventing the iron cat from tipping over, just as in the living animal. Hawkins’s method of representing the iron spine is similar to his method of representing bones in anatomical drawings, where the duality of interior space and exterior shape are present in a single image, such as in his comparative drawings of humans and animals (figure 2.7). With the sharp pencil outline giving a sense of shape and flesh they are shaded throughout. Dispelling all thoughts of death, the animals are drawn in motion, for example, a horse might be drawn in the levade posture, a common stance in articulated equine skeletons used in the study of natural history. Iron and bone are aligned in Waterhouse’s drawing and doorposter. The imagined flesh in the drawing suggests a living animal, and thus provides an x-ray view \textit{avant la lettre}. The animated pose of the cat in the functional sculpture adds life to the representation. While the iron interior is hidden, it still works structurally like the bones in an animal body.

Animal skeletons and the material of iron are also drawn together in the OUMNH. It is to this museum that I will now direct my investigation of skeletons. The museum provided a nexus for the elevation of architectural iron into a vision of natural forms, whilst at the same time taking materials from nature and making them structural. I argue that this active engagement with materials, specifically iron and bone, had a significant impact on the subsequent understanding of them.

\textsuperscript{315} Hawkins worked at the Coalbrookdale Iron foundry in 1850 and designed various objects for them. See Bramwell and Peck, in ibid., p. 20.
The OUMNH, built between 1855 and 1860, remains today more or less in its original appearance (figure 2.8). On stepping into the dimly lit entrance foyer and climbing the leaden-grey stone steps, a visitor may be unprepared for the architectural vision beyond the unassuming wooden doors. Natural light pours through the clear glass roof, illuminating the museum’s central court. The daylight touches every surface – the specimens, the walls, the floors, corners and crevasses. Numerous stone and iron columns support a roof formed of overlapping glass scales, interwoven with iron cross work, added to which are the skeletons of great leviathans suspended from this extraordinary iron and glass ceiling. The juxtaposition of the cast-iron lancet arches that support the roof with the large curving rib bones of the various whale specimens hanging above creates a remarkable sight. As the bright midday sun reaches its zenith, the bones seem to appropriate the steely-grey and ochre-yellow patina of the ironwork, making their individual forms, colours and textures indistinguishable from one another (figure 2.9).

This phenomenon of material slippage is striking, and it raises the question as to whether this chromatic conflation of bone and iron was an intentional part of the museum’s original design. In the museum, bones and iron share the visible qualities of being relatively narrow and long, particularly when considering the rib bones, with their narrow, bony processes curving delicately, and the way they are echoed in the roof’s iron lancet arches. Both materials not only yellow over time, but also have many other similar intrinsic properties in common. This kinship had not gone unnoticed by nineteenth-century scholars and academics.\(^\text{316}\) Iron and bone were considered to be ideal building materials, having the shared properties of being both light and incredibly strong. The intrinsic properties, physical resemblance and proximity of the two materials can account for the material slippage perceived in the museum.

\(^{316}\) Donald MacAlister sketched loading vectors in a simple three-cornered rafter and applied the geometry to various materials, including steel, iron and bone. He also found a correlation between these loading vectors and the internal cancellous structure of the calcaneus. See MacAlister, ‘How Bone is Built’, *The English Illustrated Magazine*, 1 (1883), pp. 640–49.
Yet there is another important connection. Iron was necessary for the creation of both the osteological specimens, that is, the skeletons on display, and the architectural structure of the building’s skeleton itself. Iron – in the form of wires, hinges and struts – was used to articulate the bones in the specimen as well as the bones of the architecture. There is something quite extraordinary in the use of iron in the OUMNH, as it is both the innocuous material necessary for the fabrication of skeletons as natural-history specimens and for its architectural frame. At the same time, the articulated bones and the iron frame were metaphorically joined by forming and being perceived as skeletons. But despite this highly visible connection, which is, as I argue, the stepping stone for the formation of the metaphor of the architectural skeleton, there is, surprisingly, no mention of the material relationship between bone and iron in the published literature on the OUMNH’s architectural vision, design and execution. A rare exception is Neil McWilliams who supposed in his 1978 article on the building of the museum that the “bleached bones [are] unconsciously paraphrasing the pattern of the glass vaults that rear above them”. However, I demonstrate that the juxtaposition of iron and bone was far from unconscious. In order to do so, I will examine the skeletons within the OUMNH and consider the ways in which the concept of the

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317 The first recorded use of the word skeleton to denote the ‘bare outline’ dates from c. 1600. The skeleton, as the architectural frame for building, entered general architectural discourse in the late-nineteenth century. Its applied use beforehand would have been figurative, and it is generally believed that the term gained validation with the development of steel and concrete architecture, particularly in reference to skyscrapers. See Douglas Harper, ‘Skeleton’, *Online Etymology Dictionary*, 2001 <http://www.etymonline.com/index.php?allowed_in_frame=0&search=skeleton> [accessed 5 June 2017].

318 Recent conservation at the museum, completed between 2013 and 2014, has seen the suspended whale specimens (relatively untouched for over 150 years) cleaned and repaired, with much of the iron and copper wiring used in the bone articulation replaced with stainless steel wires. Conservation was completed in early 2014, although not in the same order. See Gemma Aboe and Nicola Crompton, ‘Whale Conservation Chapter Completed’, *Once in a Whale* (Oxford: Museum of Natural History, 2013) <https://onceinawhale.com> [accessed 3 March 2017]

319 Neil McWilliam, ‘A Microcosm of the Universe: The Building of the University Museum’, *Oxford Art Journal*, 1 (1978), p. 23. Trevor Garnham remarks that ‘standing beside one of the gigantic dinosaur skeletons, the visitor might alternatively have the sense of being inside the body of some great creature, the iron structure itself a kind of skeleton, the glass roof the scales’, and draws a metaphorical comparison with the story of Jonah inside the whale. See Trevor Garnham, *Oxford Museum: Deane and Woodward* (London: Phaidon, 1992), p. 17.
skeleton was the device used to articulate various fundamental ideas about the natural world.

The notion of articulation is, as I have suggested in my introduction, particularly useful to address skeletons of both iron and bone, and to discuss them in their constructedness. The word ‘articulate’ itself can hold a variety of meanings: it can signify the process of joining bones together in an artificial, moveable synarthrotic joint; it can also refer to the joining point between two separate parts in a plant, such as the root with the stem or branch with the trunk. At the same time, the word is used in a linguistic sense: to articulate is to clearly enunciate or express vocally. Elizabeth Hallam describes articulation as an intimate, laborious, emotive, animating and pedagogic process, and that the articulation of bone can be considered a form of knowledge production: ‘From anatomists’ perspectives, articulation has been a matter of understanding joints – joinings and therefore relations – between bones, which they have observed in bodies and remade in the preparation of skeletons.’

In the museum, the bones are brought together and articulated with each other, the very act of joining simulating a kind of growth. This process enables the perception of an assemblage of bones as an entity that stands in for a specific animal and the potential re-animation of the animal after death. This can be seen in the specimen of the northern bottlenose whale, which has been suspended from the museum’s roof for over 150 years and seems to be floating through the air in the same manner that the living animal would swim through water. The iron wires hold the individual bones together and provide the semblance of life necessary for the reanimation of the once-living creature. Iron’s ability to animate the specimen elevates its properties from the structurally mundane to something energised and potentially organic in its application and appraisal. In its aim at aligning and unifying nineteenth-century natural philosophy with the Anglican Church, the OUMNH itself is also a site of articulation, of objects and materials as well as of the architectural ideas of the four main contributors to the

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321 For the recent conservation and re-articulation of the whale see the blog by conservators Aboe and Crompton, ‘Whale Conservation Chapter Completed’ <https://onceinawhale.com> [accessed 3 March 2017]
museum’s design and construction: Henry Acland, Benjamin Woodward, John Ruskin and John Phillips.\textsuperscript{322}

In what follows I will analyse the discussions held by these four protagonists and show how the conception of the skeleton as an alleged ‘organic’ entity impacted on the Gothic construction and interior design of the museum. I will demonstrate that this concept was embedded in the structure of the iron architecture, the decorous iron spandrels and columns, the building’s stones and geological specimens, the ‘skeleton frames’ of the display cabinets and the museum’s collection of skeletons. The ‘skeleton’ became a unifying concept, guiding the design and construction of the OUMNH. The museum’s ‘skeletons’ were articulated to visitors through various strata of resemblance, be it the material, the visual or the metaphorical, generating for the viewer a living organic vision of nature that combined architecture with the skeletal specimen. In this way, the individual architectural elements were blended into a unified whole able to suggest a harmony of nature and technology.

Dr. Henry Wentworth Acland (1815–1900) was appointed Professor of Anatomy and Lee’s Reader at the University of Oxford in 1845, and heralded a new era in the study of science at Oxford. Since 1847, Acland had been active in his pursuit of a new site for the display of the University’s scientific collections, and for the teaching of a range of subjects under the rubric of ‘the Natural History of the Earth and its inhabitants’. In July 1847 he petitioned the Oxford University Convocation for a new museum.\textsuperscript{323} Over

\textsuperscript{322} Acland’s mission was to present the ‘Art of the great Artificer’. See Acland and Ruskin, \textit{The Oxford Museum}, p. 18.

\textsuperscript{323} See O’Dwyer, \textit{The Architecture of Deane and Woodward}, pp. 153–55. The prepared memorial states: ‘We, the undersigned being officially connected with various Institutions for the advancement of Natural Knowledge in this University, are of the opinion that the several collections contained in the Geological museum in the Clarendon, The Ashmolean Museum, and the Anatomical Museum in Christ Church, are deposited in rooms of inadequate dimensions, and inconvenient arrangement, and that their present efficiency and future progress are by these means retarded’ (for the full letter, see p. 154). Quote taken from Oxford, Oxford University Museum of Natural History (OUMNH), \textit{Papers of OUNHM}, History of the Museum, box 2, MS. Acland, ‘Meeting of Convocation’, 1 May 1849. Acland submitted a letter for Convocation, signed by his fellow science professors, outlining their aspirations for the study of science at Oxford. William Buckland’s signature is conspicuously absent. See Oxford, Oxford University Museum of Natural History (OUMNH), \textit{Papers of OUNHM}, History of the Museum, box 2, MS. Acland, ‘Letter for Convocation by Acland’, 1 May 1849.
the subsequent five years, the voices advocating the new museum increased in volume and urgency as donations to the colleges’ numerable collections were unrelenting. British universities had gradually begun to recognise the public’s newfound thirst for the popular sciences, especially geology, chemistry and natural history. Although I would not go so far as to state definitively that the increased public demand for knowledge in the natural sciences overtly influenced the Oxford Establishment’s decision to grant Acland’s petition for a University Museum, they had to acknowledge that the winds of change would soon be upon them. And they could either cast their mainsail or be left adrift in a world that was fast outpacing them.

In 1853 the University finally acquiesced to the scheme, securing land for a potential museum from Merton College. It was during this time that Acland’s mission was brought to the ear of Ruskin, a good friend and a regular correspondent of Acland’s since their undergraduate days together at Christ Church. As discussed in the previous chapter, Ruskin had recently published his three-volume treatise on architecture, *The Stones of Venice* (1851–1853), in which he lauded Gothic architecture above all other styles of building, for the homage with which the decorous natural forms carved in stone paid to nature. Alongside the Bible – the word of God – nature was, for Ruskin, the epitome of God’s truth made manifest. Ruskin’s version of a neo-Gothic style went beyond the Victorian fashion for the romanticised medieval ruin. He infused

324 Acland petitioned the Oxford University governors, local and general government, as well as the aristocracy and high-profile scientists, writers, poets, artists and their patrons for support. Popularity in the study of Natural Philosophy and Theology had been steadily increasing since the beginning of the nineteenth century. Historian Horace Vernon considered the increased curiosity in nature to have been stimulated by the publication of William Paley’s *Natural Theology: or, Evidences of the Existence and Attributes of the Deity*, 10th edn (London: J. Faulder, 1809). As popularity increased, so did the university’s collections. See Horace M. Vernon and Katharine Dorothea Vernon, *A History of the Oxford Museum* (London: Clarendon Press, 1909), pp. 36, 40 & 43.


327 Ruskin and the Pre-Raphaelite Brotherhood advocated realism in art and Gothic architecture, which may have tempered the romantic feelings invoked by medieval Gothic ruination. This thirst for realism is also discernible in the changing genres of literature and the public’s growing taste for ‘realistic fiction’ at this time. See Michael Gamer, *Romanticism and the Gothic: Genre, Reception and Canon*
his admiration for the medieval Gothic with a dash of Protestant rationalism, wresting
the style from its association with Catholicism, and presented a kind of divine realism
as a method of engaging with the ‘truth’ in such Gothic monuments. It was a truth
found in manual labour, in craftsmanship, in local and identifiable materials, and in
nature.\textsuperscript{328} Held within this truth, Ruskin saw the potential salvation of both the style
and the nation from the immoral and duplicitous practices of material concealment and
imitation.

It is difficult to know if Ruskin’s aesthetics provided the backdrop for the state of
architectural theory in Britain at this point in the mid-nineteenth century, but Ruskin’s
works were certainly widely read by architects, scholars and the general reading public
of Victorian society.\textsuperscript{329} Many British architects and theorists were promoters of the
Gothic style, however none had written so prolifically on the subject and, except for
perhaps Augustus Welby Northmore Pugin (1812–1852), no other British architect had
imbued the style with such strong moral undertones.\textsuperscript{330} For many nineteenth-century
architects that preceded Ruskin, such as Thomas Rickman (1776–1841) and William
Wilkins (1778–1839), the Gothic was simply a style of building from a certain period,
from a certain geographical region and possessing certain architectural attributes such
as vaulted ceilings, pointed arches and flying buttresses.\textsuperscript{331} And although it was

\textsuperscript{328} Ruskin, \textit{On the Nature of Gothic Architecture}.
\textsuperscript{329} According to a nineteenth-century voice, art historian and archaeologist Charles
Waldstein (1856–1927), and in his book \textit{The Work of John Ruskin: Its Influence
contributed immensely to ‘the general advance in the intellectual and social life of
England’ and was ‘an active factor in producing a change in the more special sphere
of art […] bringing about a diffusion of the taste for art among the classes’.
\textsuperscript{330} Augustus W. N. Pugin, \textit{Contrasts; and the True Principles of Pointed or
Christian Architecture}, first published in 1836 (Reading: Spire Books Ltd. in
association with the Pugin Society, 2003); Nikolaus Pevsner, \textit{Some Architectural
\textsuperscript{331} For a general overview of the history of neo-Gothic architecture in Europe, see
Barry Bergdoll, \textit{European Architecture 1750–1890}, pp. 142–70. Bergdoll (pp. 55–
56) highlights William Wilkins’s proficiency in both Classical and Gothic design.
Nikolaus Pevsner presents some of the most influential architectural theorists of the
nineteenth century, including Rickman and Ruskin. See Pevsner, \textit{Some Architectural
Writers of the Nineteenth Century}, pp. 28–35 & 139–56. For a historical account see
Thomas Rickman, \textit{English Architecture: An attempt to discriminate the styles of
English Architecture from the Conquest to the Reformation} (London: Longman &
Co., 1835), pp. 37–120.
recognised that Gothic ornament imitated nature’s forms, Ruskin’s singular position was that ornament was architecture, and that mere imitation had no place in the true Gothic. Ruskin’s Gothic was about the expression of ‘spirit’, the spirit of an organic nature expressed through ideal forms, materials and craftsmen.

The announcement of an open competition to design the new Oxford museum remained intentionally vague. It requested a building ‘two stories high, three sides of a quadrangle with an area covered by a glass roof and the fourth side allowing for later expansion’ – and gave the applicants free license, encouraging originality in design. Acland readily consulted with Ruskin regarding the appropriate choice of style, and was easily swayed by his friend’s arguments for the Gothic; but Acland would have to fight for his preference within an appointed University Convocation. Thirty-two architects responded to the call, each proposing a distinctive architectural style, but in the end Acland got his wish and the Rhenish Gothic design, obsequiously titled ‘Nisi Dominus aedificaverit domum’ (‘Unless the Lord built the house’), won the day.

The ‘Nisi Dominus’ design (figure 2.10) by architect Benjamin Woodward (1816–1861), from the Irish firm Deane and Woodward, embraced the tenets of Ruskin’s Gothic wholeheartedly. This architectural team of Thomas Newenham Deane (1792–1871) and Benjamin Woodward had lately found success building another University museum decorated in the Gothic style, the Trinity College Museum in Dublin (1853–

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332 Blau, Ruskinian Gothic: The Architecture of Deane and Woodward 1845–1861, p. 51. Frederick O’Dwyer notes that there was no building style stipulated or any architectural style imposed ‘but architects should bear in mind that elegance of interior arrangement will be judged more essential than exterior decoration’. See O’Dwyer, The Architecture of Deane and Woodward, p. 166.

333 The opinions of the various competition judges on the submitted architectural designs are outlined by O’Dwyer in ibid., pp. 166–73. There may have been possible ‘back-stage’ maneuvering by Acland to have Deane and Woodward’s design selected (see pp. 173–76). Vernon and Blau assert that the museum was designed in the Rhenish-Gothic style, although Carla Yanni and Barry Bergdoll describe it as Venetian Gothic, and O’Dwyer identifies it as Veronese. See H. Vernon and K. D. Vernon, A History of the Oxford Museum, pp. 55–58; Blau, Ruskinian Gothic, p. 52; Yanni, Nature’s Museums: Victorian Science and the Architecture of Display, p. 71; Bergdoll, European Architecture 1750–1890, p. 215, and O’Dwyer, The Architecture of Deane and Woodward, p. 180. The design’s Latin title translates as ‘Unless the Lord built the house’, extracted from the book of Psalms, Chapter 126, meaning that nothing can be done without God’s blessing: ‘Unless the Lord build the house, they labour in vain that build it. Unless the Lord keep the city, he watcheth in vain that keepeth it’.
1857). Elements of the design for both Trinity College and the projected new Oxford museum could have been taken directly from Ruskin’s *The Stones of Venice*, pictorially supporting the proposition that Ruskin’s writings and drawings directly inspired Deane and Woodward’s architectural designs. On December 12, 1854, Acland informed his friend of the competition results, and Ruskin’s interest in the project was immediately ignited. There is evidence that Ruskin already knew Woodward personally, even considering him a friend, and was sure of his own influence. Ruskin immediately wrote to Lady Pauline Trevelyan, a close friend and confident, that ‘Acland has got his museum – Gothic – the architect is a friend of mine – I can do whatever I like with it […] – and expect the architect here today’. Indeed, once the commission for the new museum had been secured, communication ran thick and fast between the eminent art critic and the young architect, right up until Woodward’s premature death from tuberculosis in 1861. Ruskin championed a Gothic style that was not merely visually associative, comprising traditional and identifiable Gothic forms such as pointed arches and pinnacles, but embodied a substantial ‘truth’ or veracity of style via the choice of materials and the way it was built.

**A CATHEDRAL TO NATURE**

The worship of nature and worship of God were united in the conception of the Oxford Museum. Yet seeking such knowledge was a double-edged sword. The quest for knowledge may offer enlightenment but, in the biblical narrative, it also led to sin.

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334 Eve Blau discusses Ruskin’s direct and indirect influence upon the architectural team of Deane and Woodward. By comparing architectural sketches by Woodward with Ruskin’s drawings from *The Stones of Venice*, which look remarkably similar, Blau argues that the Gothic buildings designed by the architectural duo (including the OUMNH and Trinity College Museum, Dublin) are examples of a new ‘Ruskinian Gothic’. See Blau, *Ruskinian Gothic*, pp. 27–81.

335 Ruskin, *Reflections of Friendship: John Ruskin’s Letters to Pauline Trevelyan 1848–1866*, ed. by Virginia Surtees (London: Allen and Unwin, 1979), pp. 94–95. The letter is dated Thursday (probably 13 or 14 December 1854), the day after the results of the museum’s design competition were announced.

As such, the museum was built as a church, a place in which to marvel at God’s wondrous creations. This becomes nowhere more apparent than in the ceremony held for the laying of the first stone for the new museum in 1855:

We humbly but fervently desire to glorify Thy great Name by the edifice which we are about to erect. We earnestly pray that therein the knowledge of Thy great and glorious works may be continually advanced among us, and thereby Thy wisdom, Thy power, Thy goodness, developed and magnified.  

As the voices of the University choir faded, the foundation stone was laid for the new Oxford University Museum. This institution would attempt to unite for the first time, under one roof, the disparate scientific and mathematical fields taught at the historic and illustrious Oxford University, as well as creating a space for instruction in the new science of Physiology – a subject which was sorely lacking at such a world-renowned institution. A reason for its late reception may have been due to the entrenched ecclesiology, traditionalism and antiquarianism of existing Oxford Professors, Masters and Deans in their historicised subjects, as well as the sustained interest by new scholars in ‘practical’ subjects for application in the church, politics and commerce.

The majority of the museum was completed by 1861. In keeping with Ruskin’s conception of the Gothic, as extensively detailed in ‘The Nature of Gothic’ from the second volume of The Stones of Venice, the museum’s interior court was comprised of Leibnitz, Watt and Davy.’ [n.d]. Many of the museum’s stone carvings and statues symbolise the duality of knowledge and sin, such as the sculpture over the main portal of Adam holding a biological cell (carved in 1861 by W. C. C. Bramwell). The celebrated sculptor, Thomas Woolner, suggested ‘the use and abuse of knowledge’ as a subject for his commission, although his suggestion was later rejected. However his commissioned sculpture of Francis Bacon was satisfactorily executed and is still on display in the museum’s central court. Oxford, Oxford University Museum of Natural History (OUMNH), Papers of OUNHM, History of the Building, box 2, f.6, ‘Carvers wages receipt for WCC Bramwell – Entrance Archway’, 17 July 1861.


locally sourced white and red Mansfield and Forest of Dean stone slabs. The roof tiles were a combination of Greenmoreland and Blue Duchess slate, creating two bands of ornamental slating, and there were numerous voussoirs and stringcourses in both the interior and exterior stonework made from Bristol red sandstone (around some external windows) and bands of green Horton stone (in the interior arches). This polychromatic scheme was adopted from Venetian Gothic architecture. A local Bath stone was sourced from the closest high-quality limestone quarry and used for the building’s facing. Bath stone is white when cut, imbuing the finish with a bony, chalk-like quality. The stone then yellows over time, producing the characteristic honey-hewed finish associated with Oxford’s cityscape. The loss of the stone’s bone-white colour is a visual removal from its material composition as calcium carbonate, a natural compound formed by the layered remains of the fossilised shells and skeletal fragments of marine organisms. As well as being locally sourced, the Bath stone presented another geological stone type. This choice in stone thus embraced both the spirit of Ruskin’s Gothic and Acland’s belief that the display of geological specimens was vital in a museum dedicated to the study of earth sciences. Acland and Ruskin strongly believed in the synergy of the disciplinary fields united in the museum’s display and architecture. There is evidence that Acland supported the ‘archetype’ interpretation of fossils, as indicated by some of the dog-eared pages, highlighted sections and handwritten margin notes that I discovered in his copy of Richard Owen’s


340 Ruskin, *The Stones of Venice I & II*, taken *The Complete Works*, IX, pp. 81, 323 & 397. Also see ibid., x, p. 57. See Blau, *Ruskinian Gothic*, p. 59. O’Dwyer notes that the museum’s stone polychromy was a later modification of the original Gothic design, proposed by Woodward in 1855. The contrasting bands of colour are not strictly in keeping with Veronese polychromy, which was comprised of contrasting stone and brickwork, and not colour. O’Dwyer, *The Architecture of Deane and Woodward*, pp. 180–81 & 194–95.

341 O’Dwyer, in ibid., p. 194.

342 See Acland and Ruskin, *The Oxford Museum*, pp. 21–22: ‘Without the Geologist on one side, and the Anatomist and Physiologist on the other, Zoology is not worthy of its name. The student of life […] will find in the collections of zoology, combined with the Geological specimens and the dissections of the Anatomist, a boundless field of interest and of inquiry, to which almost every other science lends its aid: from each Science he borrows a special light to guide him through the ranges of extinct and existing animal forms, from the lowest up to the highest type, which, last and most perfect, but pre-shadowed in previous ages, is seen in Man’. 

149
**On the Nature of Limbs** (1849), now in the collections of the Wellcome Library, Euston Road, London. Owen was a renowned comparative anatomist and palaeontologist and was instrumental in the establishment of the Natural History Museum in South Kensington. Many of the fossils on display in the museum bear Owen’s name, one of the more famous being a cast of *Plesiosaurus hawkinsi*, an engraving of which is also printed in *On the Nature of Limbs*. An antagonist of Charles Darwin, Owen held that species evolution could not explain certain traits expressed by an animal. As a Natural Theologian, Owen theorised a convergence towards, or a divergence from a species archetype, and that sudden mutations in a species were in accordance with a predetermined plan. The frontispiece of *On the Nature of Limbs* is a drawing of Nike, Goddess of Victory, sacrificing a bull (figure 2.11). Owen’s took his inspiration for the frontispiece’s from a marble sculpture titled ‘Figure of Winged Victory, Goddess Nike sacrificing a Bull’, c. 2nd century AD, housed at the British Museum, where he was superintendent for the natural history collection from 1856. In the tradition of Vesalius, Owen’s utilised a recognisable sculpture to frame the internal anatomy of the body. An outline of the goddess kneels upon the outline of the bull’s back, lifting its head upwards, knife held at the ready. The bones of the human body and the bones of the bull fill the outlines of Nike and her sacrifice. The image was intended to demonstrate comparative anatomy – the similarities and differences between species – with each numbered bone of the human skeleton corresponding to a numbered bone in the bull. Owen contended that different vertebrate limbs all share

345 There is some contention as to whether Owen made the drawing himself by directly observing the sculpture or whether he copied an engraving by Henry Corbould. See ‘Richard Owen’s Winged Bull-Slayer’, in *On the Nature of Limbs: A Discourse*, ed. by Ron Amundson (Chicago and London: The University of Chicago Press, 2007), pp. 96–98. Also see Farber, *Finding Order in Nature*, p. 44.
the same archetypal plan, the design of a divine creator, and he used this image with the accompanying text by Aristotle, Bacon and Newton to indorse his claims.\textsuperscript{347}

However, at this time, geology generated an acute theological quandary. The evidence produced on the bases of fossils of extinct species contradicted any literal interpretation of the Book of Genesis. If God had planned the whole of creation, why would God have made creatures that became extinct? Fossils generated intense geological and theological debate, and they were mobilised as evidence to support atheism, evolution, and a teleological view of biodiversity. The literal interpretation of a seven-day creation was turned into a metaphorical proposition by Dr. James Cowles Prichard in 1815, a view that was firmly established prior to the publication of Charles Lyell’s influential book \textit{The Principles of Geology} (1830–1833).\textsuperscript{348} The evidence that planet Earth was millions of years old instead of mere millennia generated an enormous impact in secular society and dealt a massive blow to the prevailing theocratic powers.\textsuperscript{349} It is therefore unsurprising that the Genesis metaphor became a zealot’s anchor, a lifeline for literal believers in the biblical narrative. It is perhaps ironic that Earth itself – the original metaphor for God’s creation – would provide the evidence for the undoing of this doctrine. The religious instability generated from geology, and the ever-expanding fossil record, incited natural philosophers to question all perceived dimensions of material space. Amid such religious contentions, it remains unclear exactly what theological position the museum’s architects took during the building’s design and construction; however, it is clear that an Anglican authority

\textsuperscript{347} The quote by Aristotle, written in ancient Greek, translates to ‘of which an example is the correspondence between nail and hoof, hand and claw’ [my translation].


\textsuperscript{349} The Rev. James Ussher (1581–1656) is generally credited for establishing the day of creation as ‘the entrance of the night preceding the 23rd day of October [...] the year before Christ 4004’. See James Ussher, \textit{The Annals of the Old Testament} (London: E. Tyler, 1650), p. 1.
of University delegates, all of which had signed the Thirty-Nine Articles, oversaw the design and execution of the museum’s architecture and decoration.\footnote{Ruskin’s struggles with (and eventual loss of) his evangelical faith is widely documented. It is believed that this was attributed to the advances in the field of geology and the development of the fossil record. For an in-depth analysis of Ruskin’s struggles with religion and its impact on his writing, see Michael Wheeler, \textit{Ruskin’s God} (Cambridge: Cambridge University Press, 1999). Also see Ruskin’s letter from 1843 to a college friend, Edward Clayton, and his recognition that the bible could no longer be treated as the literal word of God. Ruskin, \textit{Letters to a College Friend (1841–1845)}, in \textit{The Complete Works}, XXXIV, pp. 478–84. Also see \textit{The Letters of John Ruskin} vol i, in ibid., XXXVI, p. 115: In 1851, Ruskin remarked that the geologists’ hammer could be heard ‘at the end of every cadence of the Bible verses’.

\footnote{Oxford, Oxford University Museum of Natural History (OUMNH), \textit{Papers of OUNHM}, History of the Building, box 1, f.5, Booklet titled ‘Statement of the requirements of the Oxford University Museum, and Plan of the Site (1854) – Prepared for the use of Architects by the Delegates who were appointed in Convocation held on 8 April 1854, for the purposes of obtaining Designs and Estimates from Architects, of examining and selecting from them, and of reporting thereon for the approval of the House’, 1854.}}

\textbf{THE REDEMPTION OF IRON}

Although the OUMNH was officially opened in 1860, certain planned exterior elements remained unrealised, resulting in a sparse external decor that contrasted greatly with the richly decorated interior. However, the essential elements of the building were finished to the architects’ plan. Through the museum’s entrance porch, the space opens into a light-filled court of iron columns. Like metallic trees, they reach the height of the structure and support the range of skylights. The glass roof was a stipulation of the Oxford delegacy when specifying the required criteria for the museum’s design.\footnote{Oxford, Oxford University Museum of Natural History (OUMNH), \textit{Papers of OUNHM}, History of the Building, box 1, f.5, Booklet titled ‘Statement of the requirements of the Oxford University Museum, and Plan of the Site (1854) – Prepared for the use of Architects by the Delegates who were appointed in Convocation held on 8 April 1854, for the purposes of obtaining Designs and Estimates from Architects, of examining and selecting from them, and of reporting thereon for the approval of the House’, 1854.} It was likely in recognition of natural light being the clearest light as well as a respectful nod to the celebrated engineering of Crystal Palace. The central, open space dissolves the high concentration of iron, used in support and ornament, from an overwhelming metallic density into an airy, almost delicate impression. Employed in this way, iron connotes not the severe hammering of industrial production, which Ruskin so vehemently opposed, but the elevated neo-Gothic cadence of nature captured within a modern material. The ferrous material is visible and illuminated by the sky’s seasonal and circadian shades, an exposure of materials
and construction that Ruskin considered ‘true’. Iron was also a practical choice. Initially, iron was selected solely for its fireproof properties and, wherever feasible, replaced wood for this reason.\textsuperscript{352} It was not long, however, before iron became the prime choice of construction material for numerous other reasons. Iron allowed buildings to grow larger whilst retaining slender support columns. Dubbed today the ‘plastic of the nineteenth century’, iron remained considerably pliable when wrought and incredibly strong when cast.\textsuperscript{353} It was also an economically viable choice, as manufacture and mass production allowed for a faster turnover of a product that could be tailored to very specific requirements, eliminating the concern of sourcing and acquiring expensive lengths of timber. It makes sense, therefore, that iron is to be found in the architectural structures of many nineteenth-century museums of natural history, such as the Natural History Museum in Dublin (1856–1857) and Natural History Museum in London (1873–1881).

Along with the cast iron of the museum’s supporting columns and roof, wrought iron was utilised in the capitals’ organic forms, very much in accordance to Ruskin’s Gothic aesthetic. This ornamental wrought iron was manipulated to imitate local botanical flora in minute detail and exactitude, and depicts various leaf formations, floral forms, buds and fern-like spirals (figure 2.12). The floral iron forms generally invite a prosaic organic interpretation, yet the iron’s materiality and its points of articulation – the sites where the cast iron-support column, wrought iron ornament and the roof’s cast iron lancet arch are brought together – were intentionally exposed. This shattered the illusion of a forest canopy by exposing the method of its making through riveted, twisted, hammerered, bowed and pined metal.\textsuperscript{354} These botanical forms were not simply positioned there to fill the articulating ‘gap’ in the museum’s architectonics with representations of nature. In positioning these bouquets of plant life at the transition

\textsuperscript{352} It is unsurprising that the first recorded building with an iron-frame structure was Bage’s flax mill, built in Shrewsbury in 1796, as mills were highly susceptible to fire damage. See Jacqueline Fearn, \textit{Cast Iron} (Buckingham: Shire Publications, 2001), p. 20.
\textsuperscript{353} Ibid., p. 14.
\textsuperscript{354} Acland and Ruskin, \textit{The Oxford Museum}, p. 51.
from iron-support column to iron roof lancet arch these sites of iron articulation are visibly filled with organic life, beyond its mere representation.\textsuperscript{355}

The iron capitals are partially painted, and thus transition from a steely grey to an orchard yellow and autumnal orange. I suggest that this choice of colour was perhaps made in homage to the oxidised iron. It is applied on the tips of the wrought-iron vegetation and gives the impression of rays of sunlight upon a fertile garden.\textsuperscript{356} The coloured mimicry of iron oxidisation lends vitality to the ironwork, suggesting that the iron is breathing, as if reacting to the moisture in the air. The transition in colour continues into the cross-beams and spandrels of the roof which have been painted, or perhaps stencilled, with a decorative floral motif in various russet hues of yellow, orange and red, the colours of fire, of earth, of life, of oxidised iron. This orchestration of iron is fully in keeping with Ruskin’s account of iron as the ‘sunshine of light and landscape’, which adds colour to Earth by producing the brilliancies of yellow, orange

\textsuperscript{355} For the animation of ornament in architecture, particularly vegetal and floral ornament, see Alina Payne, \textit{From Ornament to Object: Genealogies of Architectural Modernity} (New Haven, CT: Yale University Press, 2012).

\textsuperscript{356} In terms of the russet colours and stencilling on the ironworks, Jones and Wickham credit this process to Francis Skidmore: ‘[H]e almost certainly created the colorful stenciling on the columns at the Oxford University Museum’. See Huw Jones and Annette Wickham, \textit{Francis Skidmore: A Coventry Craftsman} (Coventry: Coventry Arts and Heritage, 2003), pp. 3–8. However, I have been unable to find any source to support this statement. In fact, although Skidmore was commissioned with the painting of the roof’s ironwork, archival documentation demonstrates that many thought that the choice in colour was too vibrant, not in keeping with the ethos of the building and that it was indeed repainted by none other than Woodward himself. See Oxford, Oxford University Museum of Natural History (OUMNH), \textit{Papers of OUNHM}, History of the Building, box 1, f.7 , MS. Skidmore, ‘Letter from Skidmore to clerk of works re. Painting of roof timbers by J.B Hill to match iron work (and additional cost)’ [n.d]. Such speculation may arise from acquaintance with Skidmore’s work. Frederick O’Dwyer writes that it was Skidmore’s idea to paint the metals in the colour of their oxides, which supports my argument for the ‘organic’ iron skeleton. See O’Dwyer, \textit{The Architecture of Deane and Woodward}, p. 265. Also see H. Vernon and K. D. Vernon, \textit{A History of the Oxford Museum}, p. 81, who write that the ironwork fell short of expectation, partly due to the ‘unpleasant tints with which it has been painted; though, if a suggestion which was made at the time of imitating the natural colouring had been carried out, the results must have been far more tragic’. 

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and red found in the sand, soil and rocks of its topography. In a lecture given at Tunbridge Wells in 1858, Ruskin considered iron as a natural material:

Iron […] sucks and breathes the brilliancy of the atmosphere; and as it breathes, softening from its merciless hardness, it falls into fruitful and beneficent dust; gathering itself again into the earths from which we feed, and the stones with which we build;— into the rocks that frame the mountains, and the sands that bind the sea.

This praise of iron is at odds with the cold, mechanical and ‘soulless’ material described by the Scottish philosopher, historian and controversial essayist Thomas Carlyle (1795–1881). In his popular commentaries on modern culture, *Signs of the Times* (1829) and *Characteristics* (1831), Carlyle portrays iron as an emblem for the ‘mechanical age’ of industrialisation. His assessment of iron as soulless resonated deeply with critics of industrialisation and the advocates of rural rights, including Ruskin himself, who believed that the British countryside was being exploited for its rich mineral deposits of iron and coal, materials necessary for feeding the machines of commerce and industry. One would thus expect Ruskin to have rebuffed the use of iron in architecture, and some historians of the subject have assumed this. They refer chiefly to his damning critique of the Crystal Palace as a ‘magnified conservatory’, and the ‘black skeleton and blinding square’ of industrialised Britain’s ferrovitreous architecture. These scholars overlook, however, how Ruskin managed to shift the

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357 In 1858 Ruskin gave a lecture on the vitality and vibrancy of iron in Tunbridge Wells. This lecture was later published as an essay. See Ruskin, ‘Lecture V - The work of iron, in nature, art and policy’, in *The Two Paths – Essays by John Ruskin*, taken from *The Complete Works*, XVI, pp. 375–411 (p. 379).
358 Ibid., p. 378.
361 Ruskin’s comment regarding ‘the black skeleton and blinding square’ was made during an address to the Members of the Architectural Association on 23 January 1857, and is published in ‘Lecture IV: Influence of Imagination in Architecture’, in *The Two Paths – Essays by John Ruskin*, taken from *The Complete Works*, XVI, p. 349. For Ruskin’s comments regarding Crystal Palace, see the pamphlet *ARTIII*: 155
connotations of iron. He was able to set aside his bias against the industrial element, and detected in iron an essential universality. Ruskin divined from iron a past, a present and a potential for the future in a single interaction, a connection with all things, at all times. Life on this planet may have been carbon-based, but iron gave life its colour, its ‘vitality’, a testament of which could be found in the diverse palate of Earth’s geology:

[T]he flush to all the rosy granite of Egypt [.....] to the rosiest summits of the Alps themselves [.....] Is it not strange to find this stern and strong metal mingled so delicately in our human life, that we cannot even blush without its help? Think of it, my fair and gentle hearers; how terrible the alternative – sometimes you have actually no choice but to be brazenfaced, or iron-faced.\(^\text{362}\)

This was iron’s redemption from the ‘ills’ of industrialisation, which allowed for both an appreciation of iron architecture and a Ruskinian interpretation of it. Ruskin’s attitude towards iron was more complex and ambivalent than previously acknowledged. In his ‘Lamp of Memory’, Ruskin describes the iron foundries of his day as becoming the people’s livelihood, bringing life through financial support. They could be heard beating out iron. While the price to pay was the loss of the quietness of nature and the rootedness of country life, he saw iron as a source of energy, and using bodily metaphors, of vitality.\(^\text{363}\) Coming back to the OUMNH, the riveted cast iron of

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the roof and the hammered wrought iron spandrels could now be understood as not only mimicking the organic but also as being organic. Iron thus became the ideal building material for a museum dedicated to the study of science and natural history. The yellowing Bath stone of the museum’s façade may have been a visual dissociation from its bony-white composition, but its deepening buttery hue was testament to the building’s life – its ageing – and a natural process of iron oxidation that Ruskin understood in terms of breathing.364

THE EARTH’S IRON SKELETON

All rocks contain traces of iron. In geological formations iron can be seen to form reddish and yellow-coloured lines, and it is iron’s oxidation that produces the vivid colours. These lines of hematite are easily discernible from the grey of the surrounding rock. They follow the sedimentary lines of deposition, differentiating them from the veins of the rock. In the fourth volume of Modern Painters (1856), Ruskin described these sedimentary lines as ‘abstract’, in that they follow the surface line of a rock’s topography or mountain’s terrain, and describe the form and mass of the three-dimensional shape of the rock or mountain in a single line. One particular illustration by Ruskin represents the geological topography of the rock’s surface as it slopes downwards into a fissure and rises onto the other side (figure 2.13). This is an example of tectonic convergence. As the rocks are pushed together, the resulting pressure causes subduction (one plate forced below the other) and creates a trench. To the left of this illustration is a schematic rendering of the rock’s interior, the lines indicating the layers of differential and sequential rock formation, which are visible through the coloration, typically yellow or red, caused by the iron. These abstracted lines clearly follow the rock striations present in the illustration on the right and were referred to by

364 Ruskin perceives minerals as possessing ‘a kind of soul’, and when metals mix with oxygen, they have ‘breath put into them’, which he calls the ‘breath of life’. See Ruskin, ‘Lecture 5 – The work of iron, in nature, art and policy’, in The Two Paths – Essays by John Ruskin, taken from The Complete Works, xvi, pp. 377–79. Also see Ruskin, Modern Painters vol 5, taken from The Complete Works, vii, pp. 14–15: ‘The earth in its depths must remain dead and cold, incapable except of slow crystalline change; but at its surface, which human beings look upon and deal with, it ministers to them through a veil of strange intermediate beings: which breathes, but has no voice; moves, but cannot leave its appointed place’.
Ruskin as ‘skeleton lines’. The skeleton thus becomes an important trope for Ruskin to describe what he regarded as essential: the extracted fundamental nature or ‘spirit’ of a thing. Ruskin’s use of the concept of the skeleton for geological formations could be described as his most prolific and synecdochical application of the metaphor. In the text accompanying his poem ‘Chamouni’ published in Poems (1891), Ruskin wrote that ‘the blue sky, shone calmly through their openings, and the labouring sun struggled strangely – now gleaming waterily on the red-ribbed skeleton crags’. Here, ‘the red-ribbed skeleton crags’ are a visual metaphor for the iron hematite. Ruskin thus took from the skeleton its line and form, utilising its unique qualities as being strong yet graceful, natural yet man-made, dead yet active, organic whilst being inorganic, and applied it to forms that could also be deemed materially ambiguous.

Ruskin further examined the concept within a literary genre that allowed him to explore his metaphors more freely: poetry. A section of his poem ‘A tour through France’ reads:

Till in the mountain’s hardened heart it lies
In nature, rock,—in form, a skeleton;
Much for the feature valued by the wise,
Or in some huge museum to be shown,—
A mystery, as wonderful, at least,
As that of apples conjured into paste!  

In this poem, the mountain has a ‘heart’ in which resides rock with the form of ‘a skeleton’. This skeleton is of rock and yet, paradoxically, rock is often comprised of the skeletons of organisms. Another interpretation could be that ‘in form’ is a reference to the human form, in which case the association between the rock and the skeleton would be a simile, i.e. the structure or ‘heart’ of a mountain is its rock, while the structure of the animal form is its skeleton. Either way, Ruskin made explicit the connection between rocks and skeletons, a connection that is manifest in certain

365 Ruskin wrote the poem ‘Chamouni’ in 1833, when he was but 14 years old. See Ruskin, ‘On tour on the continent’, in Poems (1891), taken The Complete Works, II, p. 381.
366 This poem by Ruskin is about the geological forms and mountains of France, which makes reference to the form of the mountain as a skeleton. See Ruskin, ‘Poem: A tour through France, Canto 1 stanza 29’, in ibid., pp. 396–416. Quote taken from p. 407.
fossils. He imagined these entities reunited in a museum. It is thus not clear which skeletal form was being referred to, the animal or the rock. The reference to the wondrous transformation of ‘apples’ into ‘paste’ is also of interest as it infers a change of material state, although perhaps not of essence. Downward force and pressure is needed to ‘conjure’ the former into the latter, perhaps a reference to the pressure required for fossilisation or the formation of various stone types. Another possibility is that Ruskin was referring to the process of erosion and the geological cycle, of returning the dust, the rust and the powdered stone to the earth; the mountains are ‘fed by their ruin’, creating new skeleton forms.\textsuperscript{367} One could consider this geological cycle as an ecological model, a paradigm that emerged in distinction to the other natural sciences in the mid-nineteenth century.\textsuperscript{368} Ruskin scholar Mark Frost has written that ecology ‘valorises the vital connectedness of heterogeneous phenomena – that which Ruskin perceived as early as 1843, when he noted that “there is indeed in nature variety in all things”, and that “the truths of nature are one eternal change – one infinite variety”’.\textsuperscript{369} Frost argues that one of Ruskin’s methods for connecting all ‘heterogeneous phenomena’ is in a textual organicism, a means of organising the realms of nature into a complete, organic, and unbroken whole. The connections made by Ruskin between art, natural philosophy, geology and architecture are unsurprising. However, his choice of the skeleton as his unifying concept is striking, especially when considered in relation to the OUMNH, a building that is not only a manifestation of Ruskin’s new Gothic but also a museum that holds specimens of all three types of skeleton – bone, architecture and rock. Taken together, Ruskin’s rocks of bone (as skeletal fragments) and the skeleton lines of iron produced a profound material convergence and divergence that was both literal and metaphorical and, when taken in the context of the museum, enables a new appreciation and interpretation of the interplay between architecture and display.

\textsuperscript{367} Ruskin, \textit{Modern Painters} IV, taken from \textit{The Complete Works}, vi, p. 239.
\textsuperscript{369} Ibid., p. 11.
It seems that for every shade of oxidised iron he came across, Ruskin had a controversial, and at times contradictory, remark. This makes any Ruskinian interpretation of iron architecture of the OUMNH problematic, to say the least. Yet, for the most part, these conflicting utterances are rhetorical, and inflected by their context. Furthermore, in the light of shifting secular attitudes and scientific debates regarding earth elements, as well as the rejection of Vitalism Theory in favour of the physiological and atomic understanding of matter, it is understandable that Ruskin’s own appraisals of the material would fluctuate. At the time of the OUMNH’s construction, iron was understood to be a necessary component for organic life on this planet. Haematological experiments had determined the quantity of iron in the haemoglobin molecule, confirming iron’s essential role in the oxygenation and colouring of blood. Experiments with magnetism utilised iron to prove the existence, placement and direction of magnetic lines. Engineers were also examining the


372 The confirmation of iron as a component of blood in the early-nineteenth century generated significant interest from scientists who wished to fully comprehend the composition and properties of blood. They tested extensively, creating treatments using ores and magnets. The red blood cells were osmotically burst and the iron extracted and tested. It was discovered that the quantity of iron in the blood cell varied between species. See John T. Edsall, ‘Blood and Haemoglobin: The Evolution of Knowledge of Functional Adaptation in a Biochemical System’, Journal of the History of Biology, 5 (1972), 205–257. Since the identification of galvanistic forces in the late-eighteenth century, an arms race in magnetic experimentation occurred. One experiment by Ludwig Achim von Arnim in 1800 utilized iron caps, or armatures on the poles of a magnet to deduce if there was a variable iron oxidation rate between the poles. See Roberto de Andrade Martins, ‘Ørsted, Ritter, and Magnetochemistry’ in Hans Christian Ørsted And The Romantic Legacy In Science, ed. by Robert M. Brain, Robert S. Cohen, and Ole Knudsen, Boston Studies in the Philosophy of Science: CCXLI (Dordrecht: Springer, 2007), pp. 339–85. Also see
atomic structure of iron so as to enhance its properties to make a stronger structural lattice. With the addition of various quantities of coal to iron, a lighter yet stronger steel alloy was engineered.  

Iron, for Ruskin, had its place in architecture primarily as a decorative material, and he praised its appropriate use in the finely wrought details of external decorations, such as fences and balconies. Where brittle stone would fracture or erode with repetitive abrasions, iron was stronger and lasted longer; it maintained form and structural integrity whilst being finely wrought and slender, enabling the most delicate of details. Thanks to material properties that allowed for moulding and welding, wrought iron could emerge free from structural cast iron, like a blade of grass emerging from the ground – part of the whole, yet distinct in form. The material of iron was functional in the context of mechanical and industrialised usage, yet it was the contrasting properties of slender form, malleability and vitality that enabled its ideal application to organic ornamentation. Ruskin was well aware of these properties, writing:

[T]he quaint beauty and character of many natural objects, such as intricate branches, grass, foliage (especially thorny branches and prickly foliage), as well as that of many animals, plumed, spined, or bristled, is sculpturally expressible in iron only, and in iron would be majestic and impressive in the highest degree.

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One can see the expression of this sentiment in the various drawings carried out by Ruskin during his 1869 Italian tour. In these drawings, the iron railing appears like a wall of thorny plants, imparting a sense of menace or violence, with vertical, spiky leaves enforcing the division of space (figure 2.14). The lines are more dynamic than those found in the carvings of natural forms in stone, or marble Corinthian style capitals or plinths. The iron lines created are full of the same ‘action’ that Ruskin perceived in his lettuce thistle drawing (refer to figure 1.12) and, as Ruskin writes, its form is only ‘sculpturally expressible in iron’. He admired iron thusly and lamented its removal from civil and domestic spaces. In one of his sketched examples of Scala iron (figure 2.15), Ruskin attempted to capture the expressive nature of iron, just as he tried to capture the expressive action of the lettuce thistle leaf. In this sketch on cream vellum, which bears several tea-coloured blotches and numerous speckles, a tell-tale sign of the ravages of time, Ruskin used the soft lead of his pencil to create and express the organic forms of four decorative styles forged with iron. Each sketch is briefly annotated with either their location or the method used to unite or fix the iron into place. The outlines of the iron are sharp, the ‘aweful lines’ of the leaf forms captured in the sharp pencil outline. This is contrasted abruptly by the soft shading within these lines, which perhaps adds a material density to the objects being observed, the grey tones and metallic properties of lead becoming a suitable material substitute for the actual objects.

In the Italian town of Brescia, the seventeenth- and eighteenth-century wrought-iron balconies, exposed to the elements for many generations, began to rust and were quickly replaced in the nineteenth century with newly wrought iron. The aesthetics of this now-rusty element were not appreciated and were apprehended by many as a material weakness; therefore, there were few examples of iron platforms and balustrades for Ruskin to examine. He draws attention to this lack of rusty iron in the 1858 lecture at Tunbridge Wells, remarking that it is ‘difficult [in Brescia] to find old examples of balconies and their projecting teeth of iron’. Ruskin deftly draws attention to the anthropomorphic aspects of architecture. The façade, or face of the building, typically has windows that act as ‘eyes’ that ‘look out’ onto the street. However, in this instance the balcony, typically situated beneath the window/eye, has teeth. Developing Ruskin's anthropomorphism further, one might say that the flesh of

375 Ibid.
the building is absent whenever iron is evoked or utilised in the architecture. The flesh is removed, and the skeleton or ‘teeth’ draw immediate attention due to their resemblance to the human mandible, and thusly inspire the metaphor. It is a metaphor derived from its form (the vertical and regimented arrangement of repeated lines), its materiality (the elemental strength and rigidity of teeth and iron), and its colour, or lack thereof. The light and darkness of tooth and associated gap become inversed, with the light illuminating the brickwork set back from the shadowy darkness of the iron. Ruskin captured this iron smile of the balcony in two daguerreotypes, taken in 1858 whilst in Bellinzona, a small town on the south side of the Alps (figure 2.16 and 2.17). On examination of the plates, which have begun to deteriorate and corrode around the edges, the metallic sheen of the polished steel plate gives an iridescent pale blue sheen to the clear Mediterranean blue sky over the town, and the sky frames the balcony so well that we can appreciate Ruskin’s undoubted skill with handling this new technology, and his aesthetics of framing. The abundant iron flora appears to be growing directly from the iron balustrade, and these metal flowers break through the rails and project in all direction, the perfect imitation of organic life as being unpredictable, vivacious and gregarious. In fact, due to the monochrome medium and, indeed, the metallic surface of the plate, the material conflation and ambiguity is quite striking to the point that the iron detail could be confused with organic plants and vines being grown on an Italian balcony. It is impossible to be entirely decided on the materiality of the organic forms when scrutinised thought the mirror-like surface of the daguerreotype.

When discussing the OUMNH with Acland, Ruskin refers to art, when decorative, as being ‘informative, conveying truthful statements about natural facts […] [but] if it represents organic form (and in all important places it will represent it), it will give

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376 Although Ruskin was well versed in the operation of making daguerreotypes, his manservant, John Hobbs, was instructed in the technique and likely produced the majority of Ruskin’s daguerreotypes during his employment from 1846–1851. Later plates are credited to Fredrick Crawley, Hobbs’s successor, who accompanied Ruskin on numerous trips to Europe from 1854 to 1858. For a detailed analysis of Ruskin’s use of the daguerreotype, please see Stephen Wildman, *Ruskin and the Daguerreotype* (Lancaster: Lancaster University’s Ruskin Library, 2006).
that form truthfully, with as much resemblance to nature as the necessary treatment of
the piece of ornament in question will admit of”. 377 He continues:

This principle is more disputed than the first among the Gothic
Revivalists themselves. I, however, hold it simply and entirely,
believing that ornamentation is always, *caeteris paribus*, most
valuable and beautiful when it is founded on the most extended
knowledge of natural forms, and continually conveys such
knowledge to the spectator.378

Ruskin was referring to ornamentation and its relationship to nature. He makes clear
his belief that an extensive knowledge of nature is vital for the precise rendering of
nature’s forms so as to accurately convey information. This knowledge is both gained
and shared through careful observation. There is a didactic dimension to ornament
beyond the mimetic beauty of its craftsmanship. Just like the natural-history specimens
in the museum, ornament should have pedagogical status, representative of nature, and
this nature can and should be expressed through iron. However, knowledge of nature
is not only found in its external morphology but also in the relationships and
sympathies that exist between (what was perceived to be) differentiated parts via their
‘circles of vitality’.379

From nature’s yield, the sculptor could faithfully craft the glorious bounty of Eden, the
mason and craftsman’s labour also being for the worship of God as well as for social
morality. Inspiration for this way of thinking about the intimate relation between art
and nature came from the poetry of Walter Scott and Samuel Coleridge:

Spreading herbs and flowers bright
Glistened with the dew of the night
No herb nor flower glistened there
But was carved in the cloister arches fair.380

378 Ibid.
379 Ruskin, ‘Lecture V - The work of iron, in nature, art and policy’, taken from *The
380 Sir Walter Scott, ‘The Lay of the Last Minstrel’, quoted by Ruskin in his first
It was Ruskin’s intention that the OUMNH be a monument to a new Gothic architecture. This meant that ornament needed to be placed everywhere for, as Ruskin imparted, architecture was ornament.\textsuperscript{381}

It also meant reconciling the monastic past – the ancient stone Gothic cathedral – with the technological present, hence the use of traditional stone juxtaposed with contemporary iron columns. And so floral and faunal details were hammered out of wrought iron and carved into stone pillars and corbels. For the ornament to be considered ‘high art’, it must, for Ruskin, be founded on knowledge of nature. Whilst many may view the stone carvings as mere imitations of nature, they seem to me to be filled with what Ruskin described as the ‘spirit’ of Gothic, almost to the point of being the living material captured in stone. Yet they retain a sense of stillness and petrifaction within the stone from which they are rendered, like fossils emerging from their rocky prisons. This inability to escape and emerge, free and whole, from the stone keeps their materiality in check. However, these forms also act as another reminder of the material slippage between bone and stone, the geological life cycle in which layers of skeletal fragments, under extreme pressure and over millennia, form sedimentary rocks. I consider this an example of what Ruskin meant by the idea of an infinite organic nature, perhaps influenced by the writings of the renowned Scottish geologist James Hutton (1726–1797). Hutton referred to the earth as a ‘superorganism’ and proposed in his attempt to describe the process of geological time (or ‘deep time’) the infinite geological cycle in which ‘we find no vestige of a beginning, no prospect of an end’.\textsuperscript{382}

The OUMNH acted as a site of temporal mediation between the organic nature of iron and stone. Encountering nature’s forms in the wrought and chiselled materials provided a connection with the divine as well as a unifying concept that structured and

\textsuperscript{381} Ibid., p. 11. Architecture surpasses mere building through the use of ornamentation, those ‘certain characters venerable or beautiful, but otherwise unnecessary’. See Ruskin, \textit{The Seven Lamps of Architecture} (1849), taken from \textit{The Complete Works}, XIII, pp. 28–29.

\textsuperscript{382} James Hutton, \textit{Theory of the Earth, with Proofs and Illustrations}, 2 vols (Edinburgh: William Creech, and London: Cadell and Davies, 1795). Garnham also perceived the relationship between the fossil specimens and the stones of the building: ‘Skeletons resonate with structure, fossils emerge delicately from solid stone as the past encapsulated and living plants were frozen in stone’. However, this is the limit of his observations. See Garnham, \textit{Oxford Museum: Deane and Woodward}, p. 18.
governed the building.\textsuperscript{383} It is an organicist conception of nature as theophany. Analysing the various concepts of nature manifested in the museum, Van Eck considers the OUMNH a prime example of ‘organic architecture’ and sees in it an expression of the unifying concepts of organicism. She argues that the whole structure was made of parts corresponding with each other, and that these parts expressed the form of living beings.\textsuperscript{384} Van Eck critically endeavours to interpret the OUMNH’s functional elements via an analysis of its organic ‘wholeness’, achieved through its unifying architectural structures and forms. Concentrating on nature’s external morphology as echoed in the museum’s decorous splendour, Van Eck does not consider the relations between the architecture and the objects displayed in the museum. Architectural historian Philip Steadman attempts to bridge this gap between the internal and external via a ‘biological analogy’, which he proposes as an alternative to the organic analogy. This proposition is appropriate given that biology was a newly emerging scientific discipline in the nineteenth century. His analogy allows for an analysis of the functional as well as physiological elements of building construction.\textsuperscript{385} However, Steadman’s biological analogy deals more with biological processes and systems in architecture. He neither engages with the physical skeleton nor with any of the skeleton’s material, visual or metaphorical associations.\textsuperscript{386} Both Van Eck and

\textsuperscript{383} Twice Acland paraphrases Sir Thomas Browne’s famous quote ‘nature is the art of God’ from Religio Medici, 1643. See Acland and Ruskin, The Oxford Museum, pp. 17 & 37.

\textsuperscript{384} Caroline Van Eck, Organicism in Nineteenth-century Architecture, pp. 126–30.

\textsuperscript{385} Philip Steadman, The Evolution of Designs: Biological Analogy in Architecture and the Applied Arts, pp. 31–33. In terms of the correlation of parts, Georges Cuvier believed that he could conceive an entire skeleton from a single bone. The Rational Gothic architects interpret a structure in the same manner – from one cross-section you can conceive the architectural members, then the whole monument. The work of Georges Cuvier in the field of Comparative Anatomy profoundly influenced the work and writings of architect Eugène-Emmanuel Viollet-le-Duc (1814–1879) in France during the mid- to late-nineteenth century. See Viollet-le-Duc, Dictionnaire raisonné de l’architecture française du XIe au XVIe siècle, 10 vols (Paris: A. Morel et Cie, 1869).

\textsuperscript{386} Although Steadman dedicates an entire chapter of his book to the animal skeleton in architectural theory, his level of engagement is primarily methodological. Steadman examines Cuvier’s theory of ‘the correlation of parts’, and the influence of Cuvier’s comparative method on nineteenth-century architects such as Viollet-le-Duc and Gottfried Semper. He flatly refuses to engage with the skeleton on a metaphorical level, stating that the skeleton metaphor is simply a ‘naive expression’ of the obvious structural resemblance between the animal’s internal support structure and the architectural framework. Steadman, ‘The anatomical analogy – Engineering
Steadman direct their analysis to the morphological or physiological elements of architecture, while my study brings materials and the museum’s exhibits into play. The material of construction and the material on display in the museum were of the utmost importance to the architects, whether for reasons of morality, truthfulness, naturalness, or pedagogy.

**INSIDE OUT AND OUTSIDE IN: THE CABINETS**

Henry Acland designed the museum primarily as a temple to nature and natural science, as is well documented in his small book *The Oxford Museum* (1859) originally published with contributions by Ruskin. Acland acknowledged that the laws of nature are still only partially understood and are seen ‘darkly as in a mirror’. This association of darkness with the hidden mysteries of God’s creations was a prevalent Victorian concept. That connections with divinity could only be made through nature was undoubtedly a Ruskinian attitude, yet it was also a position taken by Acland, who wrote in more detail:

> In this term ‘Nature’ are, of course, included every known and observed form of matter by which our world and its inhabitants were either made or are maintained, and whatever laws of their construction or for their maintenance have by reason been inferred. No less signification of the word Nature will in the present day be accepted; the limitation of the term History of Nature to a small portion of the biological science is not now, of course, admitted. But even this explanation does not adequately express the idea of the word Nature; the word implies not only the facts and the laws that have been noted in the structure and peopling of the globe, but still more, the relation which all those facts and laws bear to each other, in some limited instances, – the first glimpses of unuttered ideas, traces (as we believe), though we see them darkly as in a mirror, of unexpressed Art of the great Artificer.\(^{387}\)

\(^{387}\) The quote is a direct reference to the biblical phrase from 1 Corinthians 13.12 (King James Version): ‘For now we see through a glass, darkly; but then face to face: now I know in part; but then shall I know even as also I am known’. See Acland and Ruskin, *The Oxford Museum*, p. 18. Acland repeats this sentiment again on p. 43: ‘[A]nd in many succeeding generations, when we are long forgotten, may young
Everything the eye touches in the museum was meant to inspire awe in the beauty, power and organisation of nature, and a firm belief in the truth of God’s creations. The person responsible for making this work in the museum display was John Phillips. Previously Professor of Geology and the Keeper of the Ashmolean, he was appointed as the OUMNH’s Keeper in 1857. His impact on the ‘museumscape’ is poorly documented, his position relegated to footnotes and appendices of the literature published on the museum. Despite the fact that Phillips was a member of the appointed delegation responsible for drafting the architectural specifications for the new museum, his contribution has remained overshadowed by the indomitable figures of Acland and Ruskin and needs to be reconsidered. Phillips was dubbed the unofficial overseer in the arrangement and display of the enormous museum collection as well as the entire museum’s interior décor. The chiselled-stone floral capitals are attributed to Phillips’s designs, the preparatory sketches for which have been analysed by architectural historians for their remarkable botanical resemblance to various plant species (figures 2.18 and 2.19). He is also credited for the design and arrangement of the central court’s elegant polished stone colonnettes. The stones are a pedagogical device, both geological specimens of British marble and architectural supports, and are evidence of Phillips’s conceptual understanding of material as specimen and vice versa. Phillips’s sketches for the specimens’ arrangement and minds be here freshly learning and warmly loving the things which they may be allowed to perceive as in a mirror, dimly’.


391 See H. Vernon and K. D. Vernon, A History of the Oxford Museum, pp. 77, 79 & 82–83. Also see Ken C. Davies and James Hull, The Zoological Collections of the Oxford University Museum - a Historical Review and General Account, with Comprehensive Donor Index to the Year 1975 (Oxford: Oxford University Museum, 1976). The new collection was an amalgamation of various College collections, such as Dr Matthew Lee’s (1695 – 1755) after whom the first Readership in Anatomy was created, as well as others from the anatomy school at Christ Church, which took upwards of six years to relocate. Once the museum was up and running, donations
display have continued to be disregarded by historians (figures 2.20, 2.21, 2.22 and 2.23), even though his designs were precisely the hinge between the architecture and specimens. They ‘articulated’ the correlation of the museum’s iron and bone skeletons, unifying these elements into what could be perceived as an organic whole.\textsuperscript{392} Phillips’s designs were, as contemporaries noted, ‘adopted almost unchanged’ and a specification letter detailed that they were completed in a most ‘workmanlike manner […] to the entire satisfaction of the architect’.\textsuperscript{393} Phillips ordered bespoke wainscot panelling for the display cabinets. Wainscot panelling was specially designed to attach to an existing wall or frame, creating a wooden encasement.\textsuperscript{394} It is likely that this frame was constructed of iron, for in a letter regarding the specifications for the

poured in from various sources, in large part due to the museum’s facilities and space for specimen display. Authors such as the architectural historian Carla Yanni praise Phillips’s contribution to the ‘polished statement of national pride’ found in the column shafts of British and Irish stone, drawing attention to the didactic dimension of the stone columns’ chronological and type-based arrangement, which cunningly enabled the geological specimen to be ‘built into the fabric of the museum’. At Oxford, she adds, ‘while the carved stone capitals represented natural specimens, the stone column shafts actually were natural specimens’. Yanni, \textit{Nature’s Museums}, pp. 82–83. Also see O’Dwyer, \textit{The Architecture of Deane and Woodward}, pp. 223–230, who mentions Phillips’s contributions in the carved capitals, cobeles, masonry piers and polished stone shafts. Although much has been made of the novelty of the OUMNH’s didactic stone columns, it was by no means the earliest example, as Sophie Forgan points out when she writes about the marble specimens in the Museum of Practical Geology in London’s Jermyn Street, built 1847–1851. See Forgan, ‘Bricks and Bones: Architecture and Science in Victorian Britain’, p. 193–95.

\textsuperscript{392} OUMNH, MS. Acland, ‘Booklet titled “Statement of the requirements of the Oxford University Museum, and Plan of the Site (1854)’. Also see Morrell, \textit{John Phillips and the Business of Victorian Science}, p. 310. Phillips’s amenable personality has led Morrell to consider Phillips as a unifying figure in the successful construction of the museum, by preventing ‘the personal and departmental friction and jealously which could have so easily marred its early years’. Ibid., p. 307. \textsuperscript{393} Ibid., p. 316. Morrell observes that Phillips’s designs were ‘adopted almost unchanged’. Also see Oxford, Oxford University Museum of Natural History (OUMNH), \textit{Papers from the OUMNH}, History of the Museum, box 2, MS. Phillips, ‘Quote from Jackson and Graham Interior decorators and the Specification letter for the Wainscot cases’, 31 January 1862. This letter details that the work was carried out ‘in a workmanlike manner […] to the entire satisfaction of the architect’. \textsuperscript{394} Catherine Soanes and Sara Hawker, eds., \textit{The Compact Oxford Dictionary of Current English}, 3rd edn (Oxford: New York: Oxford University Press, 2005), p. 1168. Wainscot is a type of wall panelling applied to the lower portion of a room’s wall, typically made with historical imported oak. The term can either be indicative of the panelled area (singular) or the wood used in panelling (mass noun, which dates from the early-nineteenth century).
Wainscot cases, Phillips requested a quote ‘for the round iron bars, the iron cradles for shelves and the iron brackets which are to be painted 4 times in oil and colour’. In invoices and letters to do with the costing of the iron frame, Phillips explicitly refers to it as ‘skeleton frame’. In today’s architectural language, the term ‘skeleton frame’ is defined as a ‘structural frame of concrete, metal, or timber supporting the floors, roof, and exterior treatment; the spaces are filled with a lighter material or the entire structure is protected by an external cladding or curtain-wall, fixed inside or outside the frame’. The term is also used to denote buildings of a substantial height, synonymous with the internal architecture of a skyscraper. I cannot find reference to this term in joinery or architectural discourse at the time of Phillips’s writing (circa 1860), but it does become a secularised term with the development of skeleton-frame construction towards the end of the nineteenth century. It would probably have been more appropriate for Phillips to have titled the cases ‘ossatures’, using a single nineteenth-century French term, stemming from the Latin os, meaning ‘bone’, which combined with the suffix –ature, is defined as the ‘skeleton of a building, such as a frame or the ribs of a vault’. The term is still used in contemporary architectural discourse. Yet I believe that Phillips utilised the skeleton as a structural metaphor, in order to refer to a rigid frame onto which materials such as fabric, cladding, panelling or glazing were added. The skeleton was made literal in the physical object

395 For the requirements and price of iron in the making of the Wainscot cases, see OUMNH, MS. Phillips, ‘Quote from Jackson and Graham Interior decorators regarding the Specification letter for the Wainscot cases’, 31 January 1862.
396 Phillips refers to the skeleton frame’ several times. See Oxford, Oxford University Museum of Natural History (OUMNH), Papers from the OUMNH, History of the Museum, box 7, MS. Phillips, ’Letter to cabinetmakers (several mentions of skeleton frame)’, c. 1860.
of the wainscoted case. One particular drawing by Phillips, drawn in rust-coloured ink, illustrates the affiliation between the skeleton and frame (figure 2.24). There is no shading or crosshatching, only lines of varying pressure, heavy in the foreground and lighter in the background. The lines of the drawing create the sense of an architectural frame, with the roof arches arresting the eye and preventing it from escaping upwards out of the frame. The use of rust-coloured ink also makes the association with iron and further supports my assumption that the frame was made of this material. Phillips’s ‘skeleton frames’ are adroitly associated with the architecture in this drawing, as the shelves echo the horizontal architectural struts and the vertical elements reiterate the pillars. There is even a capped roof to one of the display cases, further enhancing the mimetic approach to an architectural building whilst maintaining a visual link to the Christian reliquaries of the past. In the central recess panel of the image, beneath the location of perspectival convergence, appear two people, their dress identifying them as a man and woman, in front of a doubled-trefoil arch or window. Three zoological skeletons are depicted above the cabinets lining the left-hand side/wall – a winged, an antlered and a tusked mammal – their skeletons rendered by the closer concentration of architectural lines. Animal skeletons on cabinet skeletons, within the museum skeleton. In this way, when osteological specimens are viewed within the cases, a mise en abyme effect is created, an awareness of which is indicated in Phillips’s sketches. Thus, the sketch itself takes the form of what it represents – a framed skeleton of his ideas, onto which the fleshed-out details can be added later.


The abstract ‘skeleton’ structure of the two figures emphasises the architectural elements of Victorian fashion, particularly corsetry. The majority of Victorian corsets were comprised of a metal and whalebone framework encased in cloth, with busks and stays drawing the torso inward and the breasts upwards. Hoops were added to the underskirt to create volume and accentuate the waist. Leigh Summers discusses the role of the corset in ‘articulating an appropriate Victorian femininity’, see Leigh Summers, Bound to Please: A History of the Victorian Corset (Oxford: Berg, 2001), p. 5.

Steadman detects comparable characteristics between objects (including buildings) and the way they are designed, their modes of individual and cultural
The sketch by Phillips seems to gather and articulate all the skeletons of the museum into a single image: the iron architecture, the display cases, the skeletal specimens and the living human bodies. The monochromatic medium of the rusty-red ink connects the materials of stone, wood, iron and bone within the composition in such a way that it becomes impossible to identify where one material ends and another begins. The intentional ‘gaps’ in the sketched architecture of the bodies and the building – such as between the curving rib bones in the specimen, the curved boning of the women’s hooped skirt, the vertical shelves in the cabinets, and the iron columns and pointed arches – are indicative of points of transformation and movement, either formally, directionally, materially, or conceptually. This is especially apparent in Phillips’s suggestion of ornamental iron at the top of the columns, where column, transom and Gothic arch meet. One can clearly discern that these gaps indicate points of confluence and transformation, and act as points of articulation. Articulation in the organic body provides the potential for necessary movement and growth as well as creating the necessary unification, protection and stability of the joint. By leaving gaps at points of architectonic differentiation, such as the wrought-iron bouquets situated at the top of the capitals, Phillips draws attention to the indefinable potentiality of the articulating gap when articulating skeletons.

THE ROOF: ‘SKIDMORIZED’ IRON

In the Oxford Museum, the roof is the most apparent iron skeleton on display. The industrial ironworks for its construction, which began in 1857, were conducted by a single firm under the direction of Francis Skidmore (1817–1896).402 As a member of production, which ‘lend themselves particularly well to description and communication via biological metaphor’. Steadman, The Evolution of Designs, p. 4. 402 Oxford, Oxford University Museum of Natural History (OUMNH), Papers of the OUMNH, History of the Museum, box 5, f.2, f.3 & f.5, MS. Acland, ‘Statement for OUMNH regarding the requirements for the ironworks on the roof’, c. 1859. Also see Oxford, Oxford University Museum of Natural History (OUMNH), Papers of the OUMNH, History of the Museum, box 2, f.2, MS. Acland, ‘Letter regarding the quality of glazing, in which the “Best British Plate Glass” is requested’, c. 1859, and Oxford, Oxford University Museum of Natural History (OUMNH), Papers of the OUMNH, History of the Museum, box 5, MS. Skidmore, ‘Contract for ironworks (£2,116), invoice for glazing, slating and leading (£932), and for brick work on the base columns (£87)’, c. 1859.
the Oxford Architectural Society and the Ecclesiological Society, Skidmore possessed desirable prior connections to the establishment and was faithfully granted the task of casting and assembling the structural ironworks. The exhibition of a silver chalice at the 1851 Great Exhibition is considered to have launched his career by bringing him to the attention of prominent architects, such as Sir George Gilbert Scott (1811–1878), with whom Skidmore worked with at Lichfield (1861) and Salisbury (1869–1872) Cathedrals, and perhaps most famously at Hereford (1862). At the International Exhibition of 1862, Skidmore won a medal for ‘progress, elegance of design and excellent workmanship’ for his exhibits, which included the Hereford Screen. With a discerning eye, we can see how his work at Oxford may have influenced such an architectural and artistic piece as the Hereford Screen, with its repeated Gothic patterns and floral filigree of copper and brass.  

The roof of the OUMNH is the first documented attempt at a ferrovitreous Gothic roof that I have been able to locate. Skidmore began construction in 1857, however, his initial attempt at erecting the roof in wrought iron was an astounding failure, attributed to either a miscalculation regarding the wrought iron’s elasticity or in the weight of the roofs glazing. Acland believed the former:

I am happy here to record that it is within my personal knowledge that extraordinary and unsparing pains have been taken by Deane and Woodward, to produce, often with great additional labour to themselves, the almost impossible combination of artistic effect and complete convenience, with most limited means. […] It is only to be regretted that a contrary opinion should have been expressed, due in part to

403 Skidmore also worked on the Albert memorial (between 1866–1873) and Scott’s Midland Railway Hotel at St Pancras Station (1869–1872). See Jones and Wickham, Francis Skidmore: A Coventry Craftsman, pp. 8 & 12–14. For further reading on the implementation of Gothic patterns in decoration, see Joanna Banham and Jennifer Harris, William Morris and the Middle Ages: A Collection of Essays (Manchester: Manchester University Press, 1984).

404 In his chapter ‘On the Application of Cast and Wrought-Iron to Architecture and Building’ published in 1857 (only two years prior to Skidmore’s attempt at a wrought-iron Gothic roof), the engineer William Vose Pickett addressed the history of iron in roof construction. William Fairbairn constructed the first successful wrought-iron roof in 1839 (the iron mill for Seraskier Halil Pasha, Commander-in-Chief to the Sublime Port). It was a basic three-cornered rafter. Vose Pickett does not mention any attempts at constructing a roof in the Gothic style. See William Vose Pickett, ‘On the Application of Cast and Wrought-Iron to Architecture and Building’, pp. 438–39.
ignorance of facts, and in part, more unfortunately still, to one or two singular miscalculations in constructing some estimates for extra work, as well as to an error in the calculated elasticity of wrought iron supports to the roof.405

Skidmore’s architectural inexperience may have been the cause; he was, after all, a metal worker and not an engineer or architect. Skidmore’s experience was in providing the metalwork for churches and cathedrals, his earliest known pieces of church plate (alms dishes, flagons, chalices and candlesticks) being hallmarked 1845.406 In buildings, a basic knowledge of geometry is not enough. A small-scale model will not necessarily work when enlarged on a grand scale. Forces will also increase, material properties change, in the same way that the body of a land animal can only reach a certain size, restricted by internal and external forces and stresses. Therefore, an understanding of buildings, their materials and environment was of paramount importance.

Yet there may have been the pressure for novelty in a building with such technological advanced methods of construction, being overseen by someone as prominent as Ruskin. Perhaps Skidmore’s quest for originality collided abruptly with the idiosyncratic design for the OUMNH’s initial wrought-iron roof. In a way, perhaps wanting to contribute to the ‘newness’ of the neo-Gothic, utilising his recently celebrated prowess in metallurgic ornamentation, Skidmore fabricated a roof that was unable to support the weight of the ‘best quality’ glass purchased for purpose. He did attempt to correct his error by increasing the amount of wrought iron tubing to the supporting columns. Yet following an appraisal of the additional wrought-iron supports by the structural engineer William Faribairn (1789–1874), the wrought iron was judged to be unsound.407 Evidence of Skidmore’s final attempt at a wrought-iron

405 Acland and Ruskin, The Oxford Museum, Appendix.
406 Jones and Wickham, Francis Skidmore: A Coventry Craftsman, p. 3.
407 William Fairbairn was a renowned structural engineer, who specialised in cast and wrought iron. He had published numerous articles on the properties and endurance of iron and iron alloys, and had conducted several experiments for the British Association for the Advancement of Science. He was also credited with constructing the first wrought-iron roof in 1839. See William Fairbairn, ‘On the Strength and Other Properties of Cast Iron Obtained from the Hot and Cold Blast’, pp. 377–417; Fairbairn, ‘On the Application of Cast-Iron to the Manufacture of Ordnance’, pp. 385–397, and William Vose Pickett, ‘On the Application of Cast and Wrought-Iron
roof can be seen today in the tubing that was left *insitu* under the subsequent cast iron of the new roof, built by Skidmore in 1859.\textsuperscript{408}

Yet there is evidence of Skidmore’s influence reaching beyond the architectural skeleton of the roof to a significant metaphorical association with the process of making, to articulation, even though his association with the museum was constrained to the building of the roof. The supporting narrative is that Acland returned from a voyage to Madeira with the specimen of a Tunny fish, which was subsequently articulated in the anatomy school and displayed within the main museum court in 1860 (figure 2.25). A somewhat complicated Latin epitaph, relating the Tunny’s extraordinary journey into the museum’s collection was added onto the display plinth. In 1862, a parody of this epitaph was published in the format of a congregation pamphlet, a university jest attributed to Charles Dodgson (1832–1898), who is best known under his pseudonym of Lewis Carroll. This witty epitaph substitutes the word ‘skeletonized’ with something altogether more cryptic for the Oxford outsider:

The tunny you are sneering at […] was brought to its completion and, placed as it was in the middle of the building was *skidmorized* by the skill of Benjamin Woodward.\textsuperscript{409}

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\textsuperscript{408} See Jones and Wickham, *Francis Skidmore: A Coventry Craftsman*, pp. 8–9: ‘To cast the girders for the Oxford Museum roof Skidmore would have needed a lot of workspace and it is around the time of the second roof, in [March] 1859, that he moved to larger premises in Alma Street, Coventry’.

\textsuperscript{409} Davies and Hull, *The Zoological Collections of the Oxford University Museum*, pp. 11–14. Also see the letters of Sir Henry Acland in James Beresford Atlay, *Sir Henry Wentworth Acland, Bart., K.C.B., F.R.S., Regius Professor of Medicine in the University of Oxford: A Memoir* (London: Smith, Elder & Co., 1903), p. 238: ‘The mock Statute, according to Mr. Tuckwell, was believed to have been “rough-hewn by Lewis Carroll, handed round the common-room, retouched by Gordon, Bode, and the rest, the final touch of ‘skidmorized’ for ‘skeletonized’ being supplied by Prout”’. 
In order to understand this joke on the establishment, the readers of the parodied epitaph would have had to possess prior knowledge regarding the museum’s construction, being able to associate Skidmore as the maker of the roof under which the Tunny fish was displayed.

The fact that Skidmore’s name started with a sk- for skeleton would not have evaded a wordsmith such as Carroll. In coining the verb ‘skidmorized’ Carroll brings the skeletonised specimen and the architecture together by drawing on their various levels of similitude. Firstly, on the level of material comparability, in that the iron is present in both the architecture and mode of articulation. Secondly, on the level of proximity so that the Tunny fish specimen and the iron architecture can be seen together in a single glance, and that this shared visual space enables an immediate visual association. Thirdly, on the level of visual similarity, in that the skeleton being a formation of bones and the spaces separating bone, resembles the iron and glass structures above. Lastly, and perhaps most importantly, there is the resemblance found in the process of making. The articulating iron in the roof has a weighty enough connection to the specimen, and effect on the museum visitor, as to cleverly employ a procedural metaphor from the bones of the museum to the bones of the specimen. In this way, the museum’s architecture is imposed on the specimen, and Skidmore is immortalised through the concocted verb skidmorized, a word that signifies the articulated skeleton while recalling the roof’s architect.

In the iron roof, the metaphor and material of articulation began to transform. Skidmore’s procedural failure brought focused attention to the roof and to its maker. The professors and students of the university would have been enthralled by the scandal, and as such would have spent a good deal of time looking up at the roof, perhaps even wary of it, in case it should happen fail again. This may have stimulated Carroll to conceive of the roof as somehow decaying, collapsing, falling like


410 In a similar manner to Michel Foucault in ‘The Prose of the World: The four similitudes’ in The Order of Things: An Archaeology of the Human Sciences, pp. 18–28.
disarticulated bones... or perhaps a deck of playing cards? This imagined, but potentially real animation, gives added potency to our experience inside Skidmore’s iron skeleton.

**THE GOLDEN STAIN OF RUST**

Structural repairs to the roof at the OUMNH began in January 2013. These repairs were long overdue; the roof had been leaking in numerous places since the late-nineteenth century. Over a hundred years of dripping water had taken its toll, causing severe damage to many of the museum specimens, more especially the great leviathans that were exhibited suspended from the ceiling by iron bars, and to which the trickling water from the leaky roof found its initial target causing yellow staining. No doubt this staining originated from the rust that had formed on the iron roof and the iron bars and rods articulating the whalebones. During the renovation the museum’s exhibits were closed and the undamaged specimens wrapped carefully and stored away from public view whilst those that required specialist attention by museum conservators were treated. As the last of the display specimens are secreted away, all that remained to the spectators eyes were numerous wooden creates of various sizes, juxtaposed by the large white amorphous shapes of wrapped zoological specimens, mummified beneath layers of Styrofoam and bubble wrap; unidentifiable within their plastic shrouds without the discernment of articulated bones (figure 2.26). The atmosphere of the space had also altered. No longer the cacophony of visitors’ voices or footsteps, all that remained was a profound quietness like the stillness inside an abandoned church. The visitor’s eye was no longer drawn towards the exhibits themselves. It was left gazing at the architecture of the building unhindered, and when focusing on the building’s architecture we become intensely aware of its structure, its framework and the space within its vast central hall, and we can imagine what the space would have looked like to the eyes of Phillips, Acland and Ruskin, and the contemporaries who saw it before the entry of the specimen. One also became aware of the sheer density of iron, the material that so fascinated Ruskin. Indeed, one can only speculate what Ruskin would have made of the ‘cleaning’ and ‘restoration’ process that had begun on the skeleton specimens and continued with the roof and its overlapping glass scales, given his appreciation for the process of aging.
In his work *The Seven Lamps of Architecture* (1849) Ruskin emphatically claims that ‘the greatest glory of a building is not in its stones, nor in its gold. Its glory is in its age.’ By stripping a building of its history, one strips the building of its very life:

> It is in that golden stain of time, that we are to look for the real light, and colour, and preciousness of architecture; and it is not until a building has assumed this character, till it has been entrusted with the fame, and hallowed by the deeds of men, till its walls have been witnesses of suffering, and its pillars rise out of the shadows of death, that its existence, more lasting as it is than that of the natural objects of the world around it, can be gifted with even so much as these possess, of language and of life.\(^{411}\)

In other words, age gives identity, purpose and life to a building. As the traces of time’s passing build up, they preserve something of the history of the building, encapsulating the emotional and physical imprints of the people who have touched its walls and experienced its architecture.

Heavily influenced by Ruskin's views on the veracity and authenticity in architecture, in 1877 William Morris (a dedicated disciple of Ruskin, who would publish *On the Nature of Gothic* as an independent publication, printed using his own Kelmscott Press and ‘Golden’ Gothic typeface) founded the Society for the Protection of Ancient Buildings. The founding principle for the society was the preservation of each and every layer of a building's history.\(^{412}\) However, as architect and historian Jonathan Hill has pointed out, this kind of conservation policy may have the opposite effect to what Ruskin advocated. Instead of delighting in the passage of time, architectural preservation ‘may lead to the denial of change’.\(^{413}\) Ruskin was aware of the paradox

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\(^{412}\) William Morris and Phillip Webb, ‘The Society for the Protection of Ancient Buildings Manifesto’, written in March 1877, and published in *The Atheneum*, “Restoration,” 2591 (June 23, 1877), p. 80. Morris writes: ‘the strange idea of the Restoration of ancient buildings; and a strange and most fatal idea, which by its very name implies that it is possible to strip from a building this, that, and the other part of its history – of its life that is – and then to stay the hand at some arbitrary point, and leave it still historical, living, and even as it once was.’

of preservation. For Ruskin, to preserve something was to irrecoverably change it, perhaps even to destroy it, especially if preservation turned into any kind of restoration. Attempting to return a building to its initial form may bring us closer to understanding the architect’s original vision; however, Ruskin believed that by removing a building from its natural temporality, by halting time’s natural flow, removed all signs of its life. A building becomes petrified, for the matter that animates the architecture becomes immobilised. It is like a frost passing over a spring flower. The bloom becomes frozen in ice, still beautiful but quite dead. Therefore, the traces left by the passage of time, the marks of its use and of a life well lived, animate the architecture. Even the black dust of industrial pollution had a part to play in the aging of monuments. Ruskin saw pollution as a welcome shadow of time on a building, naming such residues ‘time-stains’ in The Stones of Venice. Observed by Ruskin on his trip to Venice, the black dust became part of the essence of the floating city. It was a physical record of the passage of time and gave the palatial Gothic architectures a patina of historic value that would not have existed otherwise. Ruskin found beauty in the marks of time on buildings, as well as in the transformation of architecture from daylight into darkness, finding it ‘delightful to mark the play of passing light on its broad surface, and to see by how many artifices and gradations of tinting and shadow, time and storm will set their wild signatures upon it’. It is this unrecognised paradox of pollution, between destructive and preserving, that fed into Ruskin’s understanding

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414 Ruskin, The Seven Lamps of Architecture (1849), taken from The Complete Works, xiii, Chapter 6, ‘The Lamp of Memory’, p. 244; ‘Do not let us talk then of restoration. The thing is a Lie from beginning to end. You may make a model of a building as you may of a corpse, and your model may have the shell of the old walls within it as your cast might have the skeleton, with what advantage I neither see nor care: but the old building is destroyed, and that more totally and mercilessly than if it had sunk into a heap of dust, or melted into a mass of clay: more has been gleaned out of desolated Nineveh than ever will be out of re-built Milan. But, it is said, there may come a necessity for restoration! Granted. Look the necessity full in the face, and understand it on its own terms. It is a necessity for destruction. […] Take proper care of your monuments, and you will not need to restore them’.

415 Ruskin, The Stones of Venice, vol II, taken from The Complete Works, x, Chapter 4, p. 86.


of material dichotomies, as their visible traces and their intelligible signification mingled in his perception of the world.\textsuperscript{418} On the one hand, Ruskin appreciated the depth of dirt and blackened dust that accumulated on surface. He experienced the dust as one experiences moments through time. On the other hand, he recognised that it was superficial damage and rarely structural flaws that led to a building’s demise, and that the blackened clouds and miasmas of industrialisation were signifiers of England’s moral corruption and the destruction of her environment. \textsuperscript{419}

The mundane, yet ‘noble’ materials that fascinated Ruskin – dust, rust and moss – are testament to the passage of time, a material layering that thickens to offer a reliable index of time and historical significance to the buildings they cover, stain and grow upon. In the ‘Law of Help’, Ruskin conceives of inanimate matter, such as rocks and mud as ‘helpless’, in that the parts that compose the whole do not help each other; however, they are far from inert. If not ‘corrupted’ or diseased, the atoms within inanimate matter can ‘consist’ with each other.\textsuperscript{420} If matter is ‘consistent’ or ‘living’, it is pure and clean. It is the passage of time that animates consistent materials, and the forces and processes that occur over eons can animate and transform the most mundane of materials. Ruskin selected slime as his example of consistency, ‘the mud or slime of a damp over-trodden path’.\textsuperscript{421} He separated the slime into its constituent parts: clay (or brick dust), soot, sand, and water. Gathering and arranging each of the elements together and ‘ridding itself of foreign substance’ the clay gradually becomes a ‘white earth’. Artificial consistence of clay with ‘congealing fire’ creates the finest porcelain. If left to follow its own natural instinct, the clay transforms from white to

\textsuperscript{418} Pollution is the reason that architectural preservation as a discipline exists.
\textsuperscript{420} ‘Consistence’ is defined as ‘made up with or composed; evenness; steadiness; stability; regularity; uniformity; lack of change, or orderliness; the ’standing still’ of a living being, when it has attained its full growth, and before it begins to decay; material coherence and permanence of form; solidity or firmness sufficient to retain its form’. See ‘Consistence, n.’, in \textit{OED Online} <https://www.oed.com/view/Entry/39643?redirectedFrom=consistence#eid> [accessed 11 September 2017].
clear and then begins to harden. The consummation of matter is the point at which it is complete or finalised. For clay, that point is a sapphire. The sand arranges itself into ‘mysterious, infinitely fine parallel lines’ to become an opal. Soot transforms into a diamond, and water into a flake of ice in the shape of a star. In this way, Ruskin perceives materials along a spectrum of complexity, from simple origins to final consummation. For material transformation to occur, there needs to be both an ‘inexplicable and incommunicable’ power, and time. That power was god-like whilst also existing as a natural part of the world’s ecologies and cycles.422 ‘We never see anything clearly’, wrote Ruskin. ‘[…] what we call seeing a thing clearly, is only seeing enough of it to make out what it is; this point of intelligibility varying in distance for different magnitudes and kinds of things, while the appointed quantity of mystery remains nearly the same for all’ 423 In many ways Ruskin was referring to the idea of only every really perceiving a tiny fragment of something – part of a thing, an idea, a material, a system, part of nature – from which a whole could then be imagined. This whole will never be fully understood and will remain a glorious mystery (being the mystery of creation) that resides in all things. Although our myopic and fragmented way of looking at things means that, for Ruskin, all things possess secret unknowable meaning, there is nobility to be had in humbly dedicating one’s life to the arduous task of contemplating the fragment – to meditate on the whole through its minutest parts – in the hopes of communing with the divine in nature.

THE MUSEUM’S IRON SKELETON

Ruskin’s principles regarding building preservation were relevant during his day and remain relevant today. Heavily influenced by Ruskin’s belief in the Venetian aesthetic, some of Venice’s curators decided to refrain from cleaning the façades of the city’s historical buildings so as to retain the build-up of black dust that Ruskin so appreciated. Some curators went so far as to artificially blacken any parts of a building that had undergone recent repair, adding artificial layers of time so as to conform to the desired aesthetic for age. It was not until Camillo Boito’s publication * Conservare o Restaurare

in 1893 that Ruskin’s views were challenged.\textsuperscript{424} Boito saw Ruskin’s stains of time as mere traces of extrinsic filth and not the patina of weathered or aged materials. This prompted a number of Venetian palazzi to be brushed and whitened, including the Doge Palace.\textsuperscript{425}

In terms of the iron skeleton in the OUMNH, the 2013 conservation effort was restricted to the internal architecture. They did not touch the yellowing bath stone of the exterior masonry, only the iron roof, wrought iron ornamentation and supporting columns, and the marble stone shafts surrounding the interior court. The dark residue that coated the architectural surfaces was likely from dust, soot stains (from the burning of oil lamps and tobacco), pollution and iron oxidation. Structural cast iron tends to be sealed with industrial paints and lacquers to prevent iron exposure and oxidation. It was necessary to clean the iron so as to inspect the material for any damage that could undermine the integrity of the structure. Following the cleaning process the motifs and patterns, painted in the colours of iron oxides, were revealed. So too were the intense yellows that adorned the tips of the wrought iron foliage. Without the cleaning in 2013, the connection to Ruskin’s appreciation for organic iron would not have been made. Removing the dirt and exposing the iron skeleton in such a way has acted to deepen the layers of meaning discernible from the architecture and the specimens contained within. By revealing the layer beneath the dust, one could begin the process of re-remembering the architectural body.

Ruskin wrote, ‘it is in becoming memorial or monumental that a true perfection is attained by civil and domestic buildings; and this partly as they are, with such a view, built in a more stable manner, and partly as their decorations are consequently animated by a metaphorical or historical meaning’.\textsuperscript{426} As I have shown, the OUMNH is saturated with historical and metaphorical meaning that animates the architecture. Nathanial Robert Walker argued that the OUMNH ‘seems animated by a visual

\textsuperscript{425} Lawrence Gasquet, Conference paper, "That Golden Stain of Time": \textit{The Ethics of the Dust} from John Ruskin to Jorge Otero-Pailos’, \textit{New Approaches to Ruskin on Art and Architecture}, 1–2 December 2017, University College London and the Courtauld Institute of Art, London.
\textsuperscript{426} Ruskin, ‘The Lamp of Memory, in \textit{The Seven Lamps of Architecture} (1849), taken from \textit{The Complete Works}, VIII, pp. 221–47
metaphor that draws out mutual sympathies between iron and bone, glass and skin, architecture and biology. [...] this formal analogy is key to appreciating the core purpose of the Museum, which was to provide a meaningful and inspiring stage for the scientific pursuit of the underlying, and divinely mandated, structural logic guiding the evolution of created forms, both natural and architectural’. \[427\] In the case of iron and bone, I have argued in a similar vein, extending my analysis beyond the skeleton of the museum to the zoological specimens themselves. And, I would argue that an understanding of the skeleton as an organic architectural concept intensifies our experience of the architecture. The architecture is animate; its metaphorical meaning animates the skeleton. The architecture ages; the traces of material vitality signify an aging process. All these aspects come together and are articulated through the vital organic skeleton.

From its conception, the OUMNH was a space in which metaphors became material, and skeletons of bones and skeletons of iron came together. The skeleton metaphor acted as a point of convergence between what would have been considered two diametrically opposed materials – bone and iron – both in terms of the skeletal specimen and the architectural skeleton of the museum. \[428\] The input of the various designers and architects could have created a building of disparate elements and fractured parts, yet the OUMNH was, and remains, a space of cohesions. In *The Poetry of Architecture* (1873), Ruskin wrote that his aim when appraising architecture was to draw attention to ‘unity of feeling, the basis of all grace, the essence of all beauty’. \[429\] In the OUMNH, this unity was achieved through an articulation of its parts. For Ruskin, articulation was a part of organic growth, of establishing connections as a


\[428\] Bone is plastic, continuously being destroyed and remade within the living body in a process known as remodelling, allowing for adaptability. See D’Arcy W. Thompson, *On Growth and Form* (Cambridge: Cambridge University Press, 1917). The compact bone of the long bone is notably thicker at the midpoint of the diaphysis, where the ‘danger-point’ of bending would reside, but this ‘has been avoided, and the thickness of the walls becomes nothing less than a diagram, or ‘graph’, of the bending-moments from one point to another along the length of bone’. Ibid., p. 227.

mode of achieving a unified perception of a living thing. As growth is a condition of life, and the articulations are instruments of growth, then the points of articulation are temporal and spatial nodes full of the potential energy for further growth; and as articulated connections are made, the structure becomes physically and conceptually altered. A similar phenomenon occurs in skeletal articulation: when a bone is articulated with another bone, the two bones are conceptually altered from fragments into something larger, and with the potential to grow further.

The OUMNH was designed to embody the spirit of nature, for which the skeleton was the guiding concept. Ideally, the divisions between different surfaces and materials should be like that of living bone, a division capable of organic metamorphosis. They would form an architectonic unity via the transformation of the mesenchyme into cartilage, into bone and into ligament, at imperceptible faults of differentiation. Bone does not grow from its centre, but from its ends – the epiphysis, from the Greek επίφυση, meaning to grow towards or upon – and it is at the epiphysis that bone transforms, grows and becomes articulated. Yet the lack of organic growing tissue in building construction makes such bio-architectonics unfeasible. Artificial articulations are needed. In the museum, the material chosen for this articulation was iron, due to its understanding as both organic and inorganic. As the points of iron articulation carried the potential to embrace an organic nature, they existed as faults of possibilities between the materials of bone and iron. It is at these sites of articulation that skeletons were formed and choices made possible, choices for either an artificial or an organic architectonic interpretation, applicable in both the osteological specimen and in the building.

As metaphors work to bridge gaps in language, so too does iron articulate the gaps in the OUMNH’s many skeleton forms, and the success of this articulation depends on the perception of a potential for life whilst retaining tectonic unity. The gaps in language, in architecture and in skeletons are the fertile ground from which potential

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430 Ruskin described the two types of organic articulation in *Proserpina* (1875–1886). They are the leaf-stem articulations seen in flora and the joints in the endo- and exoskeletons of various fauna. In plants such as canes, the articulations between the parts provide strength. The joints become stiff, allowing for the cane to grow taller, to support its weight and withstand external environmental forces. On the other hand, the articulating parts in the animal, its joint, are points of flexibility and allow for muscle movement. See Ruskin, *The Complete Works*, xxv, pp. 324–25.
interpretations can spring forth, as words, material and bones are articulated in such a way that they can be perceived as natural and organic. The architects of the OUMNH wanted the organic to be the mode of their articulation. They began with bones, the essential parts, and attempted to find ways to organically unite them in the museum’s design, architecture and displays. Phillips used a skeleton to unify and ‘frame’ his displays and specimens. He articulated his ideas through sketches of the museum space, which were made all the more profound by their multifarious and recursive nature, like a Russian nesting doll of skeletons (the specimens) within skeletons (the wainscoted cases) within skeletons (the museum’s architecture). Ruskin proposed an organic ‘nature’ to articulate the Gothic, as evidenced by the structural and carved stone ornamentation, and this organic nature was enhanced by an organic appreciation of iron. The potential for iron to change, to oxidise, allows for a metaphorical growth of both the material and of the museum’s visitors, who experience a shift in the way they perceive and interpret it.

It should also be remembered that individual vision had to be subordinated within the collective effort of a building. The museum was designed by Benjamin Woodward, influenced by the edicts of John Ruskin, governed by a budget that curtailed the choice of materials, and structured for didactic use by Henry Acland who determined what was ‘essential’ to the museum, at the expense of the material.\footnote{Ibid.} In addition, there was John Phillips, professor of geology, who had a say regarding the internal decoration, selecting the type of stone for the 127 columns that surround the central court, as well as dictating the forms and positions in the variety of carved flora in the museum’s interior (figure 2.27).\footnote{Acland and Ruskin, \textit{The Oxford Museum}, p. 33. Phillips’s letter on the arrangement of the marble shafts can be found in the book’s appendix.} The stone column capitals likewise reveal the virtuosity of their individual sculptors, of which the O’Shea Brother in the employ of Deane and Woodward, were the most famed (and notorious for their supposed depiction of anthropomorphic parrots, with the faces of local clergy and parishioners).\footnote{For an detailed examination of the stone carvings at the OUMNH by brothers James and John O’Shea, and Edward Whelan (their nephew or cousin), see Blair J. Gilbert, ‘Puncturing an Oxford Myth: the Truth about the “Infamous” O’Sheas and the Oxford University Museum’, \textit{Oxoniensia}, 74 (2009), 87–113.} The museum was unique in its fusion of architectural styles and materials, the results of
which were met with mixed reviews ranging from triumphant success to wretched failure. It was experimental in the reimagining of medieval Gothic architecture with nineteenth-century industrial materials, and both monumental and controversial in its form and formation, a cathedral within which to bear witness to the birth of Natural Science. The ambition and stakes of the museum were high, architecturally, in terms of its display and the scientific positions that underpinned it. Most of the protagonists discussed here took, unlike Richard Owen, a pro-Darwinian view on evolution. Not surprisingly, the museum became the first battleground between Darwinian and theological approaches to the natural world and its formation. As we will see in the next chapter, bones and skeletons played as an important role in developing and sustaining scholarly positions in such debates as they were as architectural metaphors in both England and France.
In the previous chapter, I argued that the iron construction of the OUMNH was considered a skeleton in both its form and mechanical efficiency, and that the ‘skeleton’ was a powerful metaphor when appraising iron architecture, especially when inspired by the Gothic style. It is with this understanding that I turn my attention to the iron architectures of nineteenth-century Paris. This chapter will focus on the writings of Eugène-Emmanuel Viollet-le-Duc and will draw particular attention to the influence of the zoologist Georges Cuvier on the former’s architectural theory and designs. The chapter will demonstrate the parallels between Viollet-le-Duc’s conception of iron and bone and consider the ways in which anatomists and engineers of the second half of the nineteenth century compared the two materials. I will conclude by providing visual evidence for the influence of Viollet-le-Duc’s theory upon Charles Ferdinand Dutert, the young innovative architect of the colossal Galeries des Machines for the 1889 Exposition Universelle. Dutert became later, in 1893, the architect for the Galerie de Paléontologie et d’Anatomie comparée (Galleries of Comparative Anatomy and Palaeontology) in Paris’s Jardin des Plantes. The galleries form part of the Muséum national d’Histoire naturelle and were inaugurated in 1898 as part of the Exposition Universelles de Paris of 1900. The galleries were built expressly to showcase the celebrated collection of French natural history, with Cuvier’s cabinet of osteological specimens taking centre stage. Although the museum’s architecture has not been described as ‘organicist’ in any published literature, I offer a reconsideration of this museum as having an organic vision inspired by Viollet-le-Duc’s precepts of the Gothic. And I will argue that the skeleton acts as the vehicle for this organicist concept. I will interrogate the ‘skeletons’ of the building, in the museum’s osteological specimens, its architecture, and the process of its making. Through the emerging concept of an organic skeleton, as discussed in the previous chapter, I will present a new interpretation of this building that considers the material
interactions and slippages between the iron and bone, and how the secular comprehension of these two materials relate to the iron skeleton of the building in a relationship founded on visual resemblance and metaphor that developed into a conceptual mutuality.

GEORGE CUvier AND THE METHOD OF COMPARATIVE ANATOMY

Notions like ‘purposeful unity’ and ‘functional morphology’ were key to organicist architectural theory, and they derive to a large extent from the thinking of nineteenth-century natural philosophers and biologists. The most influential among them was, notably in France, the naturalist Baron Georges Cuvier (1769–1832), who was during his lifetime a stellar figure in the natural sciences in France and throughout Europe. Cuvier’s significance was later in the nineteenth century overshadowed by the fact that he objected to the transformist (evolutionary) understandings of nature, but recent scholarship has recognised his significance in the fields of zoology, paleontology and geology. A beneficiary of the educational reforms introduced during the French Revolution and its aftermath the young naturalist, who had grown up in Alsace and Normandy, joined the Musée d’histoire naturelle, initially as an assistant to the anatomy professor and later his successor, shortly after his arrival in Paris. This institution had been reformed and democratised during the French Revolution, when the former Jardin Royal (Royal Garden of medicinal plants) was transformed into the Museum or Jardin des Plantes. The institution had been a major site for the study of natural history and anatomy as well as for the collection of relevant specimens since the foundation in 1626.

Originally the ‘Jardin du Roi’ or Jardin Royal was created for Louis XII. At that time in the seventeenth century, the selected site was situated at the edge of the city, on the left bank of the Seine, and was intended as an institution devoted to the training of

435 Ibid.
The gardeners cultivated therapeutic herbs and plants for the making of concoctions and remedies, and anatomists performed dissections and produced publications. Courses in botany, anatomy and chemistry were taught at the site and, unlike the traditional academies and faculties, the courses were taught in French and were open to all. The garden with its teaching facilities proved to be very popular. However, under the pressure of revolutionary transformations, the gardens needed a ‘rebranding’ of sorts and became, in 1793, the Jardin des Plantes, and the Museum of Natural History.

On occasion the museum was weakened by such historical events, but it was and remains an important site for major developments in science. It played a key role in the emergence of new concepts, such as biology and evolution, and new disciplines, such as physiology, anthropology and palaeontology. The last two centuries have seen extensive changes to the garden. Old buildings have been demolished, some have been restored, and new buildings have replaced the old. The garden itself has been transformed by use and necessity. Yet the founding principles of the garden have hardly changed. The Jardin des Plantes still holds its core principles of research, teaching, publishing, collecting and ‘knowledge for all’.

Inheriting and working with the jardin’s preserved specimens, one of Cuvier’s initial tasks was the cataloguing of the collections. These collections, which Cuvier significantly enlarged during his lifetime, consisted of dry and wet specimens and fossils, and were a major basis for his research in the classification of species, alive or extinct. Cuvier proposed a way of classifying animals that was based on physiology rather than the methods of pre-revolutionary natural history. This approach was also manifest in the arrangement of the cabinet of comparative anatomy that lay under his

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438 Ibid.
439 Ibid.
control as titular professor.\footnote{Dorinda Outram, \textit{George Cuvier: Vocation, Science, and Authority in Post-Revolutionary France} (Manchester: Manchester University Press, 1984), pp. 173–78.} Cuvier described natural history as the application of general physics to nature, believing that nature was governed by ‘conditions of existence’ and ‘final causes’.\footnote{Cuvier defines general physics as that which ‘examines, abstractedly, each of the properties of those moveable and extended beings which we call bodies. That deportment of them styled Dynamics, considers bodies in mass; and, proceeding from a very small number of experiments, determines mathematically the laws of equilibrium, and those of motion and its communication’. These include statics, mechanics, hydrostatics, hydrodynamics, pneumatics and optics. See Georges Cuvier, \textit{The Animal Kingdom, Arranged According to Its Organisation by Baron Georges Cuvier}, trans. by E. Blyth, et al. (London: William S. Orr & Co., 1849), p. 13 of the Introduction.} For him, comparison was a key empirical method, as he held that ‘[t]he most effectual mode of observing is by comparison’.\footnote{Cuvier, \textit{The Animal Kingdom}, pp. 6 & 15.} Cuvier extended his comparative method to the examination of fossils, pioneering the field of vertebrate palaeontology, and attempted to reconstruct the morphology, physiology, and ‘way of life’ of non-extant animals. However he never swayed from the ‘visionist’ vision that all living beings were the result of divine creation. He related the notion of species invariability to the fossilised specimens in his collection, imagining that they disappeared in mass extinction events that he called ‘world revolutions’.\footnote{Vives and Colin-Fromont, \textit{Les galerie d’Anatomie comparée et de Paléontologie}, p. 8.} It has recently been recognised that Cuvier’s method of comparative observation resonated far beyond the field of zoology and the natural sciences, and impacted on art historical methods as well as architectural theory. Several architectural historians have discussed the influence of the naturalist upon nineteenth-century architectural theories and designs, notably those of Viollet-le-Duc (1814–1879).\footnote{See Bergdoll’s ‘Introduction’ in Eugène-Emmanuel Viollet-le-Duc, \textit{The Foundations of Architecture: Selections from the Dictionnaire raisonné}, trans. by Kenneth D. Whitehead (New York: George Braziller, 1990), 1–30 (pp. 18–23); Laurent Baridon, \textit{L’imaginaire scientifique de Viollet-le-Duc}, pp. 31–41 & 163–69; Martin Bressani, \textit{Architecture and the Historical Imagination: Eugène-Emmanuel Viollet-Le-Duc, 1814–1879} (Farnham and Burlington: Ashgate, 2014); Millard Fillmore Hearn, \textit{The Architectural Theory of Viollet-Le-Duc: Readings and Commentary} (Massachusetts: The MIT Press, 1990), and Charles L. Davis, ‘Viollet-Le-Duc and the Body: The Metaphorical Integrations of Race and Style in Structural Rationalism’, \textit{Architectural Research Quarterly}, 14 (2010), 341–48 [doi:10.1017/S1359135511000133].} Cuvier’s practice of classifying the animal skeletons at the Jardin de Plantes based on their function rather
than their form was, Bergdoll states for example, to influence the ‘writing of the history of art, and on the theory of the decorative arts and architecture in particular’. Art historian Isabelle Flour has further pointed out that the Musée de sculpture comparée, founded in Paris by Viollet-le-Duc shortly before his death in 1879, cannot be understood without reference to the constitutive model of comparative anatomy. The architect was to develop a comparative method in architecture inspired by Cuvier’s rationalist theories of purposeful unity and functionality in the field of comparative osteology.

THE COMPARATIVE METHOD

Viollet-le-Duc was also a firm advocate for the use of exposed iron in architecture, drawing attention to its properties and function being like that of bone and the animal skeleton. Vitruvius, in De architectura libri decem, described the origins of architecture through the Colchians’ primitive hut, Colchis being an ancient kingdom located in present-day western Georgia:

They lay down entire trees flat on the ground to the right and the left, leaving between them a space to suit the length of the trees, and then place above these another pair of trees, resting on the ends of the former and at right angles with them. These four trees enclose the space for the dwelling.

Vitruvius thus describes the principle of pillar and lintel – a square box-frame constructed of tree wood, a basic framework that was for him the precondition of architectural form. This was a similar framework presented by Laugier in the mid-

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eighteenth century, although the impetus to imitate nature’s methods is demonstrably absent. Viollet-le-Duc presented an alternative rationale for the origins of architecture in his publication *The First Building* from 1870. He reasoned that the first hut was constructed of branches propped up against a cave or cliff, or arranged against trees, and that the original architectural pillars were in fact the trunks of *living* trees fastened together.

Viollet-le-Duc provides an illustration of the primitive hut during its construction (figure 3.1). The thin, branchless tree trunks converge at the apex, with the top-most branches remaining intact, their canopy spreading above the circumference of the structure. Figures are dispersed throughout the scene, undertaking various tasks to secure the structure as well as enclosing the shelter through the addition of a protective ‘wall’ made from long reeds and grasses, which are being carried into the scene by two individuals. One carries these reeds across their back (left background) and the other over their shoulder (right foreground). Two other figures kneel to the right of the structure, weaving the reeds around the trees. The most noteworthy figure is located in the centre of the image. Standing at the structure’s widest opening, the figure’s right hand holds one of the tree pillars, whilst their left is grasping what appears to be a supporting branch or staff. As the most ‘dressed’ figure, this individual is also the only person that does not work. Their contrapposto stance is authoritative, it stands in for the human proportions of architecture and is the image of an architect, assessing the tree’s stability whilst looking outward and perhaps directing the on-going labour.

Viollet-le-Duc was by no means alone in doubting the established model of the Vitruvian hut. In the 1830s, French architects were reacting to an increased interest in archaeology following the return of French expeditions during and in the aftermath of Napoleon’s Egyptian campaign. The French relinquished control of Egypt in 1801 but they uncovered an abundance of artefacts beneath ‘le sable brûlant’.⁴⁵⁰ Although the British subsequently claimed many of the unearthed artefacts as their own (and are now part of the collection at the British Museum), the French savants (one hundred and fifty-one scientists, mathematicians and engineers recruited by Napoleon) amassed their material and collated their first-hand observations and experiences,
publishing an encyclopaedic archaeological series *Description de l’Égypte* (1809–1822).\(^{451}\) The recorded excavations of ancient sites, such as the Suez Canal, and the uncovering of their monuments became the impetus for scholars to rewrite the history of art, especially sculpture, and to reconsider the question of origins of architectural styles.\(^{452}\) In response to these finds, many architects revisited the theory of origins as proposed by Vitruvius. The first Vitruvian theory to be debunked by architectural theorists was the original ‘hut’ of wooded post and lintel, the supposition being that the classical orders were inspired by an imitation of these early wooden structures. It seemed no longer rational to assume that early humans would have constructed tools for cutting trees out of the blue, and for them to have formulated a process of assembly


\(^{452}\) On the excavation of the Suez Canal by the French, see Grimaldo-Grigsby, *Colossal*, pp. 8–69. In 1785 Antoine-Chrysostome Quatremère de Quincy (1755–1849) published his theory on the origins of architecture and the first architectural structures. He identified three ‘primordial types’ to architectural form: the cave (used by hunters), the tent (used by shepherds) and the hut (utilised by farmers). These three forms developed and changed throughout geographies and cultures, such as the Egyptians, the Chinese and the Greek. See Antoine-Chrysostome Quatremère de Quincy, *The True, the Fictive, and the Real: the Historical Dictionary of Architecture of Quatremère de Quincy*, trans. by Samir Younés (London: Andreas Papadakis, 1999). Also see Sylvia Lavin and George Levitine, ‘Quatremere de Quincy and the Revolution in Neo-Classical Egyptology’, in *Culture and Revolution: Cultural Ramifications of the French Revolution* (College Park, MD: University of Maryland Department of Art, 1989), pp. 160–70. Jacques-Ignace Hittorff (1792–1867) also developed a theory of polychomy, which was a novel and unique approach at an attempt to generate a generalised system for colour in architectural restoration. This was similar in manner to Quatremère de Quincy’s discussion of statues and idols in ivory and gold. See Jacques Ignace Hittorff, *Restitution du Temple d’Empédocle à Sélinonte, ou l’Architecture polychrome chez les Grecs* (Paris, 1851). Harry Francis Mallgrave writes that Gottfried Semper was influenced by Hittorff’s schema – a system of colour, compatible with the ‘orders’ and ‘was the means by which the particular character of the edifice became expressed’. See Mallgrave’s introduction in Gottfried Semper, *The Four Elements of Architecture and Other Writings*, pp. 6 & 11. Mallgrave also notes that Semper was influenced in his theory of style by the architectural unearthings and finds in the Middle East, especially drawing attention to the Assyrian find of Paul Emile Botta and Henry Layard in the 1840s. Botta and Layard were credited as the finders of the third seat of civilization, which made up the pre-classical past (the other two being Egypt and Greece). Each of the three roots of civilization had architectural and artistic attributes particular to their age and locale. See ibid., p. 21.
before seeking to construct some sort of basic shelter, be it temporary or otherwise. For architectural theorists like Gottfried Semper and Viollet-le-Duc, only natural laws and the environment could determine the conditions of human existence and manufacturing. The classical orders of architecture as they had been traditionally understood did not comply with natural laws of building. The Vitruvian hut, it was now argued, would never have held, would never have withstood the forces of nature. In formulating these new theories based on functional ecology and the laws of nature, whatever these laws may be, some architects looked to the leading theories in the then emerging field of biology. This latter term was coined by Jean-Baptise de Lamarck (1744–1829) in 1802, a zoologist at the Muséum d’Histoire Naturelle.453

As with the ordering of architecture, the ordering of nature proved to be no less controversial. The rise of natural history in France is credited to Georges Louis Leclerc de Buffon (1707–1788), later Comte de Buffon. He became director of the Jardin du roi in 1739 and developed the more secular ‘natural system’ for classifying nature based on anatomical similarity (unlike Linnaeus’s ‘artificial system’ which employed binomial nomenclature for genus and species that made no claims regarding the relationship between animal groups).454 Conceiving of the vastness of ‘deep time’ and its importance to the living world and predictive scientific theories, Buffon liberated himself from Christian dogmas and attempted to rationally calculate the age of the Earth by observing spheres of molten minerals and calculating their cooling time.455 Buffon also perceived filiations between species, which generated the theory that species could possibly transform. He introduced Newtonian mathematics to France, translating Newton’s text on calculus into French, and considered internal moulding and Newtonian gravity as forces that effected the form and function of animals.456 Louis Jean-Marie Daubenton (1716–1800) collaborated with Buffon to present the principles and method of organising and arranging species for comparison, thus laying the formative groundwork for the science of comparative anatomy, a discipline which studies differences and similarities between the structures and organs

453 Peter Collins, Changing Ideals in Modern Architecture, p. 150.
of living beings.\textsuperscript{457} At the time of Buffon’s death, the Royal Gardens in Paris was home to the largest natural history collection in Europe.\textsuperscript{458} The next generation of naturalists after Buffon, which included Lamarck, Cuvier and Étienne Geoffroy Saint-Hilaire (1772–1844), are credited with placing France firmly at the centre of European Natural History. Lamarck specialised in marine fossils, palaeontology and geology. He contended that all matter was active, and that life entered matter by natural fluids such as heat and light.\textsuperscript{459} Lamarck’s research led him to develop a theory that all animals were subject to constant change over long periods within ‘deep time’, and that animals were ‘transformed’ by their environment. He also theorised that current forms of life derived from older forms. In 1800, Lamarck defended his original and pre-evolutionist concept of ‘transformation’, which he first applied to extant species and then extended to fossils.\textsuperscript{460} As pre-Darwinian evolutionists, the theories espoused by Lamarck and, more publicly, Geoffroy Saint-Hilaire, were in direct opposition to theories championed by Cuvier.

The 1830 debate between Georges Cuvier and Geoffroy Saint-Hilaire is now considered as a significant epistemological moment in the history of science and architecture.\textsuperscript{461} The two naturalists were defending their alternative versions for intra- and interspecies variation. Was it the function of an animal that informed its morphology, or did a fundamental ‘blueprint’ exist for each animal that could be

\textsuperscript{458} Farber, \textit{Finding Order in Nature}, p. 22.
decoded through the practice of comparative anatomy? Furthermore, did animals change over long periods of time? Geoffroy Saint-Hilaire, author of *Philosophie anatomique* (1818) proposed a unity of compositions, in that all animal skeletons and organs share corresponding structures, independent of their function.\(^\text{462}\) He supposed that the ‘homologies’ in animal structure and form determined its way of life and, like Buffon before him, believed that each species could be situated within a historical framework and that animals changed over extended periods of time.\(^\text{463}\) His theory was supported by Lamarck, as well as the emerging field of embryology.\(^\text{464}\) On the other hand, Cuvier espoused his belief that an animal’s way of life, its ‘conditions for existence’, determined its anatomy. Cuvier held that comparative anatomy could provide the answer by giving order to nature, not just a functional ordering between species but a functional ordering of the entire animal kingdom. In his most celebrated work, his 1817 *Le règne animal*, Cuvier set out his taxonomic approach to the classification of animals based on his method of comparative anatomy. Animals with similar physical traits were grouped together and ordered according to their anatomical complexity, resulting in four distinct classes or ‘embranchements’ of the animal kingdom.\(^\text{465}\) It was a static picture of nature, with only catastrophes such as mass extinction and mass migrations altering the zoological landscape. Allying fossils with animals still living, Cuvier claimed that all he required was a single bone for him to be able to describe the entire animal. He hypothesised a ‘correlation of parts’ between the palaeontology and zoology specimens, which was reflected in the display strategies he employed, and which can be seen today in the Galerie de Paléontologie et d’Anatomie.

\(^{462}\) Farber, *Finding Order in Nature*, p. 38.


\(^{464}\) Early nineteenth-century embryological research had discovered that all animals begin life in a similar ‘simple’ state. As the embryo matures, the ‘higher’ animals develop more complex structures while the ‘lower’ animals remain in the simple stage. See Farber, *Finding Order in Nature*, p. 39.

Cuvier’s theories were compatible with contemporary religious belief regarding ‘origins’, and were widely distributed and accepted throughout Europe, affecting the entire western scientific community and beyond. In the introduction to an early English translation of Cuvier’s *Le Règne*, the natural scientist Edward Griffith reluctantly attests that ‘it cannot be denied that for the most perfect zoological methods we are indebted to Frenchmen’, despite (or in spite) of France’s tempestuous and warring past.

Cuvier held that the animal skeleton was a predictable model in that species followed the form of their parents. Cuvier developed the predictably of heredity further, determining that an entire life could be understood and interpreted from nothing but the bones of the animal, which he considered to hold the essence of form. In theory, all you would require is a single bone for its entire skeletal structure to be decodified and reimagined. The functional skeleton was essential for the predictive model posed by Cuvier, and this model was to be adapted by numerous architects such as Semper and Viollet-le-Duc in their respective theories of style.

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466 Farber, *Finding Order in Nature*, p. 41.
469 Semper’s classification of the forms of human crafts was based on their basic function and the technologies of their production. Gottfried Semper, *Style: Style in the Technical and Tectonic Arts, or, Practical Aesthetics*, trans. by Harry Francis Mallgrave and Michael Robinson (Los Angeles: Getty Research Institute, 2004). Mallgrave believes there to be more evidence that Semper followed in the tradition of Goethe due to the repeated use of Goethe’s terminology in his lectures. Scholars have presented evidence that Cuvier was against Goethe’s way of thinking and expressing himself, especially where his writings addressed evolution, as it is well know that Cuvier maintained an anti-evolutionary stance, promoting catastrophe theory right up until this death in 1832. See Mallgrave’s introduction in Gottfried Semper’s *The Four Elements of Architecture*, p. 26. On Cuvier’s Catastrophe Theory, see *Discours sur les révolutions de la surface du globe, et sur les changemens qu'elles ont produits dans le règne animal*, 3rd edn (Paris: Edmond D’Ocagne, 1825). Also see Foucault’s *The Order of Things*, pp. 263–79, for a fuller understanding of taxonomic study at this time in history. Also see Charles C. Gillispie’s *The Edge of Objectivity* (Princeton: Princeton University Press, 1960), p. 283, which looks at how Cuvier’s ‘comparative’ classificatory body of material made possible Darwin’s own work.
Van Eck’s position is that ‘a new concept of architecture was formulated, in which considerations of functional adaptation and an appreciation of the technical aspects replace the respect for the architecture of Greece and Rome instilled by the teaching at the École des Beaux-Arts’. It was a clear break from traditional attitudes and architectural theories. The rationalist architects of the 1830s known as the Romantic Pensionnaires – Léon Vaudoyer, Léonce Reynaud and Henri Labrouste – are the first to be credited with developing the biological analogies so crucial for organicist theory and for their rejection of the classical models of antiquity. Inspiration rewriting the history of the Gothic style and for perceiving Gothic architecture as a ‘purposeful unity’ of form, was taken from Geoffroy Saint-Hilaire, who attributed all animal morphology as being evolved from a single basic ‘type’, whilst other architects took inspiration from Cuvier’s functional morphology and comparative approach to classification. Van Eck described these architects’ work as ‘the gradual reformulation of the metaphysical and theological notion of purposeful unity in biological terms’. The remains of animals, their fossils and skeletons, became a model for this new scientific architecture.

In his classifications, Cuvier also attempted to reformulate the ‘traditional notions of unity and purposive character by which living nature is distinguished from dead matter’. In *Le règne animal*, Cuvier distinguishes life forms from other natural entities via their innate ability to become animated. He states:

> Life being the most important of all the properties of beings, and the highest of all characters, it is not surprising that it has been made in all ages the most general principle of distinction; and that natural beings have always been separated into two immense divisions, the living and the inanimate.\(^{473}\)

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\(^{472}\) Ibid., p. 219.

For Cuvier, animation was an essential process in identifying life. This passage manifests the focus of the new life sciences on life, but equally the conundrum that, as Foucault has pointed out, life tended to be defined against death.\textsuperscript{474} This view can be extended to the fact that Cuvier derived his knowledge of living species to a large extent from the vast collections of dead specimens at the museum, notably from dead bone. It has been argued that Cuvier articulated many skeletons in the comparative anatomy collections himself, and that he made is own ‘Beauchêne skulls’ to show all fourteen facial bones and eight cranial bones.\textsuperscript{475} Also called ‘exploding skulls’, the bones are reassembled on a jointed iron or brass stand with a wooden base and moveable iron supports, so that each bone can be moved, bringing them apart or closer together so that the skull can be understood as both fragmented and whole. This kind of relational understanding between the part and the whole was essential for the development of craniometrics and Cuvier’s practice of Comparative Anatomy, and contributed significantly to the field of anthropology.\textsuperscript{476}

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\textsuperscript{474} Foucault makes this point in relation to the anatomist Xavier Bichat in \textit{The Birth of the Clinic} (London: Tavistock Publications, 1976). On the transformation of natural history into biology and Cuvier’s notion of life, also see Foucault, \textit{The Order of Things}, p. 340. For more on Bichat’s physiological experiments and attempts at defining life and death, see Farber, \textit{Finding Order in Nature}, pp. 73–74.

\textsuperscript{475} See Cuvier, \textit{Lectures on Comparative Anatomy}, 2 vols, 1802, in which Cuvier draws attention to the correct articulation of ‘his’ skeletons. Also see Robert Edmond Grant, \textit{Lectures on Comparative Anatomy: Delivered in the University of London during 1833} (London: Lancet, 1833–1834), p. 815–16, in which Grant describes Cuvier supervising the articulation of a bird and correcting the articulator during the process. There is currently a Beauchêne skull on display in the galerie d’anatomie comparée, but it is not known if Cuvier articulated it.

\textsuperscript{476} Edmé François Chauvot de Beauchêne (1780–1830) was a French anatomists, surgeon and bone ‘articulator’, who developed his own method of separating the cranial bones along their suture lines and mounting them ‘disarticulated’. This enabled the anatomist to see how the bones related to one another, as well as how they fit together to achieve the continuous hard surface of the cranium and skull. It is believed that Beauchêne was influenced by Leonardo da Vinci’s anatomical drawings in the development of his method. See Robert J. Spinner, Jean-François Vincent, and Alexandra P. Wolanskyj, ‘Discovering the Elusive Beauchêne: The originator of the disarticulated anatomic technique’, \textit{Clinical Anatomy}, 24 (2011), 797–801.
The new generation of rational architects developed a new aesthetic, one built on the principles of the life sciences of their time and founded on the perspective that form must follow function. However, the notion of a ‘rational’ architecture was not a single doctrine and was interpreted in different ways by individual protagonists. Some architects, such as Louis-Auguste Boileau and Vaudoyer, believed that selecting elements from different architectural periods and styles that had proven workable and successful was a rational method of designing and building. They had thus no problem with creating a kind of pastiche of the best parts, as long as they were selected in the service of functionality. Others, such a Labrouste and Viollet-le-Duc, proposed that function was indeed key to form. For them, however, functionality incorporated the rational selection of materials. They objected to the bastardisation of past historical styles for, in their eyes – as for Ruskin – there already existed an architectural style that was developed purely in the service of function: the Gothic. The rationalist architect most recognised for his writings on and work with Gothic architecture was Viollet-le-Duc, perhaps most famous for his controversial restoration of Notre Dame de Paris and the medieval city of Carcassonne. Viollet-le-Duc certainly found the rational in the Gothic style, from both the proportions of the structures (typically ecclesiastical), the construction material and the organic forms. Even though Viollet-le-Duc’s tenets and opinions were later deemed controversial and somewhat dated, they were during his lifetime widely recognised, and his theories and designs were respected by the budding architects of the École des Beaux-Arts, where he briefly taught and whose curriculum he helped reform in 1863. His writings on the subject are still considered relevant today. With its ribbed vaulting and pointed arches, French medieval Gothic architecture inspired a generation of architects who were looking to build large and expansive structures in a similar manner to those building the great churches and cathedrals of the eleventh and twelfth century – grand in scale with the functional spirit of the Gothic style. Another of Viollet-le-Duc’s legacies was the Musée de sculpture comparée, which became, in its later, more nationalist version the Musée des monuments français. Filled with plaster cast reproductions of sculptures
and sculptural reliefs mostly from medieval architecture, it allowed for a comparative
display that was based on the methods or comparative anatomy.477

Viollet-le-Duc presented his research on French medieval-Gothic architecture, and his
argument for its implementation as the new national style in which to build, in his
Dictionnaire raisonné de l'architecture Française – a comprehensive critical analysis
of the style, its attributes and the methods of construction. When addressing the
building’s framework, he uses the terms ‘ossature’ (from the Latin ‘os’ meaning bone)
and ‘charpente’, interchangeably. In the preface to the first volume of his Dictionnaire,
Viollet-le-Duc proposes a biological analogy to his work:

[…] the moment has come to study medieval art as one studies
the development and the life of an animate being who proceeds
from childhood to old age via a series of almost imperceptible
transformations, such that it is impossible to pinpoint the day
when childhood ended and old age began.478

He compares the development of architecture to the lifecycle of a human being, with
small imperceptible changes in growth that, over time, result in a complete
transformation from the original form. For Viollet-le-Duc, the transformation of styles
in art and architecture was a biological process. It was not the evolution of a style as
such, as this would indicate a progression of sorts, a movement towards a better or
fitter model. It was the ‘life of form’, and a life spanning centuries.479 The kernel of
the thing itself remains unchanged whilst its appearance transforms in what Martin
Bressani describes as a metamorphosis.480 Yet in his discussion of the particular
elements of construction, such as the columns, arches and vaults, Viollet-le-Duc
imagined them having evolved, for example, as the Corinthian column ‘grew’, it
transformed from a decorative element to a functional support.

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477 See Flour ‘Les moulages du Musée de sculpture comparée’, pp. 221 & 228.
478 Viollet-le-Duc, Dictionnaire raisonné de l’architecture française du XIe au XVIe
siècle, 10 vols, I.
479 Ibid., II, p. 508.
480 Bressani, Architecture and the Historical Imagination, p. 274.
Barry Bergdoll and Martin Bressani have already drawn attention to Viollet-le-Duc’s continuous utilisation of anatomical and biological analogies. They have pointed out in more general terms that the natural sciences impacted on the architect’s methodology and language. Viollet-le-Duc transformed previous methods of distinguishing between styles through formal traits by applying methods of identification and categorisation derived from comparative anatomy to be more precise. Cuvier developed a method with which an entire life could be understood and interpreted from nothing but the bones of the animal. Cuvier considered the bone’s structure and not the outer shape as the essential form of the animal. In comprehending the bone’s structure, he could then construct the entire skeleton from a bone or fossil, even if fragmented, based on the form being in the service of function, i.e. if the animal was fast, its bones would be formed to enable maximum speed, and that each individual element would act in service of the whole. Cuvier exemplified his assertion with the fossilised bones of a prehistoric pterosaur, which he named ‘Pterodactyl’. In 1809 he became the first naturalist to suggest that the pterosaurs where aerial creatures.  

Viollet-le-Duc was inspired by Cuvier’s method, and the example of the pterodactyl made a particularly strong impression.

Cuvier’s approach to the relationship between fragment or part and the organic system or whole is, according to Bergdoll, the basis of Viollet-le-Duc’s *Dictionnaire*. Viollet-le-Duc proposes that his architectural dictionary is based on the ‘conviction that the essence of structural rationalism manifest most perfectly in gothic structure was equally present in every minute part of a gothic building, down to the shaping of the individual mouldings and the cutting of individual stones’.  

[J]ust as in *looking* at a single leaf, one can deduce the character of the entire plant; the bone of an animal, the entire animal; in the same way, by *viewing* the profiles, one can determine the architectural members; the architectural members, the monument. […] from a logical deduction based on all of the details, rather like that principle observable in the order of all created things, where the part is as complete as the whole, the part composes itself like the whole. The majority of  

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the entries in the *Dictionnaire* make evident the spirit of logic, the unity of principle, that always guided the masters of the Middle Ages.\(^{483}\)

As with Cuvier’s comparative method, Viollet-le-Duc’s architectural theories were founded on the skills of faithful observation; of looking and drawing the architectural structures, part-by-part, so as to acquire a clearer picture of how the whole functioned. Cultural historian Paula Young Lee argues that Viollet-le-Duc considered an understanding of comparative anatomy to be a ‘fundamental step in learning how to draw’.\(^{484}\) In his last novella, the children’s book *The Story of a Young Designer, or Learning How to Draw*, Viollet-le-Duc introduces the reader to the 11-year-old boy, Jean, who lives near Paris with his father.\(^{485}\) One day an eccentric factory owner, Monsieur Majorin, visits the family. After observing Jean’s drawing of a cat, Majorin is astonished by the boy’s remarkably astute observational skills. Although Majorin’s friend, Monsieur Mellinot, criticises the drawing for only having ‘two paws and a plume on the top of its head’, Majorin is more than impressed by it:

> You do not understand; or rather you, like many others, have only seen with the eyes of those who do not know how to see. To you a cat is a feline with four paws, a tail, two prominent ears, and whiskers. If one should omit to show you a part of this inventory, you would not acknowledge it to be a cat. The little fellow [Jean] does not care much about that: he did not see a mass of poor images pretending to represent complete cats, but a cat in a certain position which struck him, and he seized the principle features of the position. Being seated, he did not see the back of the animal, which was hidden from him by its head, and the tail appeared without any intervening part. His attention was not attracted to the hind-paws which were almost entirely concealed by those in front, and he did not see


Offering to take custody of Jean, who is from an impoverished family, and to give the boy a fine education, Majorin sets about the task of nurturing Jean’s observational skills so as to see what he might make of himself when he grows up. Jean’s education and drills in ‘looking’ and drawing primarily take place out of doors in the natural world. Through the course of the book it becomes clear to the reader that Learning How to Draw is really a pedagogical exercise on learning how to see, and that to see is also ‘to know’. Martin Bressani contends that ‘for Viollet-le-Duc this meant you had to interrogate your surroundings in order to rebuild them from the ground up – a fact he ventriloquises through Majorin’s instruction to his young pupil: “When you see anything, a piece of furniture, a tool or a house, you must ask how it is made, with what, and why, and try to guess it yourself”.

This was how Viollet-le-Duc approached architecture. He observed the whole, disarticulated it into fragments, and brought the fragments back together so as to comprehend the entire structure, its materials, how it was made, and how it worked. With a theory of fragments came illustrations that demonstrated fragmented elements of buildings. Every element of a building is thus a pars pro toto, a part that leads to the whole. Bergdoll suggests that the format of the dictionary itself echoes this approach to architecture and the fragment, in the sense that each entry – often dedicated to architectural elements such as vault or arc or to building materials – forms part of a unifying theory. In a way, the volumes embody Viollet-le-Duc’s anatomical conception of architecture; each element is dissected and separated out, with the potential of being rearticulated into a whole. This attitude can also be seen in Viollet-le-Duc’s drawings that accompany his text, for example the graphic analysis of the springing point of an arch (figure 3.2), published in 1859. The segments of stone are drawn in ‘exploded’ perspective, providing accurate stereometric calculations. As far

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486 Ibid., pp. 8–9.
487 Ibid., p. 320.
as historians can tell, Viollet-le-Duc was the first to introduce this form of architectural drawing, and it can be assumed that his anatomical approach to architecture facilitated the development of this dissection-style of drawing. In the drawing in question, the individual segments of the arch’s masonry are remarkably vertebral-like in their formation, each stacked vertically upon the other, the thickness variation of the projected spine-like elements affecting the curvature of the arch, in a similar manner to the animal backbone. This effective schematic of arch ‘dissection’ privileges functionality over form as the seamless curve of the arch is fractured into pieces as a way of describing the shape, position and geometry of the stones that support the architectural vault. Just as a functional human spinal column has a lordotic-kyphotic curve that follows the body’s centre of gravity and maintains its upright posture, the curve of the arch must also submit to physical forces whilst remaining upright and stable. Martin Bressani names Viollet-le-Duc’s architectural dissections ‘écorché’s’. He argues that in Viollet-le-Duc’s Dictionnaire, the text and image came together with the drawing to enable the seeing of an essential truth not immediately apparent to the eyes.  

Yet I find Bressani’s analysis problematic as the image of the arch can, and does function independently of the text. In the same way that the skeleton in the museum is an aggregation of parts, the animal is still perceived as a whole, regardless of explanatory text or labelling. The viewer participates in the animal’s recreation by imagining the living animal. Also, the rib of the arch appears deprived of weight, further adding to its association with the skeleton, which is held and immobilised with metal.

Viollet-le-Duc is considered the first architectural theorist to introduce the ‘imaginaire scientifique’ into architectural illustration. This scientific imagination has been identified by historians of the subject as being of great importance in the emergence of modernity, influencing the likes of twentieth-century architects Le Corbusier, Frank...

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489 Bressani, Architecture and the Historical Imagination.
490 Laurent Baridon, L’imaginaire scientifique de Viollet-le-Duc. Baridon identifies the scientific methods that influenced Viollet-le-Duc, which included anatomy (pp. 31–41), anthropology (pp. 43–57), botany (pp. 89–99), zoology (pp. 163–69), biology (pp. 101–5), geology (pp. 171–76), crystallography (pp. 119–24), geometry (pp. 179–89) and evolutionary theory (pp. 153–62): ‘Son imaginaire scientifique n’emprunte doc pas tout à la même source; il est scindé en deux attitudes, l’une analytique, inspirée de Cuvier; l’autre évolutionniste, fondée sur les thèses de Geoffroy-Saint-Hilaire’ (p. 153).
Lloyd Wright and André Hermant. Illustrations were there to render visible Viollet-le-Duc’s scientific imagination. A detailed illustration from Viollet-le-Duc’s *Entretiens sur architecture* (figure 3.3) shows iron connections that he designed for one of his vaulted buildings (*salle à voûtes*). They are referred to as body parts and clothing: leg and shoe. The parts of the *jambes de force* are fragmented to show more clearly the points of their articulation into the *sabots métalliques*. Each separate part has been labelled A to G, with T acting as the brace to support the whole structure. As the ‘leg’ (to use Viollet-le-Duc’s term) is separated into disparate component parts, the function of each fragment becomes clear – either to lengthen, to support, to transfer force, to brace or to angulate and articulate the structure. These members or limbs of the fragments labelled D and E are particularly reminiscent of a human ball and socket joint, such as the hipbone.\(^{491}\) It looks like the head of the femur being articulated with the acetabulum of the ischium. The drawing indicates that Viollet-le-Duc was familiar with anatomy and the idea of anatomical functionality, and that he was aware of the efficiency of the skeleton in carrying weight. The hip is part of a skeletal structure that has evolved to peak efficiency allowing for an efficient dispersal of vertical forces and stresses such as torsion, compression, traction and friction, enabling the bone to yield without breaking, something that traditional building materials lacked. Wooden structures could yield but the modulus of elasticity (an essential potential to yield even so partially under stress and to revert to the original form without deformation) remains low in that bending wood to a certain degree leads to inevitable bowing of material, while stone or marble can withstand larger forces without breaking but will eventually crack and break under strain. The use of iron enabled materials to be thought of more like the skeletal system. The moduli of elasticity were calculated and the materials reengineered, iron alloys created to increase the modulus whilst remaining strong and stable, limiting deformation.\(^{492}\) The results of these material tests were published in engineering reports, magazines and journals, accounting for the various loads, strains, stretching, shearing, tearing limits, crushing limits, etc. that materials were capable of

\(^{491}\) Herne makes a similar observation, remarking that ‘implicitly, he [Viollet-le-Duc] had devised structural membering according to organic principles, modeling it on the ball-and-socket joint of the hip and on the joining of upper and lower arm at the elbow’. See Herne, *The Architectural Theory of Viollet-le-Duc*, p. 241.

sustaining up to the ‘elastic limit’, that being the point at which irreversible deformation occurs. The comparable materials included plant stems derived from grasses and grains, papyrus, shells, bones, metal wires, iron bars and, from the 1880s onwards, steel cables.\(^{493}\)

Viollet-le-Duc identifies bone as an ideal material. In his exploded drawing of an arch Viollet-le-Duc’s thought process is made evident. When compared to Beauchêne’s exploding skull (figure 3.4), it becomes clear that the whole structure is still discernible through the fragment. Cuvier’s skeletons could be considered as the re-presentation of dead animals in life-like poses, simulating life through their iron articulation. In contrast, Viollet-le-Duc’s drawing is architectural disarticulation. By pulling the architecture apart, something new is being articulated, something more than just functionality and rationality in design, something that includes material properties, embodied experience and aesthetics. It combines the architecture of the past with a sense of animation, a necessary component in defining life, something here that moves beyond the mimetic and representational towards a conceptual and, I suggest, living structure. Bressani observes that Viollet-le-Duc’s architectural drawings express a kind of ‘vitality’.\(^{494}\) The illustrations show the architecture being segmented and forced apart by some kind of internal force, which animates the image. The viewer is then expected to imagine each part re-joining its counterpart on either side to form an architectural whole. This ‘animation principle’ is discussed by Viollet-le-Duc in his *Dictionnaire*:

> The skeleton of the cathedral is rigid or flexible [...] it gives or resists; it seems to be living because it obeys to contrary forces, its stability is gained only through the equilibrium of these forces, no longer passive but active [...] the stone lives, acts, fulfils a function, is never an inert mass\(^{495}\)

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\(^{493}\) The tabulated results of experiments on various materials can be found in D’Arcy Thompson’s *On Growth and Form*, and MacAlister’s ‘How Bone is Built’.

\(^{494}\) Bressani ‘The Life of Stone: Viollet-le-Duc's Physiology of Architecture’, p. 27.

In this way, removing one section changes the equilibrium of the stone skeleton, forcing the other parts to break away from each other. Viollet-le-Duc articulates here what Ruskin never fully realised in his own writings regarding ‘active rigidity’. As in the body, it is the skeleton that holds the tension in the building, that withstands the internal and external forces of activity and environment. Ruskin had read Viollet-le-Duc’s *Dictionnaire*, actually remarking that he had wished that he had written it for himself.  

Viollet-le-Duc makes another, perhaps even more profound analogy with the Gothic cathedral and the skeleton by describing the latter as an ‘organ’; part of an essential system necessary for the cathedral-body to stand:  

> We are struck by the interior organisation of these edifices. Just as the human body is held up and moves thanks to two simple, spindly supports, occupying the least amount of space possible near the ground, and complexifying and developing itself higher up as it must progressively contain a greater number of crucial organs, so the gothic building is held on the simplest kinds of support, merely a sort of pinning whose stability is maintained only by the combination and development of its upper parts. The gothic edifice can stand only if it is complete; one cannot cut off one of its organs without risking that it will perish, because it acquires stability only through the law of equilibrium.  

It is at this point that the architectural Gothic skeleton becomes realised in Viollet-le-Duc’s mind. It is a body – on thin columnar supports – that supports the more complex

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496 Ruskin made several references to Viollet-le-Duc in his published *Complete Works*, praising Viollet-le-Duc in his commentary on glaciers (xxvi, pp. 230–31), carpentry (xxv, p. 502) and Mont Blanc (xxvi, p. 223), to name but a few. His most well-known compliment was made in *The Bible of Amiens* (taken from *The Complete Works*, xxxiii, p. 465: ‘[…] relating to the period between 800 and 1200, you will find M. Viollet-le-Duc, incidentally throughout his ‘Dictionary of French Architecture,’ the best-informed, most intelligent, and most thoughtful of guides. His knowledge of architecture, carried down into the most minutely practical details […] over the entire surface of France, the buildings even of the most secluded villages; his artistic enthusiasm, balanced by the acutest sagacity, and his patriotism, by the frankest candour, render his analysis of history during that active and constructive period the most valuable known to me, and certainly, in the field, exhaustive.’ However, Ruskin does criticise Viollet-le-Duc’s restoration of Notre Dame de Paris in *Fors Clavigera* vol iv (taken from *The Complete Works*, xxviii, p. 83).

protective parts, like the ribs protecting the interior chest cavity. The Gothic edifice, when standing, can only ever be whole and complete; otherwise the building will fall. The architectural body is therefore balanced on the edge of completion and potential destruction.\textsuperscript{498} This, for Viollet-le-Duc, makes the architecture alive and the skeleton ‘living’. The building exists in time, just like we do, but their temporality is paused when the building maintains its equilibrium. However, life is an on-going process, and changes to the building’s material, its use, and its environment can unbalance the structure to the point of collapse.

The materials that Viollet-le-Duc felt responded best to change, and whose very fabric could be imbued with the desired structural and formal properties of the skeleton, was iron. The structural properties of iron and bone were known since the early nineteenth century. Numerous experiments to test (and exploit) their comparable properties were carried out throughout Europe, but primarily in Britain, France and Germany. In \textit{Learning How to Draw}, Viollet-le-Duc illustrates parts of the skeletal system in which he replaces the bone for iron. In understanding that iron had similar material and behavioural properties to bone, Viollet-le-Duc was able to conceive of a skeleton of iron. It was not just a rational design or a formal imitation of the skeleton’s function, but a conceptual synthesis of material – of iron with bone – and a dynamic equilibrium expressive of a vital energy.

The use of iron enabled materials to be thought of more like the skeletal system. Viollet-le-Duc writes that ‘when in any of our industries it is necessary to create, or make an article, it is well to proceed as Nature herself does, and to take into account the purpose of the article and the qualities of the material out of which it is fashioned.\textsuperscript{499} Materials should be considered, according to Viollet-le-Duc, in relation to the formulation of structure and that their proper use leads to a kind of aesthetic beauty through the clarity of honest structural expression.\textsuperscript{500} It is a case of form acting in service to the material, which in turn acts in service of the visual and spatial effect.

\textsuperscript{498} Jonathan Hill explores this tension between life and death through architectural ruins, which he relates to Arcadian imagery (scenes contemplating death and the tomb) in the Renaissance. See Hill, \textit{The Architecture of Ruins: Design on the Past, Present and Future} (London: Routledge, 2019), particularly Chapter 2: The First “Ruins”.

\textsuperscript{499} Viollet-le-Duc, \textit{Learning How to Draw}, p. 297–99.

\textsuperscript{500} Hearn, \textit{The Architectural Theory of Viollet-Le-Duc}, p. 172.
And all are subjugated to the conditions of nature. Bone is an ideally engineered material and Viollet-le-Duc identifies it as such, writing that ‘one could write a treatise on mechanics having for its sole subject the curvature of the bones’.501 Yet the evolution of skeletal composition and structure does not necessarily amount to mechanical optimisation. Bones must adapt to the body’s situation and create a harmonious homeostatic balance within their environment. They must be sufficiently light, stiff, strong, adaptable and repairable. However, unlike architectural plans, bones are not designed but formed. This is the key difference between their material formulation: the architect designs the building whilst innumerable internal and external factors enact on a body to form the skeleton. Viollet-le-Duc was very aware of this fact. When discussing the difference in bone biomechanics between humans and primates, he writes:

When you have studied man and understood these principles of anatomy, you will examine with more interest and knowledge the machinery of the factory; for man, in the art of mechanics, seldom does more than apply these elements. […] Having neither these supple and strong ligaments that fasten the articulations of the bones, nor the tendons and muscles, man replaces these beautiful inventions with bolts, axles, or pivots and eccentrics; but generally the organic parts of his best machines are made in conformity to the principles by which his body moves [my emphasis]. 502

Viollet-le-Duc illustrates his idea of the ‘organic machine’ through the image of the femur’s condyles articulating with the concavities of the tibia (figure 3.5). In the body, lateral tendons and cruciate ligaments connect the bones, securing the hinge joint. The mechanic or engineer imitates this system, uniting the two parts, perhaps with a pivotal bolt. Viollet-le-Duc also draws attention to the profound difference between these two mechanical systems – that of motive powers. The animal’s power lies within its very being whilst the manmade machine must rely on powers external to itself for motion. For Viollet-le-Duc, the discovery of a substance or element that possessed the power of muscles and tendons to enable lengthening and shortening, or movement more generally, would be a valuable discovery for architecture. Yet this is a desire regarding

501 Viollet-le-Duc, Learning How to Draw, pp. 132–45.
502 In ibid. Also see Hearn, The Architectural Theory of Viollet-Le-Duc, p. 225.
the properties of soft tissue. For Viollet-le-Duc the properties of bone, and by extension the skeleton, have already been met in the material of iron.

IRON ARCHITECTURE IN PARIS

The iron industry saw its heyday in early nineteenth-century Britain but was delayed in France until the Third Republic, as industrialisation took off later in France. However, in the 1890s iron became the largest contributor to the French economy with an annual growth and production margin that exceeded all other economic sectors combined, as there was a vast shift in labour force from agricultural to factory spaces.503 Due to the population boom and urban growth in the Third Republic the cities soon became overcrowded and public structures needed to be larger. With an amendment to the city’s building regulation, external and partition walls could be made thinner and lighter.504 Glass found its place within an architect’s toolkit. The combination of iron and glass was soon adopted and adapted by architects and was to become a symbol of French modernity.

The system of the public architectural spaces, as with the macrocosm of Paris and its 1855, 1867, 1878, 1889 and 1900 Exposition Universelle, was for the people to circulate in such a way as to observe in a ‘circular glace’, and to be observed, flowing through the structure (as with the city) in a measured movement, as the pathways needed to be wide enough to allow for the enormous numbers of pedestrian visitors flocking en mass to this cultural centre. The iron and glass arcades enabled exhibition and movement, and the city became a giant site of exposition – the people objects and

observers – circulating like blood, making the city come alive, and changing the face of the Parisian landscape.

With the rise in Parisian institutes dedicated to the study of engineering, the properties of iron were quickly realised and exploited. The combination of carbon and iron in different ratios produced new iron alloys, such as steel, which also enabled iron’s properties to be honed to the architect’s exact desires.\(^{505}\) New structural systems were developed, economising on materials so that a maximum structural space could be delivered at a lower costs. It was deduced by the British engineers William Fairbairn and William Vose Pickett in the 1840s that cast iron (fonte) held a better compressive strength, whilst wrought iron (fer forgé) had a better tensile strength and was used for joists.\(^{506}\) Some architects believed in retaining a structural honesty to their finished structures, proudly displaying the materials and methods of construction, which before would have been disguised behind brick facing, plaster or excessive ornament, sculpting or casting, leaving the skeleton entirely exposed to public scrutiny. The benefits of exposure and accessibility allowed imperfections and material degeneration, such as rusting, to be detected. Surface wear and damage could be seen and stopped, the corroded elements effortlessly painted and sealed so that the building could be preserved. The exposure of the material allowed for quick and easy intervention when it concerned the preservation of the surface. Such interventions enforced the rationalists’ argument for the practicality of iron as a building material. One could argue that this material rationale was a Ruskinian approach: the best material was selected for its properties and its ability to fulfil the designed function, and this structural and material honesty of form and function was considered beautiful in its ideal perfection.\(^{507}\) However, Ruskin’s vehement opposition to Crystal Palace and iron’s prolific application in industrial processes countered any approbation for the use of iron in architectures that were not in sympathy with the Gothic ideal. And

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\(^{505}\) While the production method for steel was patented by Henry Bessemer in 1855 in Britain, other technical processes for iron and steel where developed in France. See Vose Pickett, ‘On the Application of Cast and Wrought-Iron to Architecture and Building’, pp. 410–32.


he was not alone in this opinion. Viollet-le-Duc derided the utilitarian iron of the glass markets and arcades, advocating for a ‘mixed system of construction in which cast and wrought iron, brick and stone masonry, and even enamelled tile infill would all be developed to maximize their individual capacities in relation to one another’, calling such a building an ‘organism’. 508

The French designed their iron skeleton constructs all over the world, arguably the most famous of which is the Statue of Liberty, New York (figure 3.6), with its little known iron and steel skeleton construction. 509 Designed by Frédéric Auguste Bartholdi, the Statue of Liberty (c. 1875–1886) has become a globally recognised symbol of Franco-American friendship and the US’s post-civil war ideals of freedom. The internal iron skeleton is clad with copper sheets, a material suggested by the chief engineer of the project, Bartholdi’s friend and mentor, Viollet-le-Duc. 510 Viollet-le-Duc also devised the method for molding the copper sheets (a form of repoussé) and designed the internal brick pier into which the copper ‘skin’ was to be anchored to. However, Viollet-le-Duc never completed the project, which is probably why his name is rarely mentioned in regards to the statue. After assisting with the building of the head and the arm, Viollet-le-Duc fell grievously ill and died in 1879. It was following his death that Gustav Eiffel was invited to assist with the final design and construction. Working with his civil engineer Maurice Koechlin, Eiffel abandoned Viollet-le-Duc’s brick pier and decided to build an internal iron truss tower instead, adding a ‘secondary skeleton’ to the central pylon. Iron bars were riveted to the copper skin generating a metal mesh of supportive straps (known as ‘saddles’) which would reduce the tension

508 See Viollet-le-Duc, Dictionnaire raisonné de l’architecture française, VIII, ‘Style’, p. 493. In his insistence on the parallels between a natural ‘organism’ and an ‘artificial’ organism, Viollet-le-Duc writes ‘former un organisme de pierre possédant ses lois tout comme l’organisme naturel’. Also see Bergdoll, European Architecture 1750–1890, p. 232: Viollet-le-Duc ‘was at pains to argue that his organism was equally prepared to struggle for survival in the marketplace of construction bids and changing economics of materials’.
and force stresses, allowing for a slight movement of the statue when confronted with buffeting winds and other inclement weather and preventing the skin from cracking.

It could then be considered quite telling that the third skeleton, which would bear Eiffel’s name, was also an iron skeleton construct (figure 3.7). In Koechlin’s design for the iron tower, a sketch of the Statue of Liberty appears in the bottom right corner. Perhaps Koechlin was recollecting the other great monuments of Paris to which the Eiffel Tower (1882-1889) would be added. Designed again by Koechlin and Émile Nouguie, and proposed as the centerpiece for the 1889 Exposition Universelle celebrating the centennial of the French Revolution, the Eiffel Tower is a skeleton constructed of 18038 x approx. 5-meter bars of wrought iron riveted together by 2.5 million rivets on both sides.\textsuperscript{511} The skeleton frame of the tower is called the ‘ossature’, and this term is used on the header of the design plans that show the disarticulated structure, i.e. the parts that make up the entire assemblage. This illustrative ‘manual’ method of architectural representation was relatively novel and its invention is credited by architectural historians to none other than Viollet-le-Duc.

\textbf{THE EXOSKELETON: THE GALERIE DES MACHINES}

Paris attracted the world’s attention at the international Expositions of 1855, 1867, 1878, 1889 and 1900. As with London’s Crystal Palace, the glass-iron architecture of the exhibition halls was a key feature of the expositions that thus served as platforms to demonstrate France’s superior understanding of iron and associated construction principles. The international exhibitions of the second half of the nineteenth century were a means of showcasing national achievement in the sciences, industry in the arts, as well as colonial grandeur.\textsuperscript{512} The prolific utilisation of iron and glass in Paris may

\textsuperscript{511} Adrian Dogariu, ‘Mechanical Properties of Cast Iron, Mild Iron and Steel at Historical Structures’, \textit{Course for Sustainable Constructions under Natural Hazards and Catastrophic Events}, Universitatea Politehnica Timisoara, 2014 <https://www.ct.upt.ro/suscos/files/2013-2015/1E07/1E7%20Rehabilitation%20A%20D%202.pdf> [accessed 4 May 2017]. The tower weighs 10,100 tons and has a height of 324m (including the flagpole) with 1665 steps (coincidentally the exact number of specimens recorded to have been in Cuvier’s collection at the time of his death).

\textsuperscript{512} Paul Greenhalgh, \textit{Ephemeral Vistas: The Expositions Universelles, Great Exhibitions and World’s Fairs, 1851–1939} (Manchester: Manchester University
not have been uniquely driven by a desire to outdo the English, but France certainly built with a fervour, making their exhibition spaces more colossal and more innovative with every single Exposition. The 1889 World’s Fair was particularly relevant in national terms as it marked the centenary of the French Revolution, celebrating the legacy of the bourgeois revolution in the Third Republic and aimed to demonstrate French superiority in politics, science and industry. Two of its architectural showpieces were feats of iron engineering: the Eiffel Tower – at the time the highest tower in the world – and the Galerie des Machines, which became a legendary structure in its own time (figure 3.8). Declared ‘a wonder of the construction age’, an ‘ampleur maximal’ of iron, and hailed as an architectural marvel, the Galerie des Machines boasted the longest interior space with the largest surface area ever created up to that point. The building consumed a large part of the exposition budget: the 1889 fair cost upwards of 47 million francs, a fifth of which went into the building and running cost of the Galerie des Machines.

The Galerie was designed by the architect Charles Louis Ferdinand Dutert (1845–1906), a graduate from the École des Beaux-Arts and the celebrated winner of the 1869 Prix de Rome, granting him a stipend for the Villa Medici, the French Academy in Rome. Due to his innovative design for the three-point hinge arch, which created the huge open exhibition space, the Galerie des Machines is still ranked amongst the most important architectural achievements of the nineteenth century. However, for all of

514 Alfred Gotthold Meyer, Construire en Fer: Histoire et Esthétique (preface by Walter Benjamin, 1907), trans. by Marielle Roffi and Léo Biétry (2005), p. 101. The Galerie des Machines was soon surpassed in monumentality by the construction of the Palais des Beaux-Arts of Chicago in 1893, but not by much, yet the Galerie des Machine is considered to have been the prototype for all subsequent iron halls.  
515 See Stamper, ‘The Galerie des Machines of the 1889 Paris World's Fair’, pp. 265 & 281: The three-hinge arch, a novel piece of structural engineering creating the distinct shape of the roof structure, was soon surpassed by other solutions. This rapid fall in popularity led to the building’s demolition in 1910. Also see Bergdoll, European Architecture 1750–1890, p. 270  
516 See Grimaldo-Grigsby, Colossal, pp. 94–106.
Dutert’s achievements, very little has been written about the architect and his design concepts and there is, to date, not a single monograph on the architect.  

Dutert was however a relatively prolific architect, and his work consisted predominantly in national monuments and public buildings. His École des Beaux-Arts education resulted in him taking ornamentation very seriously, as ornamentation was an important element of the new aesthetic of modernity. The evidence for this can be found in the fantastic ornamentation of wrought iron, in both the Galeries des Machines and the Galerie d’Anatomie comparée. Walter Benjamin already noted the alliance of art nouveau iron architecture with ornament:

Ornament was to such a house what the signature is to a painting [...]. They found their expression in the mediumistic language of line, in the flower as symbol of the naked, vegetable Nature that confronted the technologically armed environment. The new elements of construction in iron – girder-forms – obsessed art nouveau.

Debora Silverman argues that ‘for art nouveau artists, materials were vessels; design substances, no matter how durable or intractable, were destined to yield, bend, and rend according to the dictates of the imagination.’ The art nouveau artist embodied the ideals of modernity: new vistas, new visions, new materials, new forms of representation, new industries, and new tastes. Looked at this way, the iron architectures of the fin de siècle, from the most delicate manipulations to the most colossal structures were art nouveau architectures. The French were an emerging technical civilisation and were eager to impress upon the world their dominance in

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517 A thesis on Ferdinand Dutert draws attention to his architectural contribution at the fin de siècle as well as his legacy of decorative richness in his buildings, particularly in regards to his designs for technical schools and other French institutions such as l’École nationale supérieure des arts et industries textiles (the National School of Arts and Textile Industries), founded in Roubaix in 1889. See Jean-Marie Oudoire, ‘Ferdinand Dutert 1845-1906. Une architecture du plain-pied avec le vingtième siècle’ (thèse de doctorat, université de Lille 3, 2003).

518 Silverman, Art Nouveau in Fin-de-Siècle France, pp. 1–12 and 270–84.


520 Silverman, Art Nouveau in Fin-de-Siècle France, p. 1.
every field, particularly wrought-iron engineering and architecture. They demanded that recognition through the colossal architectures of the Eiffel Tower and the Galerie des Machines.

Dutert’s understanding of the material properties of iron is evident in the design for the Galerie des Machines. A sectional perspective of the Galerie des Machines (figure 3.9), conveys the shear enormity of the space and the monumental volume of the metal to be born on the columns. Mathematical precision was needed in calculating the internal and external forces which consisted of both permanent (dead) and moving (live) loads. Permanent loads were the weight of the material itself, including the floors, walls and any necessary ornamental fixtures. Moving loads were the intermittent weights of people, animals, vehicles and merchandise on the floor and walking galleries.\(^{521}\) With the aid of the engineer Victor Contamin (1840–1893), an innovative design for the base of the truss was implemented. It would maintain structural equilibrium whilst also retaining the desired avant-garde concept.\(^{522}\) This design took the form of a pivotable truss that would articulate in the same way as a ball-and-socket joint in the body, such as that connecting the pelvis to the femur. An illustration of the pivotable iron truss demonstrates this process of articulation; the concave root of the truss was positioned onto the convex surface of the base hinge (figure 3.10). The truss was then winched up and secured with rivets.\(^{523}\) A visual comparison suggests that Dutert and Contamin’s solutions for iron connections took inspiration from Viollet-le-Duc. Their ball and socket joint/bearing is comparable with Viollet-le-Duc’s designs for the iron supports in a market hall (figure 3.11) as well as with his design for the ‘iron armature’ of a concert hall (c. 1864–66) (figure 3.12). The iron in these drawings resembles the articulated appendages of a crustacean, its limbs supporting the roof of the building. Even though neither were realised, both


\(^{522}\) The three-hinged roof truss design was first used in bridge construction, and a year before in the train sheds at Union Railway station (c. 1888) at Frankfurt-on-the-Main, Germany. However, Dutert’s design was the first application of this truss on such as large scale. Slideshare.net, ‘Building Technology 3, “Types of Roof Trusses 1”’, 2012,’ pp. 1–34; p. 23, <https://www.slideshare.net/AnsherinaDelMundo/types-roof-trusses> [assessed 3 June 2017]

illustrations clearly express the principles of Gothic vaulting in architectural design fused with contemporary materials – of brick, stone and cast iron.\textsuperscript{524}

It is more than likely that Dutert’s and Contamin’s designs owe to Viollet-le-Duc, an influential architect, theorist and conservator in his time. His opinions were, however, controversial both in political terms (he was a royalist sympathiser) and as an architect and architectural theorist (not everyone shared his commitment to the Gothic and his approach to restoration). He was regarded by the new generation of architects at the École as a traditionalist, and it was reported that he was even shouted down by the students during his brief three-month stint as a professor of architectural history at the École des Beaux-Arts.\textsuperscript{525} Be that as it may, it is likely that Dutert met him during this period, since the year Viollet-le-Duc joined the École, 1863, was the same year that Dutert entered the school. Dutert’s designs were considered innovative, and yet like his predecessor Viollet-le-Duc, Dutert built his designs upon a functional understanding of iron inspired by the anatomical mechanisms for motion.

The incorporation of anatomical knowledge is rendered visible through iron structural engineering. In the nineteenth century, the animal skeleton was deemed to act as an optimally idealised system, and this optimisation of the skeletons core architecture was extensively tested and applied to architectural materials, so that they acted like bone, transforming the nineteenth-century architectural designs and consequently, the facade of the city.

\textbf{THE BONE AS MODEL: ARCHITECTURE AND PHYSIOLOGY}

Bones and iron architecture were not only related via the use of the term skeleton or ossature. As mentioned previously, engineers and architects also investigated their

shared material properties. They are or should ideally be of an optimum strength to hold external materials and thus allow for the protection of interior spaces, and they both have acceptable levels of elasticity and plasticity in relation to mass.\textsuperscript{526} Unlike iron, bone cannot be mixed to create alloys, a process that produces more desirable properties. However, although the composition of bone cannot be changed, when it is in a living organism it adapts to the environment when growing and can be manipulated through usage. For example, the cortex of certain bones can become thicker when extensively exercised. Essentially, the morphology of the bone is subject to its function, a relationship already inferred by Galileo Galilei in the seventeenth century. In his \textit{Discorsi e dimontrazioni matematiche} (1648) Galileo remarked that the form of the skeleton in smaller animals diverges considerably from the skeletons of larger animals, concluding that larger animals require larger bones with a relatively greater diameter.\textsuperscript{527} In the nineteenth century, anatomists and engineers began to look deeper into inorganic or organic materials like iron and bone, both internally and microscopically, in an attempt at reaching a better understanding of their material properties, their lattice arrangements or irregular glomerations. The Scottish physician and mathematician Sir Donald MacAlister (1854–1934), for example, asked why the ends of the bones seem to be continuous, consisting of ‘irregular fibres and plates’ in a substance called ‘spongy’ bone. Yet, he observed that when this part of the bone is cleaned of its soft tissues, ‘a very remarkable and very beautiful order and regularity takes the place of the confusion […]. Its plates and bars run straight and clear from point to point, cutting each other in true right angles’.\textsuperscript{528} These cancellous structures (from the Latin \textit{cancelli} meaning ‘lattice’ or ‘cross-bars’) are ‘wonderfully constant’ in their relation and shape to the long bone.\textsuperscript{529} In the second half of the nineteenth century engineers and anatomist were particularly interested in the femoral head, as Viollet-le-Duc had been. Peter Fratzl, a physicist whose research focuses on biomaterials, has argued in a recent article on the history of bio-inspired design of

materials, that both engineers and anatomists observed that the inner construction of the femoral head, i.e. the internal cancellous bone composed of minute trabeculae (the internal spindle-like structure of bone, from the Latin meaning ‘small beam’), resembles a building, such as can be seen in the structure of suspension bridges or the buttresses of Gothic architecture.\(^{530}\) Considerable scientific interest developed in describing the relationship between the form and function of bones. The four major contributors to the study of biomechanics were the German anatomists Georg Hermann von Meyer (1815–1892), Wilhelm Roux (1850–1924), Julius Wolff (1836–1902) as well as the Swiss civil engineer Karl Culmann (1821–1881).\(^{531}\) Meyer published in 1867 a study on the ‘architecture’ of bone tissue, and as the title of the essay demonstrates, anatomists perceived bones and their structure in terms of architecture as much as architects understood the structure of buildings in terms of bones and skeletons.\(^{532}\) They discovered the relationship between trabecular bone in the proximal femur and stress trajectories, described at the time as Culmann’s new theory of ‘Graphical statics’. By understanding the transfer of external and internal forces in a bone, they were able to determine that trabecular size, form, and directionality reflected the bone’s particular function.

The productive collaboration between the anatomist Meyer and the Swiss construction engineer Culmann was a key moment in the understanding of bone mechanics. Culmann and Meyer discovered that bone trabeculae ‘grow’ along the same, albeit imagined, lines that the forces of gravity and load follow. The trabeculae are then interwoven with orthogonal cancelli (bony spurs) that follow the imagined lines of internal and external forces caused by tension and compression. Meyer recognised the formation of bone trabeculae in the directional-force diagrams that Culmann had mapped when designing his powerful crane. Based on their observations – that the internal structure of a bone adapts to the mechanical demand on the bones – the Berlin anatomist and orthopaedic surgeon Julius Wolff developed his theory of the

\(^{530}\) Ibid., p. 179.

\(^{531}\) Wilhelm Roux, Der Kampf der Teile im Organismus, 1881.

transformation of bones, known today as Wolff's law. Wolff established a physical relationship between trabeculae and the direction of force applied to the bone. The formation of bone spindles reflected their function as internal resistors to stress. ‘Wolff’s Law’ hypothesised that ‘every change in the [...] function of bone [...] is followed by certain definite changes in [...] internal architecture and external confirmation in accordance with mathematical laws’. Wolff’s theories, presented in 1892 in the publication of ‘The Law of Bone Remodelling’, formed the foundation for the principles of bone biomechanics today. Emphasising the mechanical basis of the functionality of bone, Wolff wrote: ‘the outstanding efficacy in providing everywhere the most appropriate element, up to the last molecule and the finest structural detail, can no longer be considered as teleological, but must be mechanical’. This law established the paradigm that bones were formed as mechanically optimal structures: they possessed maximum strength combined with minimum weight. The trabeculae and the composition of this small tissue element was seen as the key to structural optimisation. According to this law, bone is able permanently to adapt to altering mechanical situations, proving that the structure and the direction of the trabeculae in the bone was not genetically determined but the result of adaptation in the individual

533 Wolff’s Law predicts that the bone is optimally formed to resist internal stresses, and that the bone also applies a counter force to prevent deformity to the bone. This force is stress and is distributed over the cross section area of bone and measured in units of force per units of area (pascal) = 1 newton of force over 1 sq m. Julius Wolff, Paul Maquet, and Ronald Furlong, The Law of Bone Remodelling (Berlin: Springer Berlin, 1986), trans. of ‘Das Gesetz der Transformation der Knochen’, DMW-Deutsche Medizinische Wochenschrift, 19 (1892), pp. 1222–24.
An illustration for the recent re-edition of Wolff’s ‘Law of Bone Remodelling’ demonstrates the basis of Wolff’s trajectory theory (figure 3.13). The maximum and minimum points of principle stress are recorded in three images, and the lines of morphogenesis in the trabeculae correspond to these lines of directional force. The simplification or abstraction from left to right, from photograph to stylised model, is remarkable as it transforms the femur into a diagram that implements statistical data.

About a decade before, Sir Donald MacAlister had already discussed the question ‘How bone is built’ in a homonymous publication in the *English Illustrated Magazine*. MacAlister likens the internal cancellous matrix of the arch of the foot to the simple tree-cornered rafter (figure 3.14). This relationship, he explains, was first identified in the mid-1800s by Jeffries Wyman. MacAlister demonstrates the similarities between the direction of bone trabeculae and a balanced and braced architectural system with a published drawing of the foot by Hermann Meyer alongside his own illustration of a simple three-cornered rafter, comparing the directional lines of ‘load’, ‘stretch’ and ‘thrust’ with those observed by Meyer (figure 3.15). In the rafter, the forces of compression, thrust and tension follow the same orthogonal vectors as the cancellous bone. These lines act as ties and struts to withstand forces impressed upon the bone, as identified by the zoologist D’Arcy Wentworth Thompson who, in his publication *On Growth and Form* (1917), uses the example of the three-pointed rafter to explain the orientation of trabeculae in the cancellous bone of the calcaneus and talus bones of the foot.

The triangular form of two loaded jack rafter upon a ‘stretched’ lintel takes a biomechanical turn in the form of the ankle, as the illustrations move from the anatomical to the structurally engineered. This was later taken up by Thompson who utilised Meyer and MacAlister when developing his theory of morphological transformation in *On Growth and Form*, however, instead of a jack rafter, Thompson calls it a ‘roof-tree’ rafter. This metaphoric description for the heel bone echoes the Gothic roof of the OUMNH, where the curve of the iron roof arches was carefully

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calculated so that it could support the heavy glass roof tiles whilst maintaining the arches’ centre of gravity. I doubt, however, whether John Ruskin would have appreciated such an analogy being applied to the Oxford Museum. He would have much rather seen trees than spindles of bone.

As far as I can see, MacAlister’s paper is the first publication that explicitly draws attention to the mechanical and material relationship between the skeleton and architectural iron. Bone, for MacAlister, is a ‘hollow…. thick-walled tube.’ Constantly fusing the language of anatomy on the one side and of architecture and mechanical engineering on the other, he elaborates that long bones have a ‘shank or shaft which is hollow and tube-like, and the ends which are – not exactly solid – but continuous or “spongy” in texture’. These hollow ‘pillars’ bear the weight of the body. Yet if they are to take the body’s weight, MacAlister simply asks, why are they made hollow? This question bears the assumption that solidity equates strength and is an interesting albeit false notion, which MacAlister dismantles and explains through his illustrated example of the iron I-girder, which he describes as a ‘skeleton beam’. There is a relationship between bone’s natural form and iron in the engineering of iron girders. As with the long bones, they resemble in cross-section an I or H shape, which is caused by a narrowing of the ‘neutral zone’ where pressure is reduced, making the construction material economically lighter whilst maintaining strength. The H- or I-shaped cast-iron girder, considered by D’Arcy Thompson to be a design based on the shape of the tibia bone (the upper and lower flange relating to the articulating surfaces of the tibia), would transmit the load directly through the centre of the column. The upper and lower flanges provided surface area for bolt-holes (or gudgeons, if the hole is cast) and lugs, expediting the riveting process and facilitating the structure’s vertical

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MacAlister, ‘How Bone is Built’, p. 640.
Ibid., p. 644. MacAlister identified the mechanical relationship between bones and bridge engineering, likening the hollow shafts of the long bones to the hollow tubes of iron used in suspension bridges, such as the Forth Rail Bridge. He discusses the railway bridge supports as ‘skeleton beams’ (p. 645), and a simple three-sided rafter as ‘skeleton rafter’ (p. 647). The first iron girders (with a bottom flange) were made in 1801 by the firm Boulton and Watt. There was little to no variation of this design from 1801–1824, until Fairbairn increased the dimensions of the lower flange and reduced the thickness of the vertical rib to increase the girder’s strength. Experiments for fireproofing iron by Tredgold and Hodgkinson in 1827 resulted in a modification of the single-flange girder. They discarded the single-flange in favour of a double flange of equal size (H-shaped girder). See Vose Pickett, ‘On the Application of Cast and Wrought-Iron to Architecture and Building’, pp. 410–15.
and lateral growth or ‘splice’ potential.\textsuperscript{542} This solution – removing material to make it stronger – presents an epistemic shift in the understanding of materials, their structure and the forces that work upon them. The engineering of the I-girder was used to great effect as a support structure, but in order to create a support that would withstand stresses from multiple directions, such as in a tall pillar, the ability to withstand bending required the engineering of the I-girder to have a 360° balance, and so a tubular structure was developed. Thompson describes the advantages of the hollow cylinder as follows:

\[\text{[O]}n\text{ any two opposite sides compression and tension are equally met and resisted, and there is now no need for any substance at all in the way of web of ‘filling’ within the hallow core of the tube […] it is appropriate in every case where stiffness is required, where bending has to be resisted […] The long bone of a bird’s wing has little or no weight to carry, but it has to withstand powerful bending-moments; and in the arm-bone of a long-winged bird, such as an albatross, we see the tubular construction manifested in its perfection, the bony substance being reduced to a thin, perfectly cylindrical, and almost empty shell.}\textsuperscript{543}

MacAlister also drew attention to the parallels between bone and tubular-bridge construction, discussing the examples of the Britannia Tubular Bridge over the Menai Strait and the Forth Bridge with its regular latticework of hollow tubes. He writes ‘in making all its bones hollow tubes, the builder has merely realised in metal the plan on which the human skeleton has been built for some thousands of years’.\textsuperscript{544} He thus praises the hollow tube as a technology that mimics natural processes.

Even though MacAlister seems to suggest that the use of the hollow tube is an almost self-evident choice, not many engineers and architects of the period forged architectural columns from hollow iron cylinders. In some instances, however, they did. These cylinders were typically of wrought iron in Britain, as can be seen in the cluster of circular iron columns in the OUMNH, and of cast iron in France, as evidenced in the columns of Labrouste’s Bibliothèque Ste-Geneviève (1838–1850)

\begin{footnotes}
\item [\textsuperscript{542}] Thompson, \emph{On Growth and Form}, p. 225.
\item [\textsuperscript{543}] Ibid., p. 230.
\item [\textsuperscript{544}] MacAlister, ‘How Bone is Built’, p. 644.
\end{footnotes}
and Boileau’s St-Eugène-Ste-Cécile (1854–1855) in Paris. Both buildings are comprised of an iron supporting structure with cast-iron cylindrical columns. Yet these buildings have masonry external walls that aid in the transfer of vertical compressive forces and gives them a façade that makes the internal structure invisible. Circumstances in which the load-bearing frame was to be comprised solely of iron required a differently shaped column that was economical, easily manufactured, and quickly riveted. This could be one of the reasons as to why Dutert’s Galerie des Machines was constructed with H-beams instead of hollow columns. Also, as was considered by engineers such as Sir William Fairbairn (1789–1874) in the 1860, and by architects in the last decade of the nineteenth century, the ‘bone’ model of casting hollow iron cylinders came with worrisome material considerations. The first problem was how to connect the cylinders together, i.e. where to place the rivets. Another important issue was that the interior of the cast cylinder could not be inspected for flaws in the casting process, such as bubbles of trapped air, impurities or discrepancies in the iron’s thickness, which would generate discrepancies with the load calculations due to the iron’s asymmetry. The shape and hollow centre also made it difficult (and expensive) to cast and to make fireproof. Indeed, although the structural advantages to the hollow column were firmly established, architects struggled ‘to reconcile ideal performance with the need to minimise eccentric loading’ and, as the architect Thomas Leslie stated in his publication on the development of ‘steel skeleton’ construction in the late-nineteenth and early-twentieth century, the issues with hollow casting ‘constituted the primary narrative of steel column design for a generation’. Leslie argues that in the wake of a number of failures of the material iron and of iron structures, such as the high-profile Tay Rail Bridge disaster of 1879, ‘[b]y 1892, the importance of strong connections had eclipsed the concern for ideal shapes’.

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547 Other high-profile collapses include the Eibenshitz railway bridge in Austria (1894), and the Ireland Building in New York (1897). See Leslie, ‘Built Like Bridges’, p. 253.
Ironically, by the time the term ‘skeleton construction’ had become established in architectural language, bone had already ceased to be a model for weight bearing and wind resistant steel elements.

Returning to Dutert’s Galerie des Machines, there is some controversy as to the actual material used for its construction. Some sources, closer to the time that the structure was erected, described it as a steel framework; however, more recent historians claim that the steel was replaced at the last minute by wrought iron as the price of iron was, at that time, two-thirds the price of steel.548 They argue that if the structure had indeed been made of steel, contemporary reporting would have focused more on the Galerie’s materiality and on the comparison with the tallest iron structure at the time, the Eiffel tower. Regardless of this contention, Dutert’s Galerie des Machines is a functional skeleton construct based on the rational aesthetic, where beauty was to be found in developing the ideal structural system with the ideal building materials and, once again, iron articulations are compared to the optimal ‘growing’ bones of the living skeleton.

**DUTERT’S MUSÉE DE L’ANATOMIE COMPARÉE**

The comparative properties of bone and iron, and their use in the architecture of bodies and bâtiments, is an especially cognisant relationship when perceived and experienced within the exhibition spaces of natural history museums of the nineteenth century. As shown for the OUMNH in the previous chapter, the spaces created by the articulated animal skeletons and those opened by the iron and glass architecture of the exhibition halls, produce a new visibility in which one architectural skeleton is entangled with

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548 Stamper, ‘The Galerie Des Machines of the 1889 Paris World's Fair’, *Structural Iron and Steel, 1850–1900*, p. 268: ‘The principal material of the building’s structure was to have been steel, but the decision was made at the last minute to use iron instead. There is considerable confusion about this on the part of architectural historians, most of whom assume it was built of steel since that is what is mentioned by contemporary journalists before the opening of the fair. William Watson, an American engineer who wrote a thorough report on the fair after it closed states that the idea of using steel was abandoned “on the two-fold ground of expense and the necessity of hastening the execution of work.” The price of iron was about two-thirds that of steel in 1889’.
the other. As I have argued, the use of the term skeleton is not merely metaphorical, but has a material dimension based on the connection between the animal skeleton and the iron architecture and, by the end of the nineteenth century, on the comparative assessment of the material properties of iron, steel and bone. This material kinship is equally at play in the Galerie de Paléontologie et d’Anatomie comparée in Paris, designed by Dutert and built to house among other specimens the collections of Cuvier in view of the Exposition Universelle of 1900.

The Paris World’s Fair of 1900 marked the turn of the new century and celebrated, no less than the 1889 exhibition, technological progress and France’s achievements in the sciences and arts. As the French Official, Antonin Barthélemy remarked, ‘the exhibition of 1900 constitutes, so to say, a stock-taking of the nineteenth-century’.549 This monumental display, staged since 1855 every eleven or twelve years in Paris, unveiled in each new decade an extraordinary feat of architectural engineering, showcasing through colossal spectacle France’s own significant achievements in the advancement of science and engineering.550 The exhibition transformed the city into a vision of light, iron and glass. Tens of thousands of incandescent lamps adorned their monuments and bridges. The pavilions, arcades and galleries were illuminated in the evenings, allowing for public visitation during the hours of darkness. The lights illuminated the efforts and progression of a century via two of its greatest accomplishments – machine engineering and electricity.

The great Parisian exhibitions and glass iron architecture have been seen by many scholars as indicators of fundamental change and the epitome of modernity.551 The

550 On the early world exhibitions in Paris see Mainardi, Art and Politics of the Second Empire: The Universal Expositions of 1855 and 1867; for an overview see also Paul Greenhalgh, Ephemeral Vistas: The Expositions Universelles, Great Expositions and World’s Fairs, 1851–1939.
551 The Galerie d’Orléans (1828–1830) by Pierre François Fontaine was the first structure completely covered by iron and glass. With its pitched glazed roof, it inspired the development of the arcade architecture in Paris. It was demolished in 1935. The first department store with an iron frame was Paris’s ‘Magasin Bon Marché’ (1876) by Louis-Auguste Boileau and Gustave Eiffel. In 1870 the city’s building regulations changed to permit exposed iron construction, however, the Bon Marché building was still faced with stonework. The first building to show its iron skeleton on the ‘outside’ was ‘La Samaritain’ building by Frantz Jourdain in 1907.
Parisian arcades with their glass and iron roofs became the symbol of modernity in Walter Benjamin’s homonymous work on nineteenth-century Paris and the culture of modern capitalism and the spectacle of display, while Foucault discussed a different kind of new architecture: the panopticon where glass guaranteed maximum visibility of the observed prisoners. One such building, created to demonstrate to the world France’s dominance in the field of natural science, was the Galerie de Paléontologie et d’Anatomie comparée, part of the Muséum National d’Histoire Naturelle in the Jardin des Plantes. It followed in the footsteps of the Galerie de Zoologie built in 1886 on the central axis of the Jardin des Plantes after the design of the architect Louis-Jules André, and officially opened at the occasion of the Exposition Universelle of 1889. The museum was equally an iron construction with a stone coating. The building and, more importantly, the display of specimens had been subjected to major refurbishment and were reconceived as ‘grande’ – adapting to the requirements of a modern natural history museum. It reopened in 1994 as the Grande Galerie de l’Évolution. In contrast, the display of specimens at the Galerie de Paléontologie et d’Anatomie comparée remains largely in its nineteenth-century arrangement and is, like the OUMNH, a rare example in which the interaction between specimen and architecture can still be studied. While the paleontological collections are housed on the first floor, the comparative anatomy specimens are housed on the ground floor of this building, greeting the visitor when first entering the space. The cabinets of Georges Cuvier were to be made visible to a broader public within a new exhibition space, exemplifying Parisian pride in their esteemed natural scientists so closely tied to the Jardin des Plantes and its history.

In the 1890s, with the new museum buildings, France thus celebrated its longstanding tradition in the study natural history and the significant developments from the likes


of Buffon, Lamarck and Cuvier in the late eighteenth and early-nineteenth century.  

However, by the end of the nineteenth century France’s leading status in the natural sciences was threatened by the publication of Charles Darwin’s *Origins of Species* (1859, translated into French in 1862) and *On the Descent of Man* (1871, translated into French in 1872) and the dissemination of his evolutionary theories that called into question earlier approaches to evolution, notably that of Lamarck.  

However, the French naturalists adopted Darwinian theories and applied them to the fields of comparative anatomy and palaeontology, in which they arguably dominated, to make significant strides in the fields of anthropology and evolutionary biology. There could not be a better public forum to reinstate French domination than a universal exhibition and public museums.

The Galerie de Paléontologie et d’Anatomie comparée were commissioned by Georges Pouchet (1833–1894), Albert Gaudry (1827–1908), and Theodore Hamy (1842–1908), the chair holders for the seats of Comparative anatomy, Palaeontology, and Anthropology, respectively. Following the death of Cuvier in 1832, Joseph Barclay Pentland, a scientist from Britain, recorded that the collection retained in ‘Cuvier’s cabinet’ consisted of 16,665 preparations, a synthesis of the accumulating collections of scientists from the late seventeenth to the early-nineteenth century. These collections were gifted to Cuvier to provide support for his work regarding the classification of each species, alive or extinct, within the great expanse of the animal

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553 Although France’s leading status was subsequently threatened by the celebrated naturalist, Charles Darwin (1809–1882), who provided the first theoretical framework onto which facts could be bolted. P. Lemoine, ‘Extrait du volume du tricentenaire du Muséum National d’histoire Naturelle, 6e Série’, *Le Muséum National d’histoire Naturelle* (Paris: Masson et cie, 1935), VII, pp. 1–79.

554 See Farber, *Finding Order in Nature*.

On its ground floor the museum was meant to house zoological specimens, both articulated skeletons and wet specimens, most notably among them objects from Cuvier’s collections. These specimens had initially not been made for public display but were predominantly objects for the study and advancement of comparative anatomy and later provided a testimony for the accuracy of Cuvier’s deductions. Pouchet, Gaudry, and Hamy searched for an architect with a vision that could not be hampered by having to conform to the osteological ‘ensembles’ that existed prior to the museum’s construction and required a building that harmonised content within context.

In 1893 an assembly of the Jardin des Plantes’s professors chose an architect to design the new gallery space: Charles Louis Ferdinand Dutert. Alfred Picard, the Reporter General for the exhibition of 1889, promoted to the status of Commissioner General for the 1900 exposition, would have been eager to have an architect like Dutert, already celebrated for his achievement with the Galerie des Machines, design one of his exposition sites. The mission of the architect was to design and build (within budget) a structure that embodied the aesthetic and ‘style’ of the day, was functional as a space for experimentation, lecturing and exhibition, and a space that would harmoniously merge two complementary worlds: the world of animals that no longer exist with the world of vertebrates living in present-day nature. The state appealed to Dutert to design not only a ‘cabinet of curiosities’, but to present to visitors from all across the world the collection of specimens, instrumental in laying the foundations of biology, embryology, anthropology and, of course, comparative anatomy. The architecture

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556 Cuvier, ‘Catalogue des préparations anatomiques laissées dans le cabinet d’anatomie comparée du Muséum d’Histoire Naturelle’, pp. 1–4: ‘Il rappelle que les premiers squelettes sont le résultat des travaux faits en commun par les membres de l’Académie des Sciences avant 1699’. The expositions were conducted by Captain Parry, who was accompanied on various occasions by ‘Morse, Leschenault, Quoy, Gaimard, Lesson, Garmot, Raynaud, Rang, Milbert, Lesneur, Dussumier, et beaucoup d’autres voyageurs encore’.


559 Vives and Colin-Fromont, Les galerie d’Anatomie comparée et de Paléontologie, p. 4.
would have to incorporate the display of 10,000 plus skeletons in such a way as to draw attention to the comparative differences between the numerous species, whilst maintaining distinctions in size, genus and geographical habitat. Following the comparative method of Cuvier, the professors had tasked Dutert with designing a space for the systematic presentation of vertebrates, some of which would be carefully placed within display cabinets to show the close relations that exist between the form of an organism and the functions to which it adapted itself. This encapsulated view of the ‘vertebrate flock’ was reinforced by Saint Hilaire’s concept of compositional unity.\textsuperscript{560}

As the chair of Zoology, Charles Émile Blanchard (1819–1900) noted in an 1893 essay commemorating the foundation of the museum during the Revolution:

Pour chaque espèce encore, sont places dans un ordre les individus des différentes provenances, à telle fin de montrer chaque espèce dans son aire géographique et, de la sorte, rendre particulièrement instructive les comparaisons entre les différentes régions du monde.\textsuperscript{561}

The initial architectural plans for the Galerie de Paléontologie et d’Anatomie comparée illustrate an elevation supported by a solid iron framework. This is unsurprising considering Dutert’s impressive understanding of the material properties of iron, evident in the innovative design for the Galerie des Machines. In the spirit of Eiffel and Bartholdi, Dutert decided not to mask the building’s iron support and instead made a feature of the riveted metal girders. The two main galleries of the museum were designed as transposed reflections of each other, with the ground floor gallery of present vertebral life reflected above in the palaeontology gallery’s reconstructions of past life. The larger animal skeletons would be placed in the centre of the room, with cabinets filled with smaller specimens lining the walls. Above the palaeontology gallery was to be a third-floor mezzanine level, although, looking at Dutert’s transverse plan for the museum, it is difficult to know if it was initially intended as a full floor or

\textsuperscript{560} Ibid., p. 4.

\textsuperscript{561} E. Blanchard, ‘Chaire de Zoologie (animaux articulés)’, \textit{Centenaire de la fondation du Muséum d’Histoire Naturelle}. Volume commémoratif publié par les professeurs du Muséum (Paris: Muséum d’Histoire Naturelle, 1893), pp. 290–307: ‘For each species, individuals from different origins are placed in an order, so as to show each species in its geographical area and, in this way, make comparisons between different regions of the world particularly instructive’ (p. 307).
mezzanine (figure 3.16). The intention was for this ‘gallery of fossils’ to be presented in such a way as to enable visitors to ‘follow and understand the kinship and morphological relationship between species extant and extinct, as well as offering insights into the current biodiversity of present-day nature’. 562

The Galerie de Paléontologie et d’Anatomie comparée, inaugurated on 21st July 1898 in readiness for the 1900 exhibition, is a relatively modest structure compared to Dutert’s Galerie des Machines (being a near 80 metres in length compared to the 420 metre long Galerie des Machines), and is also smaller in size than the Galerie de Zoologie at the Jardin des Plantes. More than ten thousand people passed through its doors on inauguration day, which speaks to the public’s enthusiasm for this ‘temple de l’ostéologie’. 563 A contemporary photograph shows the facade of the building towards the Rue de Buffon, at the side that also serves as the main entrance (figure 3.17). The rose-coloured brick exterior is in contrast with the arcade-like iron architecture providing a transparent spectacle. In this case, the brick masonry does not partake in any way in the load bearing function of the building, only in the bracing. The weight of the structure rests entirely on the iron support columns and stanchions that create the building’s vertical frame, which the French term la armature and the British the skeleton. 564 Failure of the iron to account for the full vertical load imposed would most likely result in the cracking of the brickwork. 565 It is thus clear that the brickwork served predominantly aesthetic and decorative purposes and was built as a barrier that visibly and practically shields. From the garden view of the building, the ground floor windows allow only a glimpse of articulated skeleton structures, but these are not identifiable. They are too fragmented by the bars on the window and obscured by the busts of natural scientists decorating the windowsills.

Considering its status as a national museum that houses a significant collection of global importance, there is surprisingly very little literature published on the Galerie

563 Philippe Taquet, in the Préface to ibid., p. 4.
564 The ‘armature’ is an ‘assemblage de pièces ou de liens de métal pour soutenir ou contenir un ouvrage de maçonnerie, de charpenterie, etc’. Definition taken from Émile Littré, Dictionnaire de la langue française, vol IV.
565 Twelvetrees, Structural Iron and Steel, p. 167.
However, there is archival material in the Bibliothèque central du Muséum national d’histoire naturelle, notably architectural plans from which my work draws. As evidenced from Dutert’s architectural blueprints and sketches, the masonry to be used on the building was extensively deliberated over. One drawing illustrates the elevation of the principle pavilion on the roof, the different coloured washes representing the different stone-types (figure 3.18). Chauvigny, Tercé, St Julien Lavoux – towns in near Poitiers in west-central France with limestone quarries – and ‘Brique de Vaugirard’ are mentioned in the sketches as possible sources for the brickwork. Stones from these sources were popular at the time and had been used, for example, for Charles Garnier’s Opéra, planned during the second Empire but inaugurated in 1875. The rose-flesh colour of the brick facade of the museum was a fashionable choice towards the close of the century. In Dutert’s architectural plans, every area of brickwork has been meticulously measured, and each brick has been accounted for, its dimensions methodically recorded and positioned within the pattern of the building’s elevation plan (figure 3.19). These ‘little bays’ as Dutert calls them were designed to be adorned with various friezes.

Instead of keeping with the thematic traditions of the past, common in state buildings, Dutert invited artists such as Emmanuel Frémiet (1824–1910) and Fernand Cormon (1845–1924), who were known for their daring nonconformist thinking, to collaborate with him in designing the building’s decoration and ornament. Friezes in high relief decorate the upper part of the museum front. The subject matter for the museum’s friezes had been Dutert’s choice, as indicated by one of his pencil sketches of what looks to be the faint outline of a jungle cat on the pavilion façade (figure 3.19). Several of the friezes represent man and beast in various confrontations in which the life of both hangs in the balance, typically with man reigning triumphant over an animal he

566 Jean-Marie Oudoire’s unpublished doctoral thesis highlights Dutert’s collaborative spirit, working with artists and designers on his architectural projects, especially when executing his vision for the ornament. Sadly Oudoire passed away in 2011 so it is unlikely that his thesis will ever be published. See Oudoire, ‘Ferdinand Dutert 1845-1906. Une architecture du plain-pied avec le vingtième siècle’.

has just slain. One such high relief in bronze addressing such a theme and entitled *le Chasseur d’ours* (*The Bear Hunter*, 1893) was by the sculptor Frémiet (figure 3.20). Frémiet was one of the most prominent *artistes animalier* in France, these being artists known since the 1830s for their naturalist animal sculptures, and he had taught zoological drawing at the Jardin des Plantes since 1875. The bronze relief itself was described by one critic in 1901 as ‘strong and clever. It represents a man just victorious over a bear, though with flesh torn in the conflict; the bear lies dead at his feet while he drags the cub with him as he goes; it is realistic, but good work’. In possessing both modernist values and a deep respect for convention, Frémiet was praised at the time for cleverly bridging art and the natural sciences. Prehistory and palaeontology inspired the nascent primitivism that can be detected in *le Chasseur d’ours*, as well as a giving a deferential nod to the classical anatomised body. Decorating the façade of a natural history museum this theme enfolds its full force, and would have complied with Ruskin’s request that ‘there should not be a single ornament put upon great civic buildings, without some intellectual intention’.

Dutert was also in communication with other artists who worked on the building, in particular Ferdinand Cormon, who designed both a bronze frieze and the painted murals within the amphitheatre, before the plans for the building were even finalised. Dutert knew what he wanted to communicate through the building’s ornamentation. With the exception of a single frieze – the peaceful allegory of Nature and natural history – adorning the pediment above the museum’s entrance by the Prix de Rome winning sculptor André-Joseph Allar (1845–1926), there is a common theme that connects all the friezes: the violence of nature and the Darwinian struggle for survival. As an evolutionist, who believed human beings to be the most evolutionary advanced species in the animal kingdom, Dutert firmly believed in the educational
value of such an exposition site to demonstrate the triumph of culture over nature, of man over animal, and civilised over the wild.\textsuperscript{572}

As part of the edifice of a museum containing animal specimens, the friezes conjure thoughts of a crypt or mausoleum space, a monument to the now dead animal whose remains rest within the gallery’s glass coffins. Once again the glass utilises its reflective and transparent properties, creating a thin plane of visibility between \textit{naturalia} and \textit{artificialia}; the living and the reconstructed dead. In his book \textit{Expositions: Literature and Architecture in Nineteenth-century France}, Philip Hamon contemplates architecture as it is illustrated and articulated through nineteenth-century literature. He argues that viewing the mausoleum, as a site of pilgrimage or of exposition for remains or fragments (typically of saints), was a construct of the era: ‘One must remember that the cemetery with its crypts, an architecture of privacy in death which is often as “delirious” as pavilions at universal expositions, are essentially products of the nineteenth century’.\textsuperscript{573} One can thereby relate the museum space to the shrine and the relic, ‘whose display often relies upon architectural objects and means’, before even passing beyond the threshold.\textsuperscript{574} This semiotic association with the relic or the fragment enables the building to be perceived as a hermeneutical object. As with the crypt, the interior is never entirely revealed. In the gallery, each display case becomes a juxtaposition of ‘chambers’, with variable moments of darkness and clarity – of \textit{sfumato}, reflection and transparency. There is also an unconscious reassurance of cleanliness provided before entering, as remains housed within a sacred space are cleansed of their potential pollution. The gallery is transformed from a potential charnel house into a holy temple, a culturally acceptable space in which to freely gaze and experience enlightenment.\textsuperscript{575}

\textsuperscript{572} Vives and Colin-Fromont, \textit{Les galerie d’Anatomie comparée et de Paléontologie}, p. 78.
\textsuperscript{574} Ibid., p. 114. This is noteworthy as the relic is often contained within a transparent architectural construct, often of iron and glass although sometimes encased in gold or ivory. It is also an architectural assemblage within an architectural structure; a micro/macrosom dynamic.
\textsuperscript{575} M. M. Brooks and C. Rumsey, “‘Who Knows the Fate of His Bones?’ Rethinking the Body on Display: Object, Art or Human Remains?’ \textit{Museum Revolutions: How...
This association with the relic reminds us altogether of another form an animate material: sanctified stones. In her research on early modern relics, Caroline Walker Bynum recollects stories of amazed Catholics in the fourteenth and fifteenth century, who beheld relics, frescoes, and statues of saints that would, at times, bleed, weep, sweat, lactate, and even wink. These holy things were venerated because they oscillated between the stillness of stone and the animation of bodily processes; between the everlasting indivisibility of the immortal and the miraculously alive, dynamic, leaky status of the divinely human. It was the wavering contradiction of matter, between static and active that constituted the miraculous material:

Transformation miracles were moments in which matter contradicted itself. But it could do so only in material ways. Hence, if matter transcended its own ordinary changeability by denying decay, it could do so, it seemed, only by yet another change. Such extraordinary change could, however, last only a moment. 576

At this time, matter was recognised as ‘alive’ when it contradicted itself. Iron and bone possess animate qualities, and bones association with the relic adds historical significance to the skeletons in the museum. 577 The materials potential for change lends them vitality. As with the Oxford Museum, iron vegetation adorns areas of the gallery and floral patterns can be observed on the walkway rails and staircases in the interior. Wrought iron plants, consisting of broad stylised palm leaves that fit into one another, decorate the museum’s entrance.

Amongst Dutert’s artist-collaborators were ironworkers of exception skill, a couple of whom had worked with him on the construction of the Galerie des Machines. Some of the names listed in the archives include Emile Robert, who made the ‘gate of honour’ [la grille d’honneur] for the entrance door; Louis Bonnier, who made the flowering-iron trellis that adorns the staircase (figure 3.21), and C. Bonin, who was a sculptor

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and iron founder.\textsuperscript{578} All were ardent promoters of Art Nouveau, favouring delicacy and splendour in their designs. Dutert's hand-drawn detail of the design for the staircase (figure 3.22) demonstrates how he attempted to mimic the natural curves of the plants. Such was the detail that a botanist could identify the plant species represented. It was an attempt for the interior space to mirror the garden outside. However, although some elements of the ironwork are copied from nature, like the iron iris flowers that curve around the mezzanine staircases and balconies (figure 3.23), others appear more stylised, such as the silhouettes of bursting floral forms and the iron lacework of intertwining lines and serpentine curves. The metal arabesques cut through and soften the hard parallel lines of the iron supports that make up the banisters and balcony guardrails.

Although my thesis does not expressly address ornament or a history of the ornamental in architecture, as extensively reflected upon by the art and architectural historians Alina Payne and Spyros Papapetros, it does address articulation and articular surfaces and, by extension, the architectonics of structure.\textsuperscript{579} Ornament is typically positioned at sites of tectonic convergences, the points of structural articulation, and can therefore facilitate a kind of conceptual or figurative movement, or growth, or stability, similar in manner to a joint in the animal body, perhaps working to both flex and stabilise meaning of some kind. In his book \textit{On the Animation of the Inorganic: Art, Architecture, and the Extension of Life}, Spyros Papapetros argues for two modes of animation in architecture. First is the animation of material, which changes or transforms the material from one substance to another, such as the transition of matter from the organic to the inorganic such as from ‘animal to vegetable to mineral’. The second mode of animation is temporal, which transforms the material through meaningful life-giving eventualities such as rebirths, survivals, renewals, and anachronisms. All are temporal reanimations of, as Papapetros writes, ‘an archaic theses within the chronological college of modernism’.\textsuperscript{580} The animation inherent in

\textsuperscript{578} Vives and Colin-Fromont, \textit{Les galerie d’Anatomie comparée et de Paléontologie}, p. 10.
\textsuperscript{579} Payne, \textit{From Ornament to Object: Genealogies of Architectural Modernity}.
\textsuperscript{580} Spyros Papapetros, \textit{On the Animation of the Inorganic: Art, Architecture, and the Extension of Life} (Chicago: The University of Chicago Press, 2012), p. x of preface and p. 31. ‘Animism for the animal psychologist is an ongoing ‘myth-making’ impetus, deeply imbedded in the organic memory of the living being’ (p. 12). Even moving through the spaces in architecture is a kind of animation, certainly of the
articulation is from a latent potentiality for movement, as the purpose of joints is to offer stability and controlled movement. There is also a perceived animation of the material of iron that makes up the architectural skeleton, an organism in the architecture, as the material is capable of chemical, and by extension chromatic, change. As discussed in the previous chapter, Ruskin apprehended this property of iron, and his singular position was that ornament was architecture.

**INSIDE THE ARK**

At the threshold to the galerie d’Anatomie comparée stands the sculpture, *Orangutan Strangling a Borneo Savage* (1895), also by Frémiet (figure 3.24). The violence of the sculpture is, for those entering the space of skeletal exhibition, more traumatic in many ways than the specimens on display. Materiality is subverted by one’s own empathy. Sensation and embodiment of the torn, inorganic marble ‘flesh’ appears to articulate something more visceral than the articulated animal skeleton. This sculpture encourages the viewer to engage with their own temporality and inevitable mortality within the space. Beyond this threshold we are greeted like the biblical Noah to an army of zoological specimens: complete articulated skeletons that appear to be suspended in motion, silent and petrified (figure 3.25). Yet this biblical metaphor is subverted by the new arrangement of the specimens by the evolutionists Gaudry and Pouchet, compared to the previous extinctionist, fact-over-theory composition of Cuvier’s cabinet. Gaudry, Chair of Palaeontology and promoter of Darwin’s ideas on the evolution of species was desirous to show visitors, in both a pedagogic and aesthetic way, the history of all life on the planet, from the extinct species of the past body but also of the body in and through the space and time. See Christopher Kelty and Hannah Landecker, ‘A Theory of Animation: Cells, L-systems, and Film’, *Grey Room*, 17 (2004), 30–63.

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583 Personal communication: F. Galangau, ‘Question Regardant La Galerie D'anatomie Comparée: To what degree did F. Dutert contribute to the articulation and display of the skeletons?’.
to the extant species of the animal kingdom. Although Pouchet, who designed the layout to the galerie d’Anatomie comparée, died in 1894 before the completion of the nave space (and four years before the museum’s inauguration), his instructions on the skeletons’ arrangement and display were so specific as to enable his collaborators, Henri Neuville and Henri Fihol (who would replace Pouchet as the Chair of Comparative Anatomy), to successfully realise his vision. And it is, indeed, an extraordinary space for the comparative study of species within the Arc-like framework of iron and glass.

In accordance with Cuvier’s theory of comparison, the animals are positioned in a series that relates their forms – their external morphology and the shape of their organs – with their function, whilst also taking into account Saint-Hilaire’s concept of organising animals into groups. To each side of the main skeleton herd are display cases for histology, cytology, myology, splanchnology (the science of viscera), angiology (the study of the circulatory system) and teratology (the science of ‘anomalies and monstrosities’). Pouchet was especially exacting in the ordering and arrangement of the great cetacean skeletons, perhaps because of their history of mistreatment at the Jardin des Plantes, the larger of which had at one time been exhibited outside, exposed to the elements in its own whale gallery as space inside the original museum had been so limited. These whales seem to swim through the air, suspended on their wrought iron supports, which rise up from wooden plinths to then bifurcate and curve through the backbone of the specimens (figure 3.26). The curves and undulation of the whalebone create a bony landscape of spinal ridges and cascades. Some of the iron lines created by the supports are geometrical in form, with sharp vertical and horizontal cast-iron struts cutting through the display space, suggestive of a logical framework. Other lines are sinewy, echoing the art nouveau style, curving

585 Ibid., pp. 18 & 33. The only change to Pouchet’s original arrangement has been a minor reorganisation of a few display cases for the 1998 centenary exhibition, which the museum entitled ‘Bones’. It has since become part of the permanent display. In these display cases, the labelling has been modernised and the scientific concepts updates. Also a large group of vertebrates (amphibians, reptiles, birds, mammals) precedes the presentation of primates, highlighting the evolutionary place that humans occupy.
586 Ibid., p. 27.
through the individual bones, occasionally piercing through. The lines are repeated in the intricate botanical ornamentation of the balconies and staircases.

Nelia Dias, in her 1997 article ‘Cultural Object/Natural Objects: on the margins of category and the ways of display’, writes that in the galerie d’Anatomie comparée ‘it was possible for the viewer to catch in a glance man in his relations to other animals, and in his relations to other men […], a “circular glance”. The main purpose was to provide the greatest possible amount of information that could be obtained at a glance.’587 The variety encourages the eye to continuously rove from specimen to specimen, drinking in the enormity of life’s diversities in a single, circular glance. The notion of conveying as much information as possible in a glance was essential to the nineteenth century’s aspiration for complete visibility, yet knowledge and vision are as distinct and subjective in their meaning as they are in their mutual attainment, just as ‘truth to nature’ does not directly equate itself with the legitimacy of one’s perceived and experienced reality.588

The display cases show an arrangement of skulls on the upper shelves, exploded preparations on the middle shelves and the articulated skeletons of smaller animals on the bottom shelves. There are mounted ‘trophy’ skulls on the walls which show the main orders in the animal kingdom. The sheer enormity of the collection is overwhelming and presents visitors with an inexhaustible kingdom of iron and bone, of ‘d’ivoire et d’ossatures’.589 On the day of its inauguration in 1989, the number of specimens on display was estimated at nearly ten thousand.590 Walking around the room presents each specimen from a different view – dorsal and ventral, frontal and lateral – and a number of disarticulated parts are arranged in separate display cases, providing visitors with information on how each part functions in order to facilitate certain bodily functions.

588 Ibid., p. 43.
590 Ibid.
The glass in the ‘ossatures’ or display cabinets once again acts as a means of compartmentalising the space, separating the object from the observer and allowing transparency and a freedom in looking. The unique property of glass, as both transparent and reflective, was central to Walter Benjamin’s ‘double visibility’ in his arcades project; of synchronously seeing both yourself and the object of your desire. In a similar way Philip Hamon also created a window/mirror schematic, to account for the glass storefront creating a controlled separation between internal and external space, subject and object, yet allowing a temporary possession by virtue of the gaze. He contends that ‘all desire, be it attraction or repulsion, is nothing more than the institution, the abolition, or the confirmation of a distance, of an estrangement, or of a deferral, in other words, of a space between a self and another self, or between a subject and object’. Hamon succinctly articulates the paradoxically unfixed nature of architecture, for ‘in as much as it organizes the interplay of exterior and interior, of public and private, architecture [thereby] also emerges as the art of the body, with all its “fatigues”, its desires, its envelopes, its articulations, its dislocations, its “reversibilities” and its relations to other bodies’. He goes on further to compare architecture with the skin and clothing that cover the body. For Hamon they are equivalents only differing through scale, as ‘[a]ll three concretize an ambiguity, for skin, clothing or walls are all sheaths that establish contact and distance, that both bring things together and hold them apart’. Not only can architecture act as a force for the imagination, providing substance to projections, but the walls of the building are as skin is to the body, creating a barrier for the containment, protection and preservation of an interior space. The transition of the skeleton is not as simple as the binary of inside/ outside in terms of space and temporality. It is in a state of perpetual fluctuation with boundaries continually renegotiated, materiality reclassified, gaps closed and reopened, bones re- and disarticulated. In the specimen, the species is represented yet its presence affirms its absence, more potently so in the cases of extinct species. The articulated skeleton becomes the body, represented as ‘alive’ although most definitely dead, but the process of articulation is taken further to the point of the imaged body, from the realm of the extinct to the mythological – a subject for the imagination. In the living body, bone is hematopoietic, the marrow the source of all the blood cells. The natural foramina, often utilised by metal wires as a means of creating the articulation

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592 Ibid., p. 20.
of the skeleton, were created by blood vessels when in the living body. Full of blood, the bones and these vessels sustained life. In the specimen this resemblance to life is replaced by iron. The iron weaves its way around the specimens, permeating the bone in some instances. The limbs of some of the specimens resemble futuristic cyborgs; a blending of animal and machine; a hybrid of organic and inorganic; a melding of structural form. In the gallery the iron supports are, on occasion, so intertwined with the bone that it looks like a visible vascular system, winding through the natural foramina and hugging the bony material, providing support whilst also communicating a notion of artificial life (figure 3.27). In their article ‘The Substance of Bones’, part of the special ‘Bone’ edition for the Journal of Material Culture in 2010, Cara Krmpotish, Joost Fontein, and John Harris record an astonishingly similar observation to my own when confronted with an articulated human skeleton:

In addition to the matter comprising the bones, the apparatus used to maintain the forms of the skeletons – metal wires, plates and hooks – become intrinsic to the overall form. The chemical designation of organic and inorganic were replaced by an interdependence of form and function. The metal became a life-support at the same time that the osteological matter became architectural.593

The supporting iron structure of the museum consists of painted metal girders, their flat surfaces punctuated by round-headed rivets. Although Dutert gave specific details as to the type of stones used in the building composition, the type of iron was not specified. From what I observed of the iron supporting the ceiling of the ground floor gallery, it is likely that rolled wrought-iron joists with flanges (which the French called ‘Système Thuasné’) were used to connect the joists to the iron columns buried within the masonry.594 This method allowed for wrought iron beams to span a space of over 40 foot in length without the soldered joints necessary when using cast iron. The method allowed the beam to be equal in strength to cast iron but without the

594 The other flat-rolled joist (without the flanges) is called ‘système vaux’. See Vose Pickett, ‘On the Application of Cast and Wrought-Iron to Architecture and Building’, in The Useful Metals and their Alloys, with their Applications to the Industrial Arts, pp. 436–38.
intervention, and thus points of weakness, of soldered joints.\textsuperscript{595} In the production of good-quality wrought iron, the English engineer William Vose Pickett (mentioned previously for having been consulted by John Phillips regarding the structural calculations for Skidmore’s iron roof in the OUMNH) praised the French, calling their methods for rolling and finishing wrought iron ‘better’ than any other European product (although he was quick to point out that English cast iron was far superior than the French). Vose Pickett observed the wrought iron on display at the 1855 Exposition Universelle in Paris and remarked that the French wrought iron showed ‘a degree of perfection such as has not yet been attained in this country’ (meaning Great Britain).\textsuperscript{596}

In describing iron structures, he wrote the following:

\begin{quote}
[\textit{While} the affinities of stone and marble are with dead and inanimate matter in the quarry, those of metals are with life and spontaneity in the higher orders of animal structure; and that as the one has been found to dictate the arrangements of block upon block, and the carving of forms upon their surface, and the propping up of certain masses by piers and columns, and the absence of an external covering to the surface; so in the other will the arrangement of skeletons and plates, or continuous coverings, including hollow spaces, and the suspension of forms and features, and the spreading out of a covering over the surface when ever need shall require]. \textsuperscript{597}
\end{quote}

It is unsurprising that Vose Pickett used the word ‘skeleton’ to describe what he perceived to be iron structures. He was a prominent engineer of bridges, having worked on the first suspension bridges in Britain (the Britannia and Conway tubular bridges), as well as an expert in iron shipbuilding. He was the author of the Encyclopaedia Britannica’s entry on ‘iron’ and his publications on cast and wrought iron were translated into all the main European languages. Vose Pickett’s book \textit{On the Application of Cast and Wrought Iron to Building Purposes} was translated into French

\textsuperscript{595} If the beam needed to span a space above 50 feet, a tubular girder was recommended. See ibid, pp. 432–33.

\textsuperscript{596} Ibid., p. 432.

in 1855 and numerous French engineers in the latter half of the nineteenth century cited his work.\(^{598}\)

What I find most remarkable about the iron beams that support each floor of the Galerie de Paléontologie et d’Anatomie comparée is their resemblance to the riveted beams and joists seen in William Fairbairn’s 1865 treatise on iron shipbuilding (figure 3.28).\(^{599}\) Fairbairn demonstrated the comparable strength of the single- and double-rivet girder, concluding that the more rivets used in the beam, the greater its ability to withstand crushing. This was because the rivets offered points of relief in the material, redirecting the multiple crushing, tearing and loading forces from the centralised point of tension. In the museum, the extensive number of rivets seems to be an aesthetic choice as well as a functional one. Unlike in the Galerie des Machines, the iron has been sealed with a coat of off-white and pastel-green paint, very much like the paints applied to iron steam boats. Is it possible that Dutert wanted to articulate the navicular in the museum’s iron skeleton?\(^{600}\)

During the eighteenth and nineteenth centuries, European scientists sailed across the world, accumulating botanical and zoological specimens for their national collections.\(^{601}\) It was a golden age for natural science, and the majority of the museum’s collection was made up of the spoils. Perhaps Dutert recognised this voyaging legacy and attempted to pay tribute to it in the riveted wrought iron. I have been unable to locate any literature that would support such a conjecture other than the visual association between the architecture of boats, the museum’s detailed history of

\(^{598}\) It was translated into French, by M. L. Perret, in 1855. See the Introduction in Byron, *William Fairbairn: The Experimental Engineer – A Study of Mid-Nineteenth-century Engineering*.


\(^{600}\) The ‘navicular’ is a small carpel bone in the wrist. It was given this name as it was thought to be shaped like a boat. Also see Viollet-le-Duc, *Discourses on Architecture*, 1889, VI (translation taken from Hearn, *The Architectural Theory of Viollet-le-Duc*, p. 20): ‘Navel engineers in building a steamship […] do not endeavour to reproduce the forms of a sailing vessel of the time of Louis XIV […] they simply conform to the novel principles with which they have to deal, and thus produce works that have a character, a style of their own, as indicating to every eye a definite purpose’.

\(^{601}\) For example, Bonaparte’s Egyptian campaign in 1798. Bonaparte was accompanied by a ‘Commission for Science and the Arts’ which included more than one hundred and fifty engineers and scientists. See Grimaldo Grigsby, *Colossal*.  

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voyages of expedition, and the purposeful positioning (by Pouchet and Dutert) of the skeleton herd ‘marching two-by-two’. At the head of the heard is a bust of Cuvier, the proverbial Noah. However, this is an Ark of artifice. The living may enter but only the dead live here.

Dutert’s use of exposed iron can be recognised as the expression of rational truth, which would imbue the structure with a kind of meaningful logic; a truth to the visibility in the gallery’s presentation and a clarity to the clear and traceable form of building and bone, as well as a trust in the authenticity of the displayed specimen. There has to be a ‘truth’ or a perceived veracity to the skeleton, as either evidence or reductive proof of something paradigmatic. If not, all the credibility of science is obscured by scepticism. Hence the age in which visibility was truth. The translucent glass becomes the practical representation of the spaces between the bones, revealing the interior.

ARTICULATING SKELETONS

The juncture between the living animal and the articulated skeleton is an unnatural divide. Nineteenth-century manuals that detail methods for taxidermy or skeletal articulation draw attention to artificial nature of their making. In a French natural history preparatory manual from 1890, taxidermy was not thought of as a science but as a way for a skilled naturalist to make money. The articulator was considered a sculptor of sorts, ‘sculpting [the specimen] with their own materials’ of metal, iron hooks and wires, into attitudes of living nature. In short, they ‘replicate the movement of the animal they do not stuff’. Indeed, articulators seemed to apprehend in bone a kind of tactile naturalism, treating the bones like they would when preparing wax, wool or wood.

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603 Ibid., p. 15.
604 Ibid.
When preparing the bones for mounting as a dry specimen, they would first need to be cleaned of flesh and gristle. To do this the bones would be boiled and left to simmer [e‘bullition], with the water changed every five days. Potassium was added one hour before the end of the process, at the point when the bones were completely free of meat. The cranial and facial bones were carefully separated from each other. This was accomplished by filling the skull of the animal with dry peas. The head was then boiled with the peas inside. As the peas expanded, they gently separated the bones along their suture lines. Cooked bones never produced the desired degree of whiteness as blood left inside the cortex of the bone would rise to the surface and produce a brown tinge that was almost impossible to make disappear. On occasion the bones would turn a yellow colour and have a disagreeable ‘rancid smell of medulla fluid’. The best technique for whitening the bones was natural or artificial bleaching. Natural bleaching involved placing the bones in a ‘meadow’ [un pré], and utilised the same technique for bleaching wax or canvas. The process required ‘air’, ‘sun’ and ‘dew’ exposure and took two to three months to complete, but the results were considered worth the time as the bones were left with a ‘shiny whiteness’. Artificial bleaching required the preparation of an acid bath of chlorine, sulphur and an alkaline soap solution [lessives]. The English articulators would use lime [chaux] as their alkaline element. Bleaching could also occur outside in bright sunlight, with the bones placed inside a glass box and dipped in turpentine or lemon concentrate. Having prepared and bleached the bones, they were reunited, ‘each in their place’ and fixed with the help of artificial articulations that replaced the ligaments. Mounting the skeleton [montage du squelette] was a complex process and each articulator had their own particular method for doing this.

The tools required included a strong magnifying glass, tweezers, three or four scalpels, fine and sharp curved scissors, and a pair of straight scissors. There were two methods: ‘squelette natural’ or natural articulation (for a natural preparation where the cartilage that caps the ends of each bone remains intact and keeps the bones united) and ‘charpente osseuse’ or artificial articulation (figure 3.29). A soft white wood was

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605 Ibid., p. 375.  
606 Ibid., p. 358.  
607 Ibid., p. 372.  
608 Ibid., p. 375.  
609 Ibid., p. 379.
required for mounting the skeleton onto, soft enough that you could easily stick a large needle into it. Depending on the size of the specimen, the preparator would either use thin silk or iron wire as their articulating materials. The preparator would need to hold the bones carefully as small bones were known to easily slip out of their hands and be lost. When articulating a small specimen, like the size of a mouse, the silk needed a certain amount of tension [tenir tendue] for the skeleton to stay whole. The skeleton was mounted in ‘l’attitude que l’on trouve’, or a ‘convenient attitude’ so as to replicate the movement that the animal had during its life.\textsuperscript{610} To articulate anything larger than a small rabbit required the use of ‘fil de fer’ [iron wires] as well as iron ‘d’anreau’ [ring/ frame/holder] into which the vertebral spine of the animal rests.\textsuperscript{611} In larger specimens, holes were made near the articular surfaces of the bones (the joints) using a hand drill [mèche] or saw [clous d’épingles].

Elizabeth Hallam posits that articulated skeletons can be interpreted less as objects of science and more as ‘artefacts of emotion, produced through [the] attentive labour’ of the articulator.\textsuperscript{612} These skilful technicians would have invested a great deal of time and energy in creating the articulated specimens, now on display in the gallery. The work would have been exploratory, developing individual methods and techniques. Articulation would have been a process of learning, presumably through trial and error, the properties of bone and iron and developing the ability to unite two different materials in a way that is both aesthetically pleasing and structurally sound. Preparators did this by utilising the tools of the trades that manipulated such materials, such as blacksmiths, shoemakers and masons.\textsuperscript{613}

The architecture of the skeleton is united and solidified through the iron ‘life-support’ of the hooks, bolts, struts and suspension bars for the exhibits. The iron creates the articulation that has been lost through the process of death and decay, acting as a substitute to the essential nature of bone. The iron replicates its properties, such as load bearing, stress resistance and being protective. Its functionality as bone no longer exists for the internal trabeculae, created via the bone’s adaption to external forces, are

\textsuperscript{610} Ibid., p. 385.
\textsuperscript{611} Ibid., p. 379.
\textsuperscript{612} Hallam, ‘Articulating Bones’, p. 483.
\textsuperscript{613} Ibid., pp. 480–84.
made redundant. Following Elizabeth Hallam’s argument, this act of articulating bones can be understood as imbuing the dead and thus inanimate material of bone with the potential for movement and hence with life.\textsuperscript{614} This animation allows for the bone to once again be considered as ‘alive’. The articulated skeleton allows the dead bones to stand in for the living animal and to perform as a purposeful unit.

The emotional investment of the articulator is viewed by Hallam as an emotional embodiment – an imprint. Imprinting can be interpreted as a mode of imbuing inanimate forms with ‘life’ via a physical or psychic transfer. She writes:

\begin{quote}
In this exchange between anatomists and preserved bones in the making – requiring extended periods of manual contact with, and intimate shaping of, bones – anatomists’ techniques were also their signatures. Indeed, anatomists could become so attached to the bones with which they intensively worked that there was, as Seremetakis has observed in other domains of labour such as embroidery, a “transfer of self into substance that disseminates a history of the person in dispersal”. If traces of anatomists became, in this way, part of the bones they engaged with, their anatomical preparations would then stand as materializations of their endeavour – imprints of themselves to which they might remain deeply attached during their lifetimes and which would later be regarded by others as present manifestations of that anatomist’s past work. \textsuperscript{615}
\end{quote}

As mentioned earlier in the chapter, there is evidence that Cuvier himself articulated many skeletons, as did the subsequent chairs of comparative anatomy. These scientists would certainly have had assistance, perhaps even a permanent member of staff employed at the museum. Dutert’s plan for the interior of the ‘nouvelles galeries’, including a preparation room, which had been approved and signed by professors’ Gaudry, Pouchet, Milne-Edwards and Hamy (figure 3.30).

The articulated skeleton not only embodies the expertise of the articulator but is also imprinted with the contribution of all those who assisted, even down to the author of

\textsuperscript{615} Ibid., pp. 483–84. Also see C. N. Seremetakis, ed., The Senses Still: Perception and Memory as Material Culture in Modernity (Chicago: University of Chicago Press, 1994), p. 15.
the manual they may have used. Each encounter is articulated with the specimen, forging connections across time and space so that ‘bones that were preserved and articulated could become materialisations of multiple persons, some more apparently manifest than others, depending upon the power relations in which the bones were enmeshed’. 616 Those power relations are made visible in the busts decorating the external and internal spaces of the gallery – the visible, durable presence of distinguished scientists, as presented in a photograph from 1899 of the Galerie d’Anatomie comparée (figure 3.31). It captured the arrangement of skeletons behind a bust of Cuvier, a configuration that is still enacted today. The bust is an object of honoured remembrance and its position at the head of the skeletal herd symbolises leadership and perhaps even ownership. The skeletons are visually and spatially imprinted by Cuvier.

The Galerie de Paléontologie et d’Anatomie comparée is a dynamic space of exposition. The materiality and design of the architecture gives rise to multiple levels of interpretation, which can act to obscure the true vision of the architect and render their meaning illusive. However, what remains clear is that the presentation of skeletons in the gallery is a nineteenth-century distillation of anatomical knowledge through the contemporary modes of presentation, and that the social moment of the 1900 Exposition Universelle is preserved in this building and imprinted upon the specimens its contains. We can therefore view these articulated skeletons as ‘situationally constituted’ relics. 617

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617 Ibid., p. 466.
CONCLUSION

MATERIAL METAPHORS AND THE OMNIPRESENT SKELETON

In the summer of 2017, a blue whale named ‘Hope’ became the talk of London. Although Hope was actually the 126-year-old skeleton of a blue whale, in some respects ‘she’ was, and continues to be, talked about like a living breathing animal. Curators and conservationists at London’s Natural History Museum were enthusiastic about the change to the exhibition space of Hintze Hall, while others were appalled that their precious ‘Dippy’ the Diplodocus was being replaced. As far as the naysayers were concerned, Dippy was, and should forever remain, the museum’s mascot. However, Dippy was ‘only a plaster cast’, and the conservators of the museum successfully argued that the bones of an extant species of impressive proportions would be a more appropriate display in a museum of natural history that wished to promote cutting-edge zoological research and animal conservation.

Natural history museums often convey the impression of bone as being immortal, suggesting that they preserve something of the animal after death; an illusion derived from the notion that specimens are allegedly transparent ‘images of themselves’. In scientific discourse, particularly in nineteenth-century biology and natural history, the skeleton was often conceived of as the body’s ‘essence’, a manifestation of its design and hence imbued with the idea of truth. The skeleton was frequently used as evidence to prove a species’ ‘evolution’ or as a tool for classification. Indeed, today’s...

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619 The argument for the authenticity of the specimen of the blue whale, verses Dippy’s inauthentic status as ‘only a cast’ was used as a talking point by supporters for the change from dinosaur to whale. A new bronze cast of Dippy will soon be placed in the museum’s grounds. See Ibid.

knowledge of comparative anatomy is still derived in part from the skeletons exhibited within museums dating back to the nineteenth century in order to visually manifest stages of evolution or the taxonomy of animals.

As my thesis has shown, the materiality of bone, and our relationship with said material, is far more complex. The skeleton specimens in the museum oscillate between nature and artifice, their bones which formed their living skeleton, boiled, bleached, varnished, brought together and articulated by wires and hooks so as to give an immediate impression of life. The gathering and assemblage of parts creates a ‘whole’ that is both incomplete and complete at the same time. By incomplete I mean that the bones are without soft tissues or homeostatic systems. By complete, I mean that in its articular afterlife, the skeleton has become something new, has become reanimated and reimagined, with the material of bone being removed from the realm of the dead to inspire new affective materialisations.

Such a transformation has also taken place with Hope. Suspended from the museum’s glass and iron roof by steel and titanium cables, the 25.2-metre skeleton of the blue whale swims into view. Richard Sabin, the museum’s curator for large mammals, selected the pose in order to give the specimen ‘dynamism’. The skeleton is tilted in such a way that the specimen looks to be diving into the space, with its tailbones raised so as to create a sinuous serpentine line. Lorraine Cornish, the museum’s head of conservation, said that ‘Hope is the only blue whale skeleton in the world to be hung in the diving lunge feeding position. Suspending such a large, complex and historical specimen from a Victorian ceiling was always going to be challenging, but we were determined to show her in as lifelike position as possible and we are thrilled that the result is truly spectacular’. As Hope hovers above the space, visitors are given the ‘opportunity to walk underneath the largest creature ever to have lived’. Following the blue whale’s installation, Richard Sabin explained that Hope was selected as the new specimen to replace Dippy as she conformed nicely with today’s Darwinian ethos.

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623 Ibid.
of the museum, presenting a living species, part of the planet’s ecology today.\textsuperscript{624} The fact that the blue whale is a species under threat extends the metaphor of conservation beyond the specimen to the species. The museum hopes that Hope will bring awareness of the wonders of the animal kingdom, especially those that still inhabit the planet, unlike the sensational dinosaur exhibits. Sabin felt, as a caretaker for the museum’s specimens, that it was the museum’s responsibility to ‘articulate the importance of animal conservation efforts’. In view of climate change and mass extinction, the curators decided on the name Hope to turn the specimen into a symbol of ‘humanities power to shape a sustainable future’.\textsuperscript{625}

Of course this contemporary display of a skeleton of a sizable marine mammal brings the anonymous Charing Cross whale to mind. But while the Victorians passed their time and took refreshments inside a whale’s enormous thoracic cavity, Hope is suspended far above the visitors of Natural History. As the eyes are drawn up towards the roof, the curving lines of the whalebone find echoing forms in the rounded stone arches of the windows and colonnades (figure 4.1). The curators and exhibition designers today still seem to be working with the visual analogies between the architectural structure and the animal skeleton. The cetacean’s spine runs directly parallel to the central spine of the building, perfectly bifurcating the central window. Seen from below, her lateral fins are placed exactly above the two flanking Romanesque windows. Even the chalky white colour of the bones finds harmony in the bluish-grey iron and grey bands in the stone. Through the display the building is made to feel like an extension of the specimen. As this thesis has demonstrated, this metaphorical extension perceived in Hope is a legacy of nineteenth-century encounters between the material skeletons of iron and bone within the space of nineteenth-century expositions. The architecture was intended to offer a transformative encounter, and the skeletons acted as material mediators.

My training as a forensic anthropologist has not only informed my research, it has informed how I see. I look at buildings with the spatial thinking of a forensic anthropologist. My scientific background has enabled me to provide a fresh

\textsuperscript{625} Ibid.
‘anatomically informed’ account of the art, architectural, anatomical, engineering, and museum archive material. This enabled me to articulate together conceptually different materials, which have made the skeleton more than simply a metaphor. I have been informed by literature that architectural historians do not take into account, such as the physiology of bones (as discussed extensively in my third chapter, where the link between nineteenth-century physiology and engineering was brought to the fore), and I read art and architectural sources from an anatomically informed perspective. This approach has enabled me to look at the material of iron and bone, and the skeleton metaphors that they make, in a completely new way.

The skeleton is generally understood to be a homogenous system comprised of bones whose structural function and hard solid materiality bears a striking visual similarity to the iron and glass architectures of arcades, conservatories, greenhouses and skyscrapers. The mimetic, mechanical and imaginative anthropomorphic relationship that exists between the two inspired its metaphorical application. However, I have shown that in the nineteenth century the skeleton was conceived in a multitude of ways; dead and alive; static and generative; abstract and material, articular and growing. Yet the skeleton, outside of our bodies, is always a fabricated construct which is made whole through the careful process of articulation.

Although the body – its proportions, surfaces, cavities, and functional parts – is an established trope in architectural history and theory, its skeleton is less often engaged with if at all. Twentieth- and twenty-first century research on organicism in architecture has generally been more focused on architecture’s relationship with nature and the environment, generating theories of spatiality, organicism, biomimicry and architectural ecology in which the human exists in ‘sympathy’ with nature and building materials.626 But the skeleton, itself so very particular in its material dimension, had been disregarded as an avenue of critical architectural inquiry, as the metaphor became too ubiquitous to be noticed. Considering its material dimension made it possible to highlight that the metaphor of the skeleton has the power to turn architectural parts, defined by their form and material, into a conceptual whole.

Today’s digital planning of architecture results in a dematerialisation, entering the computer as coded information to produce digital forms that flow or ‘float’, the desired form takes precedence over its substance. As if to compensate for this dematerialisation, biomorphic terms such as ‘shell’, ‘skin’, ‘bubble’ and ‘blob’ are employed to describe the building. In his book *Bio-Architecture*, the organicist architect Javier Senosiain lists the four light structures of contemporary bioarchitecture that are inspired by nature: cable networks (from spider’s webs), pneumatics (from bubbles), vaults (from shells and eggs) and geodesics (from radiolarians). Bones are part of this biological reference system. Senosiain visually relates the design of Buckminster Fuller’s Geodesic Dome (1967) with the tetrahedral shapes apparent in bone’s internal structure, yet he states (quoting Felix Candela) that in such architectures ‘the structural form is chosen first, and afterwards you look to see if it is possible to integrate function’. Function is not a part of the initial design concept and, as such, the functional skeleton is not conceived as a holistic, adaptive principle in contemporary organic architecture. Its form is considered too rigid, its function too structural. Virtual modelling systems apply the term skeleton to any structural process that requires ‘rigging’ and onto which surface detail can be added to and adapted later.

Contemporary architectural discourse and practice works with the skeleton as a metaphor, but it has produced a dematerialised skeleton; the metaphor has become an abstract concept. In contrast, I have argued in this study that this metaphor has a material dimension. In the case of the skeleton constructions of nineteenth-century architecture, the metaphor still recalled its provenance; its material substrate. I have demonstrated the material conversion from bone to iron that occurred within the long nineteenth century and argued that it should not be taken for granted. Within a period of industrialisation, of scientific experimentation and discovery, the use of metaphors, especially metaphors of the body, became a necessary vector for the conveyance of knowledge about previously uncharted fields of inquiry, providing a linguistic and

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628 Ochsendorf and Block, ‘Exploring Shell Forms’, pp. 7–12.
630 Ibid., p. 44.
631 The first recorded use of the skeleton as indicating a ‘bare outline’ is thought to have been c. 1600. See ‘Skeleton’ in ibid. <http://www.etymonline.com/index.php?allowed_in_frame=0&search=skeleton> [accessed 5 June 2017]
conceptual framework with which to impart observations and theories to scholars and layperson alike.

Nineteenth-century architectural practices are with us today, and the ideas and concepts that surround their making can be productive ground on which to question contemporary ways of building. Could the skeleton be part of architectural organicism in contemporary architecture? Should we engineer materials to be like the adaptable extracellular matrix? Could we approach architecture in a sustainable way by using bones’ ability to ‘remodel’ as a paradigm and a possibility for developing adaptive materials and structures?

I am certainly not alone in thinking about architectural futures and sustainability, and bone is often considered as a model in ‘animal architecture’; however, it is the exoskeleton that holds the architect’s interest. Not the endoskeleton; the skeleton of structure. Some architects might say that all architecture has structure, and therefore all structures have a skeleton. Otherwise they would collapse. On the other hand, the exoskeleton has huge morphological potential, as evidenced in the swirl of a nautilus shell in Frank Lloyd Wright’s Guggenheim Museum.

As this thesis has demonstrated, the skeleton is an organist concept with a material history written in bone and nineteenth-century iron. I presented bone as a complex dynamic material which, when visible, can connote death, but has the potential to become re-animated through articulation. The bones extracted from the dead body formed the first incarnation of physical skeletons, which extend beyond the living body’s invisible skeletal system into the visible realm of artifice and re-presentation. The word ‘skeleton’ was, and continues to be, used to describe the invisible bony parts of the living body along with the visible bony components of the dead body. However, bone in the living body is part of an ever-changing dynamic cellular matrix of minerals, collagen, water, marrow, and blood that continuously remolds itself based on the needs and stresses of the body.

The musculoskeletal system is the framework of the body, and gives the body its size, shape and features. This creates an interesting tension in the skeleton when outside the body. The bones still retain their size, shape and features but the dynamic process, muscle attachments and articular surfaces are absent. Therefore artificial modes of
connecting bones together were imagined, giving rise to skeletons of bone. These skeletons are only seen in the dead animal, when the flesh has rotted, the bones have collapsed into dusty piles, and have been brought together through articulation. Bone and bones have generated a multitude of cultural practices and meanings. It is a mobile object synonymous with rigidity and durability, which can act upon and be re-imagined within the constructs of larger societal systems. These unique properties of bone subject them to remarkable afterlives, both physical and metaphorical. In fact, with their oil-rich bodies, whalebones (particularly sperm whalebones) continue to secrete oil onto the surface of the bones hundreds of years after their skeletonisation. I have observed that this dark brown whale oil stains the bones a rusty-yellow colour. Yet the skeleton is more than an aggregation of fragments, of bones – it is something assembled and conceived of as whole. The legacy of this conception of bones and the skeleton is difficult to break away from, as remains and relics, death and memento mori imagery, biblical narratives and Gothic imaginings all have a role to play in our comprehension of the skeleton. This thesis considered the two structural and biomechanical components of this so-called skeletal system: the bones, which make up the skeleton, and their joints or articulations. I proposed that in the nineteenth century the skeleton became a ubiquitous term or ‘metaphor’ to denote what is essential, structural, linear, supportive, and what underlies or gives form to a thing, idea or concept. I analysed the metaphoric transformation of the skeleton into architectural discourse where the material iron stands in for the bone and the iron frame for the skeleton.

Vitruvius linked the human body with architecture, creating a set of standardised measurements using the segments and proportions of the living body. His books on architecture informed Renaissance architects like Alberti, who took the Vitruvian theory of ‘unity of parts’ and actually looked to see how this could be accomplished in architecture. Though the notion of concinnitas, an organisist concept in architecture, to describe the artful knitting or joining together of architectural parts (what I consider to be Alberti’s way of describing articulation) he conceived of a building as a living body, with bones and sinews, nerves and ligatures, communicative parts artfully joined together. While Alberti used anatomical metaphors, the term skeleton was not part of his architectural language. In the eighteenth century Laugier reduced architecture to three essential elements: the column, the entablature and the pediment. He naturalised
these architectural ‘members’ through their association with architecture’s arboreal origins. His writings were highly influential in Europe, and it is likely that his naturalism and esteem for Gothic architecture was acknowledged by Ruskin. In contrast to Laugier though, the skeleton proved to be a highly significant metaphor for Ruskin and served, as I have shown, a number of purposes. Firstly, it was a cognitive tool that allowed him to visualise and articulate the active lines he perceived in nature. My visual analysis showed that he composed his drawings by perceiving the active lines of growth in nature, following them with his pencil. This growth could be like a bifurcating branch, or an unfurling fern or, like in The Walls of Lucerne, an articulated spine, each generating and connecting parts so as to create a unified whole. These essential, abstracted lines of growth and action in nature, the ‘aweful lines’ or ‘skeleton lines’ from trees, plants, rocks and landscape, helped Ruskin to see and demonstrate the structure, unity and vitality of nature.

Secondly, the skeleton lines gave an immediate dynamism to art, ornament and architecture. These dynamic lines include the Gothic line, which gives a very particular energy or movement to Gothic architecture that Ruskin called ‘active rigidity’. The skeleton lines that Ruskin perceived in rocks and mountains were composed of iron compounds and oxides. In my critical reading of Ruskin’s texts in chapter one I demonstrated the relation between iron and bones, and demonstrated that two materials potentially associated with death, could be perceived as living when seen in a different setting. Ruskin considered iron as an organic material that ‘sucks and breathes the brilliancy of life’. In the second chapter I explored Ruskin’s apperception of iron in the architecture and articulating ornament of the OUMNH. I considered the OUMNH as a space with which the metaphor of the skeleton becomes material, and that this metaphoric relationship was a guiding concept in the design and execution of the building’s architecture and displays. The neo-Gothic architecture was united with the specimen through an organic appreciation of iron, which animates the iron elements in the articulated skeletons.

In the last chapter, the relationship between bone and iron moved beyond the visually and structurally mimetic to a functional and biomechanical alignment in the ‘ossatures’ and ‘squelette de fer’ in French architectural discourse and Parisian architectures. This transnational approach allowed me to highlight that the skeleton metaphor, while
equally relevant, could have different functions in nineteenth-century European architecture. Focusing on the writings of Viollet-le-Duc and Cuvier, who considered bone as the optimum building material, and the animal skeleton as the optimal mechanical system, I demonstrated that the ‘correlation of parts’ in the skeleton was evidence that the functional skeleton held the essence of form. The shape of bones and their articulations in the body inspired new engineering and architectural designs in iron casting and building. A key example is the important, yet understudied architect Ferdinand Dutert, who designed the Galeries des Machines for the 1889 World Fair. Fusing art nouveaux ornamentation with articular iron, he created a building that epitomised the architectural avant-garde of the industrial age. He was subsequently commissioned to design the new Galerie de Paléontologie et d’Anatomie comparée for the exposition of 1900. In the museum the metaphors become fully realised and animated through the museum’s ship-like architecture and vegetal ornamentation. As I have shown, it is also a museum where the building’s architect actually had a hand in designing the mounts for the articulating specimens that line the centre of the two main galleries. Bone is truly animated by the iron’s articular life-support, which weaves its way around the specimen. On occasion there seems to be more iron than bone in the specimen on display. The architect and naturalists that encountered, handled, tested, and manipulated the skeletons of iron and bone understood their articular nature, and the potential impression that skeleton forms could make on those who beheld them. At this fin-de-siècle moment, the organic iron ornamentation of Ruskin’s Gothic meets the structural functionality of modern architecture, which would then lead to the skeleton-constructed high-rises and skyscrapers of the twentieth century.

Although the material relationship between iron and bone had been identified, discussed and, indeed, tested since the early-nineteenth century in architectural and natural-history texts, the relationship was always one of functional mimesis. With plastic, elastic and anisotropic properties, bone was considered to be an optimal building material, and iron, if carefully engineered, could be made to function like bone. Yet the relationship between ‘skeletons’ of bone and ‘skeletons’ of iron in the

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632 Bone is plastic, continuously being destroyed and remade with the living body, allowing for adaptability, a process known as remodelling. The compact bone of the long bone is notably thinner at the midpoint of the diaphysis, where the ‘danger-point’ of bending would reside but this ‘has been avoided, and the thickness of the
nineteenth century was far more complex and complicated to trace. The first complication came when defining the skeleton: for what is a skeleton? The term could mean different things to different people. In the nineteenth century, skeletons transformed in multiple ways, from the structural parts of the body and spectre of death, via the artificial aggregation of desiccated animal bones in a natural history museum, to the lines found by John Ruskin in layers of sedimentary rock, to the iron bridges, skeleton frames and *ossature* of colossal architectures. In the early-twentieth century D’Arcy Thompson, inspired by the schematics and models made by Clerk-Maxwell, would use the skeleton as a metaphor to describe a theoretical framework in physics and mathematics. Completely devoid of material, the skeleton would become a ubiquitous concept; an adjective that floats through the languages of numerous academic disciplines, and used to describe anything abstracted, essential, or the bare outline.

Thus far, the skeleton has no place within twentieth-century organicist theory – it is still conceived as a lifeless, dry, and inert entity – purely the static framework onto which the important parts, the flesh of the walls, floors, cladding, can be added onto. I propose that there is indeed an organicist dialogue to be had when thinking about the history of skeleton construction, from nineteenth-century to contemporary architecture, and argue for a review of early twentieth-century skeleton construction in light of its application. This skeleton concept could provide a new model for the organicist’s consideration.

The skeleton in the museum embodies the notion of transformation, as metaphors and materials come together and are articulated in the spaces of natural history. I am reminded again of the Arcadian imagery that Melville painted when describing his whalebone temple within a glade; of death trellised with life; part of an ecological system of bodily decomposition, seeping nutrients that enrich the soil and feed into the

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wells becomes nothing less than a diagram, or ‘graph’, of the bending-moments from one point to another along the length of bone.’ See Thompson, *On Growth and Form*, p. 227.

plants that then grow upwards to embrace what feeds them. Death and decay are a natural process of estrangement whilst articulation is the systematic regrouping and artificial attachment of body parts, yet what this thesis has shown is that through this artificial process of articulation an organic whole can be reimagined. As the iron weaves around and through the bones to make up the skeleton specimen, the iron trellising makes what was dead whole again. The natural history museum is no longer a place where we see the skeleton specimen as just bones fixed in place by a metal armature; it is a place where skeletons are made, where they come into being, and where death is still life.
INTRODUCTION


v. Skeleton schematic used by forensic anthropologists when taking bone inventory and compiling a biological report. Taken from J. E. Buikstra and D. H. Ubelaker, Standards: For Data Collection from Human Skeletal Remains (Arkansas: Archaeological Survey, 1994).
CHAPTER ONE


CHAPTER TWO


2.3. Carl Haag, *On The Sabine Hills*, c. 1856 Watercolour on paper, 17.5 × 50.5 cm.
Private Collection.


2.16. John Ruskin and Frederick Crawley, *Study of a balcony (front view)*, Piazza Collegiata, Belinzona, 1858. Daguerreotype, Half Plate; Laterally reversed, 19.0 × 13.6 × 0.4 cm. Ruskin Foundation (RF Dag 110). Ruskin Library, Lancaster University.
2.17. John Ruskin and Frederick Crawley, *Study of a balcony (side view)*, Piazza Collegiata, Belinzona, 1858. Daguerreotype, Half Plate; Laterally reversed, 19.0 × 13.6 × 0.4 cm. Ruskin Foundation (RF Dag 111). Ruskin Library, Lancaster University.
2.18. John Phillips, *Design for capital ‘Phoenix dactylifera (with animals)’, c. 1857.* Pencil, ink and watercolour on paper, 19.0 × 22.0 cm. Collection of the Oxford University Museum of Natural History (HBM02-173). ©Oxford University Museum of Natural History.


2.23. John Phillips, *Sketch for combining the new gallery display cases with the existing cases*, c. 1858–60. Ink on paper, 10.5 × 7.0 cm. Collections of the Oxford University Museum of Natural History (HBM02-048). ©Oxford University Museum of Natural History.
2.24. John Phillips, *Sketch of a museum aisle, detailing the architectural columns, display cases and zoological specimens*, c. 1858–60. Ink on paper, 11.5 × 17.0 cm. Collections of the Oxford University Museum of Natural History (HBM02-150). ©Oxford University Museum of Natural History.


3.13. *Illustration of Julius Wolff’s trajectorial theory*, 1892. On the left is a midfrontal section of the proximal femur, showing trabecular architecture; in the middle is the schematic representation; and on the right the stress trajectories (curves representing the orientations of the maximal and minimal principal stresses in the material under load) in a model analysed by Culmann. The maximal and minimal stress trajectories always intersect perpendicularly. Adapted from Wolff, *Das Gesetz der Transformation der Knochen* (Berlin: A. Hirchwild, 1892), translated by P. Maquet and R. Furlong, *The Law of Bone Remodeling* (Berlin: Springer, 1986). Taken from Rik Huiskes, ‘If Bone Is the Answer, Then What Is the Question?’, *Journal of Anatomy*, 197 (2000), 145–56 (p. 146).

3.15. Illustration to show the internal stress lines in the bones of the human foot, which follow arching internal trabecular bone, as observed by von Meyer in 1867. Taken from John Skedros and Richard A. Brand, (2011). ‘Biographical Sketch: Georg Hermann von Meyer (1815–1892)’, Clinical orthopedics and related research, 469 (2011), 3072–6 (p. 3074).


3.23. Iris stems adorning the staircase leading to the mezzanine level of the galerie de Paléontologie, Jardin des Plantes, Paris. Photograph taken by author, 2015.

3.27. The iron support weaving around the hind limb of this paleontological specimen *Lestodon armatus*, embracing the form and of the bones and the unique architecture of the limb, in the galerie de Paléontologie, Jardin des Plantes, Paris. Photograph by author, 2013.
3.31. Pierre Petit, *Galerie d’Anatomie comparée (bâtiments vues)*, 1899. Photograph. The bust of Cuvier can be seen at the head of the collection. The specimens are impressively raised on iron columns, the juxtaposition of bone and iron chaotic at first glance. Courtesy of the Bibliothèque centrale du Museum national d’histoire naturelle, Paris.
CONCLUSION


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