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An evolutionary tale of architectural spandrels and double helical stairs appropriated by biology and delivered back changed through their double translation.

Exaptive translations between biology and architecture

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Introduction

'Translation' is dealt with in this paper as a descriptor of the transformation that occurs as a concept, structure, image or notion is appropriated from one discipline to another. This understanding of translation as process or movement, rather than a field of overlap between disciplines, is facilitated by the work of the philosopher Michel Foucault. Foucault considers disciplinarity as the structural demarcation of knowledge and information (discourse) and the demarcations that are disciplined by knowledge.[1] This understanding may be expressed as: *disciplines as a disciplining*. Foucault rejects the idea of disciplines as bounded self-similar content, arguing instead that disciplinarity lies in the framing of logics applied to content. The disciplines in question are considered in their contingency and temporality yet are not entirely bound by them. Thus, a coherent and organised discipline such as biology dates from the beginning of the nineteenth century. Before then its subject matters either were comprehended within other disciplinary frameworks (natural history) or were considered outside science itself (natural theology). In *The Order of Things* (1966), Foucault groups several naturalists, including Buffon (French eighteenth century) and Darwin (British nineteenth century), as belonging to the same 'discourse' or discursive family.[2] Separating disciplinarity from the origin of ideas and time of writing fosters the productive translation of concepts, images and artefacts between disciplines.

The present paper is concerned primarily with two events of translation between architectural history, biological theory and architectural practice that elucidate the processes and techniques of disciplining knowledge. The first event of translation is the movement of a Byzantine architectural feature from Venice into the 1979 proceedings of The Royal Society of London. In a paper titled 'The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme', palaeontologist Stephen Jay Gould and geneticist Richard Lewontin attack the laissez-faire application of the adaptationist paradigm in biology to explain all manner of organism and organ.[3] The Basilica di San Marco in Venice and the architectural logic of 'spandrels' is engaged to articulate the argument to an audience of scientists. As stated by Gould and Lewontin: 'architectural constraints abound, and we find them easy to understand because we do not impose our biological biases upon them.'[4] Their motive is simply stated but the implications of the translation are complex.

The second, parallel, event is the translation of the image of architecture's double helical stair into genetics. 'Scala Leonardesca', as the double helical stair was known to Renaissance architects, significantly predates and informs Watson and Crick's announcement of the structure of DNA in 1953. Translated from architecture into biology, the double helix subsequently returns to architecture bearing the legacy of this process of translation. The structure is deployed in numerous buildings for science from the Chemistry Department at the University of Reading (1961) to the EMBL Advanced Training Centre in Heidelberg, Germany (2010). The circulatory function and geometry of the double helical stair is little changed yet the expressive qualities of both contemporary and historical examples are radically altered as they are translated through disciplines.

The traffic between biology and architecture has been heavy in both directions since the beginnings of biology as a scientific discipline in the 1800s. And before that, at the inceptions of architecture with the appearances of the acanthus in ancient Greek and Roman capitals, motifs adopted from flora, fauna and the human body have abounded. Models and motifs drawn subsequently from the suite of life science disciplines – anatomy, physiology, zoology, botany – present biological subjects first through the mediating lens of science and its historic apparatus of visualisation and secondly through the disciplining lenses of architecture. In reverse, engagements with architectural structures and notions such as *baupläne*, cells, foundations, Buckminster Fuller's geodesic domes and tetrahedral structures, and parables of houses

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have permeated biological discourse and attenuated its investments.[5] Attention is drawn away from the superficial appearance of the living organism to its structure, function, growth and evolution and the ways in which these are understood and represented in scientific terms. 'Biomimetic design', as coined by Janine Benyus in 1997 (and, apparently, exemplified in the invention of Velcro), is the most recent mode of engagement with biology to garner enthusiasm among architects. Biomimetic design aspires to use natural processes to solve human problems or, in the terminology of the Biomimicry Institute, to 'biologise' a challenge.[6] In the context of architectural designs purporting to emulate the vertebrae of whales, the lean structure of dragonfly wings or the valvular pollination mechanism of the Strelitzia, to name just a few examples, it is necessary and timely to examine the disciplinary effects of translations between biology and architecture with more circumspection than has yet taken place.[7] The events described below have traceable histories that can be extracted from broader engagements. At the same time, each object – the spandrel and the DNA stair – remains stubbornly recognisable despite wide circulation, journeys into other disciplines and disparate actualisations.

The disciplines of biology and architecture will take up and opportunistically frame and reframe notions, images, structures and ideas in their own terms. It is the contention of this paper that the translation of scientific and architectural ideas, ideals, images and expressions is not *adaptive*, but rather *exaptive*.

Spandrels between architecture and biology

Gould and Lewontin commence their 'Spandrels' paper with the statement:

> *The great central dome of St. Mark's Cathedral in Venice presents in its mosaic design a detailed iconography expressing the mainstays of Christian faith. Three circles of figures radiate out from a central image of Christ: angels, disciples, and virtues. Each circle is divided into quadrants, even though the dome itself is radially symmetrical in structure. Each quadrant meets one of the four spandrels in the arches below the dome. Spandrels – the tapering triangular spaces formed by the intersection of two rounded arches at right angles – are necessary architectural by-products of mounting a dome on rounded arches. Each spandrel contains a design admirably fitted into its tapering space. An evangelist sits in the upper part flanked by the heavenly cities. Below, a man representing one of the four biblical rivers (Tigris, Euphrates, Indus, and Nile) pours water from a pitcher in the narrowing space below his feet.*
>
> *The design is so elaborate, harmonious, and purposeful that we are tempted to view it as the starting point of any analysis, as the cause in some sense of the surrounding architecture. But this would invert the proper path of analysis. The system begins with an architectural constraint: the necessary four spandrels and their tapering triangular form. They provide a space in which the mosaicists worked; they set the quadripartite symmetry of the dome above.*[8]

The Basilica di San Marco sits on the Piazza San Marco, adjacent to the Doge's Palace. It is the third basilica to have been built upon the site. The current basilica dates to between 1063 and 1094 and is widely considered to be one of the most stunning examples of Italian Byzantine architecture.[9] The pendentives of the central dome of the Ascension at San Marco are decorated with four evangelists as Gould and Lewontin describe above. The pendentives are the spherical triangular areas allowing the placement of a hemispherical dome over a square space of four circular arches *[1]*. It is these forms that Gould and Lewontin refer to as 'spandrels'. While the dome dates from the early thirteenth century, the elaborate gilded mosaics and decorative work that adorn the interior of the basilica including the pendentives were only completed in the nineteenth century.[10]



1 Basilica di San Marco in Venice

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Gould and Lewontin evoke architecture to make a point about the existence of characteristics that may be misread as 'adaptive', but are instead a by-product of an adaptation – vestigial in some senses. Their point is that the spandrels and their decorative scheme are a by-product of the architectural constraint and not the primary cause of the architectural form. The 'Spandrels' paper strategically sets itself up to 'support Darwin's own pluralistic approach to identifying the agents of evolutionary change'[11] in the face of texts such as Richard Dawkins' *The Selfish Gene* (1976) which represents a particularly forceful extension of Darwin's adaptationist account.[12] Very briefly the 'adaptationist programme', as Gould and Lewontin refer to it, is the theoretical accounting of every possible biological feature of an organism as an expression of an adaptation. The logic is that Darwinian natural selection, the primary thesis set out in Darwin's *The Origin of Species* (1859) might account for the most abstruse of features and characteristics of an organism.[13] Darwin himself struggled to capture the complex mechanisms proposed in *The Origin of Species*,[14] but others have offered 'a reasonable summary of the general broad thrust of Darwin's argument.'[15] In 1986 the historian of science, David Oldroyd, offers the briefest possible outline of the theory of Natural Selection:[16]

For organisms in a species:[17]

Geometric Ratio of Increased Existence + Limited Resources → Struggle for Existence

Struggle for Existence + Variation → Natural Selection

Natural Selection + Time → Biological Improvement

It was not until the 'grand synthesis' of Darwinian selection theory and Mendelism of the 1930s that natural selection had anything approaching paradigm status.[18] Before this those sciences *outside* Darwinism were able to assert their own constructs and, indeed, *eclipse* Darwinism for a short and intense period at the turn of the twentieth century. By the time of the 'Spandrels' paper, Gould and Lewontin were able to assert that 'an adaptationist programme has dominated evolutionary thought in England and the United States during the past forty years', and imposed a narrower version of evolution than Darwin himself proposed.[19] Gould suggests that the 'Modern synthesis' (as Julian Huxley would label it[20]) of Mendelian mutationism (genetics) and Darwinian natural selection progressively 'hardened' from the 1930s to the '50s against those theories that promoted pluralistic forms of non-adaptive trends in the evolution of organisms.[21] According to Gould; '[r]andom forces were pushed to a periphery of absolute unimportance'[22] and physical, material, 'architectural' constraints are one such 'random force'. This is not merely the creation of a homogenous disciplinarity but also the creation of a homogenous body to populate that field.

Gould and Lewontin's 'Spandrels' paper (and Gould's work over many decades) raises important supplements to the theory of natural selection and adaptation such as a theory of *variation*, the notion of *sexual selection, punctuated equilibrium* and the role of physical constraints on the transmutation of species. Gould and Lewontin attack the logic of 'pure' adaptationist readings to account for all manner of organism, organ and social practice:

> [w]*e strongly suspect that Aztec cannibalism was an 'adaptation' much like evangelists and rivers in spandrels, or ornamented bosses in ceiling spaces: a secondary epiphenomenon representing a fruitful use of available parts, not a cause of the entire system. To put it crudely: a system developed for other reasons generated an increasing number of fresh bodies; use might as well be made of them. Why invert the whole system in such a curious fashion and view an entire culture as the epiphenomenon of an unusual way to beef up the meat supply. Spandrels do not exist to house the evangelists.*[23]

Their reference to cannibalism appears to be directed at Dawkins' attempt to account for cannibalism in the terms of adaptation in his 1976 text 'The Selfish Gene'.[24] Until Gould and Lewontin's 'Spandrels' paper there was not a singular word nor simple phrase in common usage in evolutionary biology to describe a non-adaptive character or part of an organism that nonetheless fulfils a function. The influence of the paper was such that the term 'spandrel' came to common parlance in the discourse of evolutionary biology, and from there to evolutionary psychology, neurosciences and even linguistics (Chomsky subscribes to the view that human language itself may be a side-product of an increase in overall brain size).[25]

In 1982, Gould and Elisabeth Vrba draw upon the work of Foucault and propose the word 'exaptation' to describe a characteristic of an organism that, while useful in its current existence, was not arrived at for this role via natural selection.[26] The term 'exaptation' describes 'characters, evolved for other usages (or for no function at all), and later "coopted" for their current role'.[27] In terms that will resonate with architects, Gould and Vrba were to suggest that exaptations 'are fit for their current role, hence *aptus*, but they were not designed for it, and are therefore not *ad aptus*'.[28] The commonly cited example is feathers in birds. Feathers are believed to have *adapted* as an aid to insulation and *exapted* as an aid to flight. Exaptations can either be what is referred to as 'preadaptation' or 'spandrels'. Briefly the term preadaptation is used to describe a characteristic that evolved in an ancestral species that serves an alternate function in a descendant species. The difference to the idea of the 'spandrel' being that the 'preadaptive' feature is not a by-product.

In 1997 Gould defends his use of the architectural feature in a paper titled 'The Exaptive Excellence of Spandrels as a Term and Prototype'.[29] He identifies two key points of critique that his earlier paper with Lewontin provoked. The first was 'the terminological claim that the spandrels of San Marco are not true spandrels at all' and the second was 'the conceptual claim that they are adaptations and not by-products'.[30] As to the terminology, Gould concedes that while there are

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examples of architectural writers and historians who use the term 'spandrel' to describe such spatial configuration 'most architects, apparently, do not do so'.[31] Gould still contends, however, that:

> [...] *if evolutionary biology needs a general name for the concept of a nonadaptive architectural by-product of definite and necessary form – a structure of predictable size and shape that then becomes available for later and secondary utility – the architectural term spandrel seems eminently (may I even say optimally) suited.*[32]

In order to defend the second key critique that Gould summarises by the question: 'Are Spandrels Spandrels or Adaptations?', the palaeontologist invokes the architectural historian and civil engineer Robert Mark. According to Gould, Mark 'affirms our central claim about the necessary form and number of spandrels as by-products (while also noting the active role of pendentives in buttressing)'.[33] Gould suggests that buttressing was a secondary adaptation that results from the original intent of enclosing a square volume with a dome and thus non-adaptive in origin, though adaptive in a secondary sense. The claim thus supports the general hypothesis that '[c]auses of historical origin must always be separated from current utilities' and that 'their conflation has seriously hampered the evolutionary analysis of form in the history of life.'[34]

What can be concluded from the episode of the translation of an architectural historical feature into the discourse of evolutionary biology is that the term 'spandrel' (though incorrect for the architectural feature described) served a very particular purpose in the discipline of evolutionary biology. What is astonishing is that the same term and idea comes to be re-translated back onto architecture, albeit briefly. In a paper of 1996 titled 'Architecture and Evolution', Mark re-integrates the now biological notion of spandrel in a translation back into architecture proper. Mark goes as far as to suggest 'that building technology itself follows an evolutionary pattern'[35] and suggests that Gould and Lewontin may have indeed benefited in some manner by 'a more general discussion of evolution, one that could have expected at least a passing reference to the evolutionary aspect of architectural design.'[36] The movement of the image of the spandrel (pendentive) here becomes complex indeed: taken from architecture, deployed in biology as an analogy, and then reintegrated back into architecture as a sign of the evolutionary character of architecture itself.

In more recent times the term 'exaptive', too, has been re-translated into architectural discourse. In their *Atlas of Novel Tectonics* (2006), the architects Jess Reiser and Nanako Umemoto note the architectural value of Gould's term 'exaptive' as, 'an alternative theory that describes the emergence of novelty not as error but as byproduct'.[37] Again, this definition seems not entirely aligned with its contemporary use in biological discourse. Reiser and Umemoto argue the (non)teleological function of exaptation in suggesting that it is not possible in a conventional design process 'based on a top-down logic' where 'concepts and goals will be established at the outset, even before actual design starts'. They go on to suggest that '[t]he emergence of secondary elements to the design project under this regime can only be seen as either faults of the concept or mistakes to be eliminated from the final product'.[38] There is something perplexing in Reiser and Umemoto's defining and usage of the term 'exaptive'. Their engagement of the idea of 'by-product' means that the definition they generate is rather closer to the definition of 'spandrel' than the broader category of 'exaptation'. Given the architectural history of the spandrel, Reiser and Umemoto's usage does cause one to reflect on the actual 'novelty' of novel tectonics.

The double helix between genetics and architecture

Francis Crick and James Watson described the molecular geometric structure of DNA as a double helix shape for the first time in a one-page paper in *Nature* in 1953.[39] They proposed that the three-dimensional structure of DNA is like a double spiral staircase: 'the "banisters"are composed of alternate phosphate and sugar molecules, but the key to DNA is the "steps" made of pairs of nitrogenous bases locked together crosswise.'[40] Fifteen years after the event, Watson published a personal version of the story of the discovery. In *The Double Helix* (1968), Watson talks about noticing spiral staircases, and of thinking that the structure of DNA might be like a spiral staircase. Watson admits:

> [t]*he idea* [of helices] *was so simple that it had to be right. Every helical staircase I saw that weekend in Oxford made me more confident that other biological structures would also have helical symmetry. For over a week I pored over electron micrographs of muscle and collagen fibers, looking for hints of helices.*[41]

Ronald Giere explains: '[h]ere we would say that Watson was using the spiral staircase and the A-helix as analogue models for the DNA molecule [. . .] One might also say he was modeling the structure of DNA on that of the a-helix or a spiral staircase.'[42] The double helix structure of DNA did not, of course, arise entirely out of a serendipitous encounter with a spiral stair on the grounds of Oxford University. Its shape emerged gradually out of previous research dating back to the nineteenth century and through successive discoveries by Oswald Avery, Linus Pauling, Erwin Chargaff, and Maurice Wilkins and Rosalind Franklin.[43] The structure was almost immediately accepted because it was supported by the experimental data and connected logically to previous discoveries. Aesthetics also informed its visualisation and quite likely fostered its acceptance. The double helix model, Watson said was 'too pretty not to be true.'[44] Crick credits 'its intrinsic beauty' to its immediate resonance in the sciences.[45]

Francis and Crick's original 1953 paper was illustrated by a drawing of a double helix by Crick's wife Odile, with the cautionary caption: 'This figure is purely diagrammatic'.[46] Subsequently, a more developed physical model was cast in brass and famously photographed by Antony Barrington Brown.[47] In turn, that model was superseded by

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more refined versions made at King's College, London, including a space-filling model with Van der Waals surfaces by Wilkins that has been widely disseminated. The double helix diagram of DNA is an idea whose communication is achieved via a series of media and models, the most recent of which are digital animations that attempt to capture it in motion. Francis and Crick were at pains to emphasise the translation that had taken place in the process of its entry into the discipline. The DNA diagram belongs to the historic engagement science has had with representational techniques – indeed, the development of techniques of visualisation and representation is as significant a force in the history of scientific knowledge as it is in architecture. In other words, the geometric structure of the double helix, known through mathematics via the stereotomic knowledge of the stonemasons of the seventeenth century, pre-dates and is a constructive agent in our knowledge of DNA and its workings.

'Prior to the discovery of DNA's double helical structure in 1953,' writes Linda Gretton, 'the term "double helix" was virtually nonexistent', yet the thing itself was very much present in architecture and, thus, in the public realm for centuries.[48] According to Friedrich Mielke, the double helical stair is an old Islamic device, found, for example, in the minaret of the Suq al-Ghash of Baghdad (902–08).[49] The double helix staircase in the tower of St. Editha's parish church in the town of Tamworth in Staffordshire, England – one of the earliest European examples – was built between 1380 and 1420 *[2]*. There are numerous Renaissance examples, the most well-known being the grand double helix staircase at the Château de Chambord in the Loire Valley, France (1515–25), built by Domenico da Cortona for François I, most likely following drawings by Leonardo da Vinci.[50] Leonardo da Vinci drew numerous double spiral staircases for military applications (for example, in a drawing of a corner tower of a fortress from around 1488).



2 The stair of St. Editha's church in Tamworth, Staffordshire, England.

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Donato Bramante's two spiral staircases at the Vatican Museum (1502) and the double helical ramps at Pozzo di San Patrizio (St. Patrick's Well) in Orvieto near Florence designed by Antonio da Sangallo (1527–37) are well known.[51] Jacopo Barozzi da Vignola designed numerous helical staircases in the 1560s.[52]

The *Scala Leonardesca* was argued by Palladio in Book I of his treatise *The Four Books of Architecture* (1570) as a solution for multi-family housing in Venice, since it resolved the challenge of small lots and multiple families desiring distinct ceremonial entries. Nicolas Le Camus de Mézières in the eighteenth century and William Bouwens van der Boijen in the nineteenth similarly used it as an effective device for achieving separation between social groups without increasing the stair's footprint.[53] Its popularity, however, was likely due to its theatrical form and its capacity to showcase the skills of the stonemason. There is, Sandra Blutman writes, 'a kind of magic' in the helical stair that 'is not dispelled by the most elaborate technical explanation of the structural principle on which the form is based and still prompts one to wonder how it stays up.'[54] Sebastiano Serlio declared helical staircases such arduous structures that any architect who has not completely mastered the traditional ones 'should not even try to design those which are more complex.'[55] Robin Evans describes elements such as unsupported flying and curvaceous stairs as 'magnificent demonstrations of stereotomy' that in the seventeenth and eighteenth centuries were increasingly seen as 'deformed, showy tricks that had issued from stonecutting' for they lay outside the classical order.[56]

The retreat in the eighteenth century from complex geometries diminished the opportunities stonemasons had for exercising their integrated and applied knowledge of the physics and geometry of stone structures and correlates with the emergence of the engineer, the architect and the mathematician. In the last half of the eighteenth century, the knowledge of stereotomy moves from projective to topological geometry and is taken up and furthered in mathematics, rather than in architecture. The helicoid, after the plane and the catenoid, was the third minimal surface to be known and was discovered by Jean Baptiste Meusnier in 1776, just four years after this branch of mathematics was founded by the publication of Lagrange's 'Essai d'une nouvelle méthode pour déterminer les maxima et les minima des formules intégrales indéfinies'. Gaspard Monge's *Géométrie Descriptive* (1795) advances the study of geometric surfaces in engineering. Gauss, J. B. Listing, Poincaré, Brouwer, and others drove topology into many other scientific disciplines.

It is irrefutable that the knowledge of geometry reached by master stone-cutters exceeded and pre-dated the formulation of the helicoid as a topographic surface in mathematics. The master stonemasons:

> [...] *did not know the name of the surfaces; nor the classifications of ruled surfaces (it was sufficient for him to distinguish between developable and warped); nor terms like 'plane director', 'asymptotic plane', 'axis' or 'vertex of the surface', and so forth. However, he did know how to distribute the courses to originate joints that were either straight or curved lines; for double curvatures, he identified where they were concave or convex and could, therefore, correctly identify the different sections that would be generated by a plane on such a warped surface thanks to his empirical knowing. He was capable of proposing different solutions to guarantee a smooth transition between surfaces without knowing the tangential conditions that could be applied.*[57]

Stereotomic design requires theoretical knowledge of the surfaces that make up the bodies as well as knowledge of methods of representation appropriate to the representation of surfaces and lines in the plane or in space. Stereotomic knowledge anticipates the contemporary theory and tools of descriptive geometry. Mathematical objects discovered in the nineteenth century such as the Möbius strip and Klein Bottle, Giuseppe Fallacara observes, already have their morphological analogies in elements such as the stringer of helicoidal stairs called 'limon' in French technical literature.[58]

The mathematician's knowledge of the double helix, via the stonemason, has been crucial to its implementation as a model for DNA, yet, while in the fields of biology and mathematics, visualisations of DNA became more differentiated as attempts were made to model and manipulate DNA in motion and in combination, in the popular imaginary the diagram became more generalised, literal and static.[59] The image of the double helix gradually shifts from one of didactic instruction to 'the icon



3

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for the communication of a generalized message.'[60] The double helix became, according to the art historian and science writer Martin Kemp, 'the image epitomizing the biological sciences'[61] and soon after was elevated to icon status, finding its place 'not only in the halls of science but in the galleries of art, fashion, and pop culture.'[62] It has become a generic image of scientific endeavour and promise and this is most evident in buildings for science.

Kisho Kurokawa famously made helical structures the basis of an entire city in his unrealised Helix City project of 1961, where the helix functions as an icon of information transfer and biological processes. Other architects confined their double helixes to stairs: Jean Tschumi's lean double-helix stair for Nestlé's Headquarters (1960), Vevey, Switzerland; the central stair at the Chemistry Department (1961) at the University of Reading by Easton Robertson Cusdin Preston & Smith; the external stair at the Faculté des Sciences at the Université de Paris by Edouard Albert (1965) *[3]*, and the main stair at the Lemieux library at Seattle University (1966) by John Maloney of Maloney, Herrington, Freesz and Lund.[63]

The double helix stair becomes commonplace in the 1990s as investment in new research buildings in the life sciences increased exponentially. The architect of the Molecular Biology Research Building (1995) at the University of Illinois told a reporter that '[t]he first thing we did was ask the university for books on genetic engineering.'[64] The outcome is a gaudy double helix stair with lights embedded in its treads. At the BC Cancer Agency Research Centre (2004) in Vancouver the architects declare that the twelve-storey central stair 'allows scientists to inhabit an oversized DNA spiral while enhancing informal interaction.'[65] The stair features on the cover page of the November 2012 issue of the journal *Nature Biotechnology*.

For their 2007 design for the exterior of the Institute of Molecular Genetics for the Czech Academy of Science, architects Jan Sesták and Marek Deyl of the Prague-based firm Studio P-H-A appended circular steel emergency stairs 'designed in a shape which represents the symbol of genetic inheritance – the DNA double helix.'[66] The Nijmegen Centre for Molecular Life Sciences in the Netherlands (2000) and the Technology Center of Medical Science, Berlin (2009) feature double helical staircases. At the EMBL Advanced Training Centre in Heidelberg, Germany (2010) the entire building, which is circular in plan 'is inspired by the structure of the double helix, the carrier of genetic information, DNA'[67] *[4]*. Scientist and philanthropist Klaus Tschira reportedly drew the first design, entrusting its formal resolution to architects Bernhardt + Partner. The architects took up the metaphor with enthusiasm, describing the ramps as 'two functional strands' and the interconnecting walkways as 'rungs'.[68] The architects:

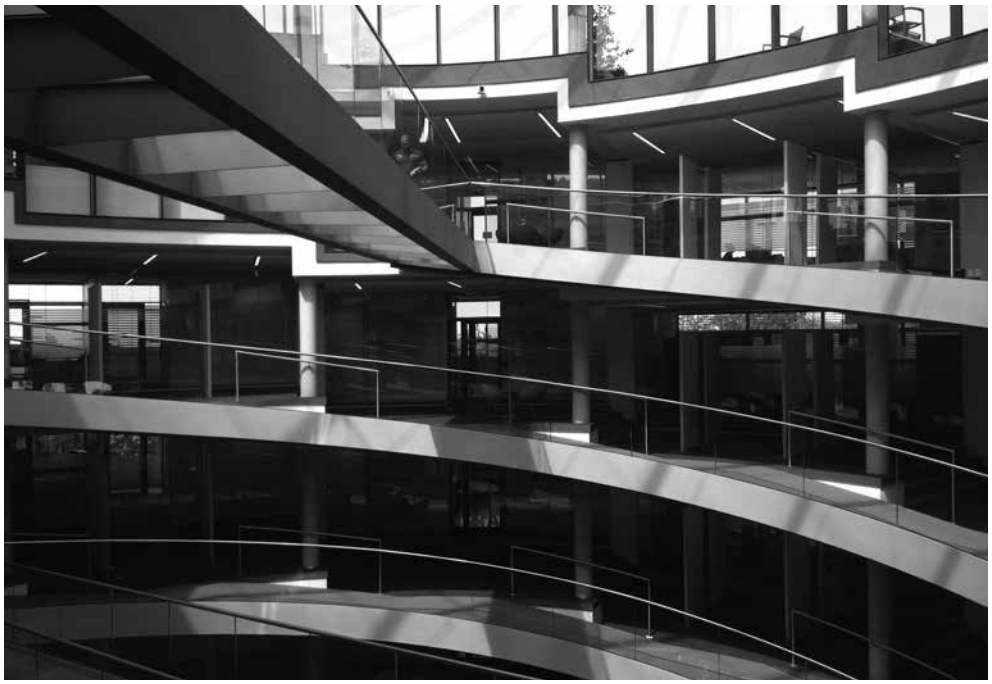
> [...] *believed that the molecular biologists using the building would find it easy to comprehend the structure, as all the focal areas of their research ultimately revolve around DNA, with whose configuration they are intimately acquainted.*[69]

In reality the scientists find it discombobulating and its realisation required tortuous planning and an inflated budget.

The re-appearance in contemporary architecture of the double helical stair could be argued as a revival of earlier precedents, such as the famous example at the Château de Chambord. The identification of the double helix with the most iconic diagram of twentieth-century science, however, obscures prior architectural associations – as suggested by architect Ken Woolley's recollection that his proposal to include a double helix stair rising through the six-storey Garvan Institute of Medical Research in Sydney (1993) produced in his clients 'a kind of relief that the building (would) be about them, not (me).'[70]

3 The external stair at the Faculté des Sciences at the Université de Paris by Edouard Albert (1965)

4 Atrium of the EMBL Advanced Training Centre in Heidelberg, Germany (2010)



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Although the built version is only a single helix, for Woolley 'the association is blindingly obvious – the moment you hear that you will design a laboratory for genome research, or any aspect of modern biological science for that matter.'[71]

For Actelion, a small and specialised pharmaceutical company,[72] the architects Herzog & de Meuron designed an office building on the outskirts of Basel that has been widely published and, in 2010, a laboratory building that has not.[73] Not unusually, Actelion's website features an image of the DNA molecule. Worried about its corporate identity, the consultancy Interbrand was commissioned to carry out a scoping exercise that confirmed the widespread use of a small pool of generic scientific motifs. So for its 2011 Annual Report, Actelion employed Onformative, a young Berlin-based studio specialising in 'generative design solutions' – graphics and animations that employ custom software and computer code.[74] Onformative developed the Actelion Imagery Wizard, a tool that in their words 'enables the generation of a unique, in-itself homogeneous graphic image world out of heterogeneous visual material.'[75] Essentially, the tool maps points, lines and curves over any existing image. In the process it makes a new image that appears more technical, precise and 'scientific' than the original.[76] There is no information of scientific use to Actelion's researchers in the web of lines and points generated by Actelion Imagery Wizard, but there is great value in its persuasive power. The project for Actelion won the Corporate Design Prize in 2011 for the best relaunch of a corporate design and Onformative's approach has won them considerable acclaim – directors Cedric Kiefer and Julia Laub co-authored *Generative Design*, a book that conveys their method and thinking. The 2012 English version of the book was published by Princeton Architectural Press *[5,6]*.

The potency of Onformative's design lies in its metaphoric relationship with DNA as code. The central dogma of molecular biology, as formulated by Crick in 1970, is that 'instructions' are passed on from DNA to RNA to protein and never in the other direction. DNA, it is argued, contains all the coded information (necessary and sufficient) to specify the appropriate folding of a polymer (RNA or protein) and its structural or catalytic function – or more simply genetic material contains a coded version of the organism itself.[77] So many scientists now contest this view that the field of 'biosemiotics' has arisen to put forward its case. Lewontin, for example, points out that 'first, DNA is not self-producing; second, it makes nothing; and, third, organisms are not determined by it.'[78] Contemplating what he calls the 'whole epistemological misery' of the DNA dogma, Jesper Hoffmeyer contends 'the cell interprets the DNA as a set of instructions', the cell is the doer not the DNA.[79] Although it is said that DNA produces proteins, it is the proteins (enzymes) that produce the DNA.[80]

Regardless of the complexity and nuance of the arguments between geneticists and epigeneticists, what is understood by a public rooted to the image



5a



5b

of DNA fostered by television's version of criminal forensics or sci-fi films such as *Gattaca* (which, not incidentally, features a single helical staircase in the apartment of one of the main characters, Jerome Morrow, a man with perfect DNA confined to a wheelchair after attempting suicide), is a kind of molecular genetic determinism. With that comes what Hoffmeyer has called *the fallacy of digitalism*, 'the more or less automatic preference for explanations that ascribe primacy to digitally coded information or see such information as an explanation bottom line.'[81]

The helical stair in the laboratory building designed by Herzog & de Meuron, features in Actelion's 2011 Annual Report as the backdrop to two photographs, one of the Chairman of the Board and the Chief Executive Officer, the other of the Board of Directors *[5,6]*.[82] It is arguable that the stair's *adaptive function* is its appearance in these photographs, where its presence asserts the direct translation from code to physical reality and back again. The photograph awaits coding by Actelion Imagery Wizard at the same time that the stair, and the human figures in front of it, are the result of the coding processes that Actelion Imagery Wizard and DNA produce. The ability of the helical stair, here and in other contemporary examples, to convey people between floors is, like the pendentives of San Marco, an exaptive secondary adaptation or by-product that serves merely to ease its progress past the scrutiny of clients and those overseeing construction budgets.

Conclusion

For Bruno Latour the rhetorical power of scientific representations, their persuasive capacity, lies in their mobility – their capacity to move across

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5 Onformative's graphics as featured in Actelion's 2011 Annual Report

6 Page of Actelion's 2011 Annual Report showing Herzog & de Meuron's helical stair



scientific fields.[83] As it moves across architecture, stonemasonry, mathematics, biological science and advertising, the double helix does not remain intact and unchanged, like a football passing from one player to another. It is framed by the multiple disciplinary lenses it has passed through. The question that preoccupies the epigeneticists, of the causal relationship between code and expression, has relevance here, for the relationship between representations and disciplines is similarly complicated. Observing that the double helix stair in contemporary architecture functions as a representation of a scientific representation is not necessarily to condemn architecture as a discipline to a secondary role in relationship to science. In an edited book examining the power and impact of scientific prose through the lens of Gould and Lewontin's essay – Gould wrote: '"Spandrels" succeeded because it developed a novel imagery – the picture of an architectural spandrel itself – that turned out to be striking, easy to understand, simple to convey and, above all, ripe for extension'.[84] The spandrel's impact on the field of biology was such that palaeontologist David Raup told Gould, '[w]e have been all been spandrelized.'[85] Yet, this detour through evolutionary theory has barely affected its architectural legacy or contemporary use, indeed, few architects would be aware that dictionaries now refer to its architectural and its biological meanings. The helical stair was, likewise, an architectural object that gained success in science, yet its architectural history and currency have been transformed by this event.

Architecture has the capacity to re-translate and (re)present concepts, images, ideas and ideals. In this sense it may be thought of less as a spatial and generative art and more as an art of exaptation. This would seem to be particularly the case in the capacity for architecture to feast upon biology and promote biotechnology, pharmaceutical and medical research institutes. The phenomenon raises a number of pertinent questions about architecture's historic and current relationship to the visual iconography of science, and about the relationship between disciplines and representational material more broadly. If anything, it complicates and deepens architecture's current attempts at biomimicry, revealing the contested and fluid status of diagrams presumed to represent biological knowledge and their transformation under the gaze of another discipline. Such a position would not be at odds with Foucault's idea of disciplinarity as the framing of logics applied to content. In this sense architecture itself becomes something of a spandrel.

In *The Order of Things,* Foucault announces that Man 'is only a recent invention'.[86] It is not that the contemporary human body nor its organs are physically different from those of earlier centuries, but that they are thought of and engaged in radically different manners. Foucault's argument is that the ideals, images and expressions of the body and its organs were translated in different ways in different contexts. Foucault's account of disciplines

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in *Discipline and Punish* suggests a very similar negotiation of ideals, images and expressions as they migrate and are appropriated from one discipline to another. Disciplines emerge in respect to and are altered by the objects of their fixation, just as the objects focused upon are altered by, disciplined by, the disciplines that frame and reframe, classify and translate them. It is not that the spandrels and the helical stair are physically different from when they emerged. Their radical difference is that they are thought afresh in architecture and biology largely because of their translations between these disciplines. These objects of architecture are the theoretical organs of biology; and vice versa. In this sense the objects are taken up not as adaptations within the discipline but as exaptations that reframe the disciplines themselves.

Notes

1. Paul A. Bove, 'The End of Humanism: Michel Foucault and the Power of Disciplines', *Humanities in Society*, 3 (1980), 23–40. Refer also to Jan Goldstein, 'Foucault Among the Sociologists: The "Disciplines" and the History of the Professions', *History and Theory* 23, no. 2 (1984), 170–92.
2. Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences*, trans. by Alan Sheridan (New York: Vintage, 1973), pp. xii–xiii.
3. Stephen Jay Gould and Richard C. Lewontin, 'The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme', in *Philosophy of Biology: An Anthology*, ed. by Alex Rosenberg and Robert Arp (Sussex: Wiley-Blackwell, 2010), pp. 125–36. This is a reprint of Stephen Jay Gould and Richard C. Lewontin, 'The Spandrels Of San Marco And The Panglossian Paradigm: A Critique Of The Adaptationist Programme', in *Proceedings of the Royal Society of London* B, 205, no. 1161 (1979), pp. 581–98.
4. Gould and Lewontin, 'Spandrels', p. 126.
5. Fuller's geodesic domes and tetrahedral structures were referred to by virologists modelling spherical viruses such as polio in the 1950s.
6. Biomimicry Institute, <http://www.biomimicryinstitute.org/about-us/> [accessed 6 March 2014].
7. The Vertebrae Staircase (2013) by Andrew McConnell is inspired by a whale's spine. Tom Wiscombe's *Dragonfly* (2007) installation at SCI-Arc is named after the source of its structural model. Flectofin (2011), a louvre system developed by Simon Schleicher at the University of Stuttgart, emulates the Strelitzia flower.
8. Gould and Lewontin, 'Spandrels', pp. 125–26.
9. For a fuller description of San Marco refer to Deborah Howard, *The Architectural History of Venice* (Singapore: B. T. Batsford, 2002), pp. 17–31.
10. Howard, *The Architectural History of Venice*, 26.
11. Gould and Lewontin, 'Spandrels', p. 125.
12. Richard Dawkins, *The Selfish Gene* (New York City: Oxford University Press, 1976).
13. Charles Darwin, *On The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* (London: John Murray, 1859). First edition page references are to a facsimile of the first edition with an introduction by Ernst Mayr (Cambridge, MA: Harvard University Press, 1966).
14. We will not reproduce a history of Darwin's thoughts as this has been done extensively elsewhere. Reference is to: Peter J. Bowler, *Charles Darwin: The Man and His Influence* (Cambridge: Cambridge University Press, 1996); Adrian Desmond and James R. Moore, *Darwin: The Life of a Tormented Evolutionist* (New York: W. W. Norton & Company, 1991); Edward Manier, *The Young Darwin and His Cultural Circle: A Study of Influences which Helped Shape the Language and Logic of the First Drafts of the Theory of Natural Selection* (Dordrecht, Holland and Boston: D. Reidel, 1978); and Dov Ospovat, *The Development of Darwin's Theory: Natural History, Natural Theology, and Natural Selection, 1838–1859* (Cambridge and New York: Cambridge University Press, 1981).
15. David R. Oldroyd, 'Darwin's Theory of Evolution', *Biology and Philosophy* 1 (1986), 133–68, (p. 135). Oldroyd offers multiple qualifications to this statement.
16. Oldroyd, 'Darwin's Theory of Evolution'. The reduction of Darwin's theory to a small number of propositions was also attempted by Antony Flew, 'The Structure of Darwinism', *New Biology* 28 (1959), 25–44.
17. Darwin considered natural selection to act at the biological level of the individual organism, though there are instances within Darwin's studies of social insects in *The Origin of Species* where he suggested that the phenomenon of altruistic behaviour of hive-bees and ants might be accounted for in regarding a hive as a unit of selection; Darwin, *The Origin of Species,* p. 472.
18. Peter J. Bowler, *The Eclipse of Darwinism: Anti-Darwinian Evolution Theories in the Decades around 1900* (Baltimore: Johns Hopkins University Press, 1983).
19. Gould and Lewontin, 'Spandrels', p. 125.
20. Julian Huxley coined the phrase 'eclipse of Darwinism' in his 1963 survey of evolution theory *Evolution: The Modern Synthesis* to describe the situation of biology before the conjoining of selectionism and genetics. Julian Huxley, *Evolution: The Modern Synthesis* (London: Chatto & Windus, 1963).
21. Stephen Jay Gould, 'The Hardening of the Modern Synthesis', in *Dimensions of Darwinism*, ed. by Marjorie Grene (Cambridge: Cambridge University Press, 1983), pp. 71–93.
22. Stephen Jay Gould, 'The Ontogeny of Sewall Wright and the Phylogeny of Evolution' (Essay Review of William B. Provine, *Sewall Wright and Evolutionary Biology*) *Isis*, 79 (1988), 277.
23. Gould and Lewontin, 'Spandrels', p. 126.
24. Dawkins, *The Selfish Gene*, p. 130.
25. Gould himself would reflect (with some humour) on the uses of the term spandrel in the later work: Stephen Jay Gould, 'Fulfilling the Spandrels of World and Mind', in *Understanding Scientific Prose*, ed. by Jack Selzer (Madison, WI: University of Wisconsin Press, 1993), pp. 326–34.
26. Stephen Jay Gould and Elisabeth S. Vrba, 'Exaptation: A Missing Term in the Science of Form', *Paleobiology* 8, no. 1 (1982), 4–15.
27. Gould and Vrba, 'Exaptation', p. 6.
28. Gould and Vrba, 'Exaptation', p. 6.
29. Stephen Jay Gould, 'The Exaptive Excellence of Spandrels as a Term and Prototype', *Proceedings of the National Academy of Science, USA* 94 (1997), 10750–10755.
30. Gould, 'Exaptive Excellence', p. 10750.
31. Gould, 'Exaptive Excellence', p. 10751. See also for example, Daniel C. Dennett, *Darwin's Dangerous Idea: Evolution and the*

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Meanings of Life, (London: Penguin Books, 1995). Dennett not only argues that Gould and Lewontin's spandrel is, more correctly, a pendentive, he proposes that other architectural features such as corbels or squinches could have served the role of the pendentives in San Marco basilica. Dennett concludes that the pendentives are, therefore, 'selected' (albeit for an aesthetic purpose) and cannot be relegated to mere by-products.

32. Gould, 'Exaptive Excellence', p. 10751.
33. Gould, 'Exaptive Excellence', p. 10751.
34. Gould, 'Exaptive Excellence', pp. 10750 and 10754.
35. Mark, 'Evolution and Architecture', p. 383.
36. Mark, 'Evolution and Architecture', p. 384.
37. Jesse Reiser and Nanako Umemoto, *Atlas of Novel Tectonics* (Princeton NJ: Princeton Architectural Press, 2006), p. 194.
38. Reiser and Umemoto, *Atlas of Novel Tectonics*, p. 194.
39. James D. Watson and Francis H. Crick, 'A Structure for Deoxyribose Nucleic Acid', *Nature* 171 (1953), 737–38 (p. 737).
40. Anna Hodson, *Essential Genetics* (Bloomsbury: London, 1992), p. 97.
41. James Watson, 'The Double Helix: The Discovery of the Structure of DNA, Part 2', *Atlantic Monthly* 221 (1968), pp. 91–117 (p. 114).
42. Ronald N. Giere, *Understanding Scientific Reasoning* (New York: Harcourt Brace Jovanovich, 1991), p. 23.
43. In 1943, Oswald Avery proved that DNA carries genetic information. In 1948, Linus Pauling discovered that many proteins take the shape of an alpha helix, spiralled like a spring coil. In 1950, biochemist Erwin Chargaff found that the arrangement of nitrogen bases in DNA varied widely, but the amount of certain bases always occurred in a one-to-one ratio. In 1952 Maurice Wilkins and Rosalind Franklin found that X-ray diffractions images of DNA had the characteristics of a helix.
44. Watson, 'The Double Helix', p. 114.
45. Francis Crick, 'The Double Helix: A Personal View', *Nature* 248 (1974), 766–69, (p. 768).
46. James D. Watson and Francis H. Crick, 'A Structure for Deoxyribose Nucleic Acid', *Nature* 171 (1953), 737.
47. Barrington Brown's photos were taken for, but never used, by *Time* magazine. Picture reproduced here in 'Obituaries: Antony Barrington Brown', *The Telegraph*, 14 February (2002), available online: <http://www.telegraph.co.uk/news/obituaries/culture-obituaries/9082749/Antony-Barrington-Brown.html> [accessed 3 April 2014].
48. Linda Burak Gretton, 'The Rhetorical Helix of the Biotechnology and Pharmaceutical Industries: Strategies of Transformation Through Definition, Description and Ingratiation', *Business Communication Quarterly* 72, no. 238 (2009), 242.
49. Friedrich Mielke, *Die Geschichte der Deutschen Treppen* (Berlin: Wilhelm Ernst & Sohn, 1966), p. 42.
50. A detailed discussion of the debates around the authorship of the spiral staircase at Chambord can be found in Hidemichi Tanaka, 'Leonardo da Vinci, Architect of Chambord?', *Artibus et Historiae* 13, no. 25 (1992), 85–102. Tanaka concludes that da Vinci drew much of the plans for Chambord, including the spiral staircase, and that after his death these were taken over and modified by Domenico da Cortona and the French masons who carried out the construction of the chateau in the course of subsequent decades.
51. John Templer, *The Staircase: Histories and Theories* (Cambridge, MA: The MIT Press, 1992).
52. In vaulted masonry at the Isolani Palace and the Boncompagni Palace (1560-68), and in stone at the Town Hall of Castro sometime after 1568.
53. Nicolas Le Camus de Mézières' design for the circular market the Halle au Blé, Paris (1763–67), included a pair of double-helix stone stairs to separate administrative personnel from the merchants' trading grain and flour. At the Crédit Lyonnais headquarters in Paris, built between 1876 and 1883, the grand double-helix stair around which the Dutch architect William Bouwens van der Boijen organised the entire building, enforced a strict hierarchy between management and employees.
54. Sandra Blutman, 'Geometical Staircases', *Journal of Architectural Historians* 26, no.1 (1967), 35–39, (p. 37).
55. Sebastiano Serlio, I Sette libri dell'architettura treatise (1584), quoted in A. Barbieri, A. Di Tommaso, R. Massarotto, 'Helical masonry vaulted staircase in Palladio and Vignola's architectures', in *Proceedings of the First International Congress on Construction History*, Madrid, 20–24 January 2003, ed. by S. Huerta, Madrid: I. Juan de Herrera, SEdHC, ETSAM, A. E. Benvenuto, COAM, F. Dragados, (2003), 300–18 (p. 300).
56. Robin Evans, *The Projective Cast* (Cambridge, MA: MIT Press, 2000), p. 213.
57. Rocío Carvajal Alcaide, 'Stairs in the Architecture Notebook of Juan de Portor y Castro: An Insight into Ruled Surfaces', *Nexus Network Journal* 13 (2011), 646–47, available online: <http://www.springerlink.com/content/x8651g74628rm381/fulltext.pdf> [accessed 23 October 2012].
58. Giuseppe Fallacara, 'Digital Stereotomy and Topological Transformations: Reasoning about Shape Building', *Proceedings of the Second International Congress on Construction History* 1, Cambridge University (2006).
59. See, for example, the discussions and diagrams in: Ronald D. Vale and Ronald A. Milligan, 'The Way Things Move: Looking under the Hood of Molecular Motor Proteins', *Science* 288, no. 5463 (2000), 88–95; Barbara Saccà and Christof M. Niemeyer, 'DNA Origami: The Art of Folding DNA', *Angewandte Chemie International Edition in English* 51, no. 1 (2012), 58-66; Jeffrey Birac, William Sherman, Jens Kopatsch, Pamela Constantinou, Ned Seeman, 'Architecture with GIDEON, a Program for Design in Structural DNA Nanotechnology', *Journal of Molecular Graphics and Modelling* 25, no. 4 (2006), 470–80.
60. Martin Kemp, 'The Mona Lisa of Modern Science', *Nature* 421 (2003), 416–20 (p. 416).
61. Kemp, 'Mona Lisa', p. 416.
62. Linda Burak Gretton, 'The Rhetorical Helix', p. 242.
63. The Lemieux library underwent a renovation that erased much of the original structure but the stair has survived.
64. Joan Giangrasse Kates, 'Like a DNA Molecule, Staircase is 1 of a Kind', *Chicago Tribune*, 3 October 1995, p. 2, available online: <http://articles.chicagotribune.com/1995-10-03/news/9510030036_1_genetic-engineering-chromosome-dna-molecule> [accessed 9 September 2012].
65. 'BC Cancer Research Centre,' Henriquez Partners Architects: <http://henriquezpartners.com/work/bc-cancer-research-centre/> [accessed 31 August 2012].
66. 'IMG', *Studio P-H-A*: <http://www.studiopha.cz/en/project/img-building> [accessed 24 October 2012].
67. 'New Training and Conference Centre for the Life Sciences at EMBL in Heidelberg', *EMBL Press Release*, 9 March 2010,

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available online: <http://www.embl.de/aboutus/communication_outreach/media_relations/2010/100309_Heidelberg/>[accessed April 1 2013].
68. 'RSL Lightprojects', *1 magazine, Bernhardt + Partners, ATC Heidelberg*, 38, available online: <http://www.rsl.de/en/magazine/lightprojects-01/architekten-bernhardt-partner/>[accessed 1 April 2013].
69. 'RSL Lightprojects', p. 38.
70. Ken Woolley, email message to author, 20 October 2012.
71. Ken Woolley, email message to author, 21 October 2012.
72. Actelion's three drugs for the treatment of pulmonary arterial hypertension (PAH) target molecular G-protein coupled receptors, products that would not have been possible without knowledge of DNA.
73. The laboratory building spans two allotments with two street addresses. The first stage at Gewebestrasse 06 has been occupied since 2010, the second stage at Hegenheimermattweg 86 appears to be almost completed yet remained unoccupied at the end of 2012 when the author visited the building. Actelion is located in the Bachgraben quarter in the planned 'I-Park'.
74. Onformative are responsible for a multi-touch installation for the Max Planck Institute that reveals how Max Planck institutes collaborate with each other and with their international partners. The international flow of ideas is represented metaphorically by streams of energy particles, being continuously exchanged between the institutions. For this visualisation, Onformative analysed over 94,000 publications, from more than 16,000 institutions over the last ten years from SciVerse Scopus.
75. 'Actelion Imagery Wizard', *Onformative: A Studio for Generative Design*, available online: <http://www.onformative.com/work/actelion-imagery-wizard/> [accessed 1 November 2012].
76. Essentially Actelion Imagery Wizard takes an analogical image, such as a photograph, and translates it into computer code that can be manipulated and re-presented as lines and dots resembling highly technical and generative information. There is no information of scientific use to Actelion's researchers in the web of lines and points generated by Actelion Imagery Wizard, but there is great value in its persuasive power. The project won the Corporate Design Prize in 2011 for the best relaunch of a corporate design and Onformative's approach has garnered them considerable acclaim. Onformative's directors, Cedric Kiefer and Julia Laub, co-authored *Generative Design (2012)*, a book that conveys their method and thinking published by Princeton Architectural Press. 'Actelion Imagery Wizard: A Set by Onformative', available online: <http://flickeflu.com/set/72157627278219485> [accessed 1 November 2012].
77. Francis Crick, 'The Central Dogma of Molecular Biology', *Nature* 227 (1970), 561–63.
78. Richard Lewontin quoted in Hernán A. Burbano, 'Epigenetics and Genetic Determinism', *História, Ciências, Saúde – Manguinhos* 13, no. 4 (2006), 851–63, (p. 857).
79. Jesper Hoffmeyer, 'Genes, Development and Semiosis', in *Genes in Development: Re-reading the Molecular Paradigm*, ed. by Eva Neumann-Held and Christoph Rehmann-Sutter (Durham: Duke University Press, 2006), p. 157.
80. Lewontin, 'Epigenetics', p. 857.
81. Jesper Hoffmeyer, 'The Central Dogma: A Joke that Became Real', *Semiotica* 138, no. 1/4 (2002), 1–13.
82. 'Turning Research into Results', Actelion Annual Report, available online: <http://www.actelion.co.uk/documents/corporate/annual_reports/AR_Actelion_Current_E.pdf> [accessed 24 December 2011].
83. Bruno Latour, 'Drawing Things Together', in *Representation in Scientific Practice*, ed. by Michael Lynch and Steve Woolgar (Cambridge, MA: MIT Press, 1990), pp. 26–27.
84. Gould, 'Fulfilling the Spandrels of World and Mind', in *Understanding Scientific Prose*, ed. by Jack Selzer (Madison, WI: University of Wisconsin Press, 1993), p. 333.
85. Stephen Jay Gould, 'Fulfilling the Spandrels of World and Mind', p. 325.
86. Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Vintage, 1973), pp. xxiii. Foucault would suggest the same about sex in his *The History of Sexuality*. Michel Foucault, *The History of Sexuality Volume I: An Introduction*, trans. by R. Hurley (New York: Pantheon, 1980), pp. 103–05.

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Actelion Imagery Wizard by Onformative, 5
Actelion Pharmaceuticals Ltd., 6
Theodore Cook, *The Curves of Life* (1914), fig. 325, 'Double Spiral Staircase in Tamworth Church Tower', 2
Adam Katz Sinding, 3
Chris L. Smith, 4
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Dr Chris L. Smith is the Associate Professor in Architectural Design and Techné in the Faculty of Architecture at the University of Sydney. Chris has lectured internationally. His research is concerned with the interdisciplinary nexus of philosophy, biology and architectural theory. He has published on the political philosophy of Gilles Deleuze and Félix Guattari; technologies of the body; and the influence of 'the eclipse of Darwinism' phase on contemporary architectural theory. His recent work, *Architecture in the Space of Flows* was a book co-edited with Professor Andrew Ballantyne (London and New York: Routledge, 2012). Presently Chris is concentrating upon an Australian Research Council Grant research project with Professor Sandra Kaji-O'Grady focussed on the architectural expression of scientific ideals in bio-medical laboratories.

Professor Sandra Kaji-O'Grady is Dean and Head of Architecture at the University of Queensland. She researches in the architectural humanities, with a focus on the transfer of ideas and techniques between contemporary fine arts and architecture, and architecture and the experimental sciences. Her work has been published in leading journals including the *Journal of Architecture*, *The Journal of Architectural Education*, *Architecture &*, and *le Journal Spéciale'Z*. She has won several competitive external research grants, including the current grant from the Australian Research Council with Dr Chris Smith. Sandra curated the 2013 National Conference of the Australian Institute of Architects with John de Manincor and is a regular contributor to the professional design press.

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