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A Sketch of the Universe – the Visual Influences of D’Arcy Thompson’s *On Growth and Form*

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Abstract

D’Arcy Thompson’s ground-breaking book *On Growth and Form* (1917) pioneered the science of mathematical biology. Its literary qualities have been frequently commented upon but arguably more influential have been its illustrations, particularly the famous transformation diagrams. This article discusses the origins and context of these iconic images, exploring D’Arcy Thompson’s own artistic and scientific interests, the long development of his controversial theories and the other collaborators involved, including illustrators Doris MacKinnon and Helen Ogilvie. It explores the various influences that the images have had in science, geography and particularly in art. Many notable artists have been drawn to the images and visual analogies of D’Arcy Thompson’s work, and the article concludes by describing examples ranging from the early graphic work of Henry Moore to the illustrative exercises created by Richard Hamilton and Victor Pasmore for their pioneering Basic Design Course, and on to current artists including Lindsay Sekulowicz and Gemma Anderson.

Keywords: D’Arcy Thompson, natural history, mathematical biology, natural patterns, morphology, scientific visualisation

Article

For the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty (Thompson 1917: 778-9).

On Growth and Form is one of the key works at the intersection of science and the imagination. Hailed by Stephen Jay Gould as ‘the greatest work of prose in twentieth century science’ (Gould 1992: ix), it is a book that has inspired scientists, artists and thinkers as diverse as Alan Turing, C. H. Waddington, Claude Lévi Strauss, Jackson Pollock and Norman Foster. It pioneered the science of biomathematics, and its influence in art, architecture, anthropology, geography, cybernetics and many other fields continues to this day. This article aims to chart the book’s development, with particular attention to its iconic illustrations (Figure 1), and look at some of the extraordinary interdisciplinary influences they have had.

D’Arcy Wentworth Thompson was born in Edinburgh in 1860. His father was Professor of Greek at Queen’s College, Galway and the young D’Arcy inherited his love of classics, while his passion for natural history was inspired by his grandfather and one of his early teachers. He was encouraged to join the Edinburgh Naturalists’ field club, and it was to them that he gave his first public lecture, on micro-organisms called Foraminifera – a topic that would continue to fascinate him later in life.

D’Arcy entered the University of Edinburgh in 1878, intending to pursue a medical degree. One of his tutors was the marine zoologist Charles Wyville Thomson, and D’Arcy was given the opportunity to research specimens collected by him on the celebrated *Challenger* expeditions. As his interest in biology developed, D’Arcy decided to give up medicine and pursue a degree in Natural Science at Cambridge. Graduating with First Class Honours in 1883, he took up a position as junior demonstrator in Physiology with Professor Michael Foster, who would also become a close friend and confidante.

Just over a year later, D’Arcy was given the opportunity to become a university professor at the age of just 24. University College in Dundee had opened to

students in 1883 and although small was eager to expand. In 1884, a chair in biology was founded and awarded to D'Arcy, although he nearly didn't apply at all after learning that one of the other candidates was a young botanist called Patrick Geddes. Another great interdisciplinarian, Geddes would return to Dundee four years later to occupy a specially endowed chair of botany in D'Arcy's department, and the two men would become strong allies.

Student numbers started small (D'Arcy had just two students in his first class), but quickly started to grow, particularly after the founding of the Medical School in Dundee, which D'Arcy also did much to bring about. As well as teaching biology students and medical students, he was soon teaching arts students from the Dundee Training College, giving him a taste for interdisciplinary teaching which he evidently relished.

D'Arcy quickly acquired a reputation as a wide-ranging and increasingly eccentric teacher. His successor in Dundee, Alexander Peacock, recalled: 'Fortunate were all who saw him use sketches, bits of paper and string, and soap bubbles to explain the mathematics of the honeycomb, the nautilus shell and such like recondite things' (Peacock 1960). One of his later students in St Andrews recalled:

You didn't learn Zoology, but you were educated. You learned a smattering of Latin tags, and you appreciated the immeasurable beauty of the tiny Foraminifera, whose minute chalky shells make so much of our ocean floors. You learned of Aristotle's views on the sea-urchin: and the story of Palolo worms that congregate regularly in the warm seas off Samoa was a fairy story, not merely a useful reference to the migratory habits of the lower animals. Even anatomical differences had their beauty; the fourth tooth of a

crocodile fitting into a notch in the upper jaw, and not into a pit as in the alligator, was a fact to be gloried in, not merely to be learned. One felt that God was the Creator, and the wonder was never lost. One knew the beauty of the whole animal kingdom, and one was not limited to learning minute details about single animals (Harris nd).

D'Arcy admired the German universities for pursuing 'the idea of Universality of Knowledge' and he deplored the fact that in Britain 'our Universities are limited to the teaching of a somewhat meagre array of subjects, of what is obviously necessary, of what will attract what we choose to call a respectable number of students, in a word, of what may be said to pay (Thompson 1903: 9).' He passionately believed in giving students as great a breadth of knowledge as possible, telling them

if you dream, as some of you, I doubt not, have a right to dream, of future discoveries and inventions, let me tell you that the fertile field of discovery lies for the most part on those borderlands where one science meets another. There is a cry in the land for specialisation... but depend upon it, that the specialist who is not reinforced by a breadth of knowledge beyond his own specialty is apt very soon to find himself only the highly trained assistant to some other man... Try also to understand that though the sciences are defined from one another in books, there runs through them all what philosophers used to call the *commune vinculum*, a golden interweaving link, to their mutual support and interpretation (Thompson 1903: 9).'

It would be precisely this interweaving link that D'Arcy would demonstrate so powerfully in *On Growth and Form*. But with so much work involved in the running of his department, building up an extensive Natural History Museum in the College and teaching both day and evening classes, D'Arcy struggled to find time for his own research. The seeds of what would become *On Growth and Form* (published in 1917) were sown as early as 1889, when he wrote to one of his students: 'I have taken to Mathematics, and believe I have discovered some unsuspected wonders in regard to the Spirals of the Foraminifera! (Thompson 1889)'

D'Arcy became increasingly convinced that the laws of mathematics could be used to explain the growth and form of living organisms. But when he first shared these ideas with others, the response was discouraging. 'I confess I am not very much attracted by the line of work, and doubt if it's likely to be very fruitful,' his Cambridge mentor Michael Foster wrote in 1894. 'I suppose everyone must admit that there are 'laws of growth' ... but after all one does not feel sure how far this is really admitted' (Thompson 1958: 89-90). One of D'Arcy's assistants, Doris Mackinnon, later recalled that 'he had no thought of writing what was in his mind... he would walk up and down the Laboratory thinking his thoughts aloud and discussing his 'heresies' with her (Thompson 1958: 161).' It was 1908 before he published anything detailed on the topic: a paper in *Nature* on 'The Shape of Eggs and the Causes which determine them' (Thompson 1908). In 1911 he raised the subject at the British Association meeting in Portsmouth, claiming that 'the form of an object is a 'diagram of Forces',— in this sense, at least, that from it we can judge or deduce the forces that are acting or have acted upon it' (Thompson 1911a: 423). This powerful visual metaphor, restated in *On Growth and Form*, would become one of his most influential ideas.

By that time he had already been asked by Cambridge University Press to write what he initially described as ‘a tiny book... on Growth and Form (Thompson 1911b)’. After completing the first draft in 1915 he was forced to confess to the publishers that ‘the little book... has now turned out to be a work on a much larger scale (Thompson 1915a)’. Partly due to wartime paper shortages and partly due to D’Arcy’s insistence on numerous last-minute changes, the book was finally published in 1917.

In writing *On Growth and Form*, D’Arcy drew extensively on the resources available to him in Dundee, including the specimens in his Museum and the expertise of his colleagues – particularly the physics professor William Peddie and the engineering professor Thomas Claxton Fidler, both of whom reviewed his text in detail and contributed numerous ideas and illustrations. In particular, Fidler provided what would become some of the most famous illustrations in the book, at least for architects and engineers, in which he compares the skeletons of dinosaurs with the shape of cantilever bridges. Fidler was the author of an influential *Practical Treatise on Bridge Construction* (1887), and D’Arcy replied to him saying ‘I shall make no scruple about ‘lifting’ a greater part of them into my own text, giving you, of course, my grateful acknowledgement in the preface of the book’ (Thompson 1915b) which indeed he did.

Although not specifically credited, the increasingly far-reaching ideas of Patrick Geddes must also have played a part – by this time Geddes had turned to town planning and was drawing comparisons between cities and biological systems, dealing with issues of growth and form on a much broader level.

Like Geddes, D’Arcy was a great visual thinker and throughout *On Growth and Form* he not only describes the aesthetic qualities of nature’s patterns but uses

artistic analogies, comparing forms to those of the potter's wheel, for example, or the art of the glassblower. Although not an artist himself, D'Arcy had a great love of art and had many artist friends. In 1890 the Dundee Graphic Arts Association had been formed to promote the work of the city's professional artists, holding annual exhibitions from 1893. D'Arcy would certainly have known of their work through the active engagement of Geddes, who employed members of the Association to create a series of illustrations of plants in their natural settings to use as teaching aids for his students. It may have been through this scheme that Geddes first met one of the leading Dundee painters John Duncan, who became an important figure in Geddes's Celtic Revival movement in art and culture, acting as lead illustrator on Geddes's seasonal publication *The Evergreen*.

D'Arcy clearly shared Geddes's interest in supporting local artists. Soon after taking up his post he began employing James Eadie Reid, an illustrator for the *Dundee Advertiser*, to create drawings and diagrams for him. He also made the acquaintance of members of the Graphic Arts Association (of which he would later be made an Honorary Member), and in 1900 he commissioned one of its leading members to design a series of three decorative panels for his study. The artist was 21-year-old George Dutch Davidson, one of the most promising of the Celtic Revival artists in Dundee, acclaimed for his richly decorative symbolist drawings and embroidery designs. Davidson chose as his subjects Orpheus, Neptune and Juno, each surrounded by animals. Tragically, the young artist died before these could be carried out, leaving only a pencil study for the Orpheus panel (now in the collection of Dundee Art Galleries & Museums). In its use of the four elements, the twelve animals of the zodiac and possible references to the Golden Ratio, it shows that Davidson clearly understood D'Arcy's interests in natural history, mathematics and Classics,

and is arguably the first example of an artist drawing inspiration from D'Arcy's work, albeit seventeen years before the publication of *On Growth and Form*.

D'Arcy's interest in art also led to one of his specialist areas of study – the symbolic representation of animals in classical and ancient art. In 1898 he presented a paper to the Royal Society of Edinburgh on 'The Emblems of the Crab in Relation to the sign Cancer', one of a number of talks given on the subject. In 1896 Geddes wrote to him saying 'I am glad to see that you are holding forth on Symbolism, and write to remind you of my suggestion that you should contribute a short paper to the Summer [issue of the] Evergreen on this subject (Geddes 1896).' Sadly D'Arcy never took Geddes up on this invitation.

With interests such as these, it is no surprise that many of the people whose work helped to shape *On Growth and Form* were also great interdisciplinary thinkers. Above all, Aristotle and Goethe were D'Arcy's biological heroes. It was Goethe who introduced the term 'morphology' to define the study of form in living organisms, although (as D'Arcy was quick to note) he 'ruled mathematics out of place in natural history (Thompson 1917: 2).'

Other influences were of more artistic significance. They included Ernst Haeckel, the German biologist whose extraordinary illustrations of radiolaria in *Art Forms in Nature* (published 1899-1904) D'Arcy drew on liberally; indeed, he owned a set of plaster models of radiolaria based on Haeckel's artworks (Figure 2). Another important precursor was the art critic Theodore Cook, whose books *Spirals in Nature and Art* (1903) and *The Curves of Life* (1914) contained an admirably wide range of examples, although D'Arcy dismissed the 'mystical conceptions' of those like Cook who saw in the logarithmic spiral 'a manifestation of life itself' (Thompson 1942: 751), and bluntly dismissed the notion that the sequence of numbers dictating it

converged on the Golden Mean as ‘a mathematical coincidence, devoid of biological significance’ (Thompson 1917: 649).

Also of interest is D’Arcy’s friendship with the Danish artist and palaeontologist Gerhard Heilmann. Having abandoned his medical studies to become a professional artist, Heilmann’s series of papers on the origin of birds (published 1913-16) were dismissed by the biological establishment in Denmark but found an enthusiastic welcome from D’Arcy, who described them as ‘beautiful and original’ (Thompson 1942: 1080) and began a correspondence which led to Heilmann contributing several of the celebrated transformation diagrams in *On Growth and Form*.

Other sources are notable by their absence. By the time *On Growth and Form* was written, University College, Dundee had become part of the neighbouring University of St Andrews, though the relationship between them was extremely fractious. D’Arcy had been one of the principal catalysts of Dundee’s Medical School, which first brought the two institutions together, but he disliked the people at St Andrews he had to work with, particularly James Bell Pettigrew, the Professor of Anatomy & Medicine. In 1908, Bell Pettigrew published a lavishly illustrated three-volume book on *Design in Nature*, which D’Arcy must surely have read, but he makes no mention of it anywhere in *On Growth and Form*.

The most celebrated images in D’Arcy’s book are those illustrating his Theory of Transformations. D’Arcy had long believed that Darwin’s theory of evolution by natural selection could not explain all of the changes of form witnessed in nature, and he had first publicly proposed this at the 1894 British Association meeting in a paper called ‘Some Difficulties with Darwinism’, in which he suggested that laws of growth rather than natural selection were responsible for the myriad of forms and colours of

humming birds. Now, D'Arcy proposed that physical forces could cause a transformation from one species into another based on mathematical principles. He sought to demonstrate 'that discontinuous variations are a natural thing, that 'mutations' – or sudden changes, greater or less – are bound to have taken place' (Thompson 1942: 1095).

To demonstrate this D'Arcy drew on his knowledge of art, taking as his starting point Albrecht Dürer's work on geometry and proportion. In his *Four Books on Human Proportion* (published 1512-28), according to D'Arcy, 'the manner in which the human figure, features, and facial expression are all transformed and modified by slight variations in the relative magnitude of the parts is admirably and copiously illustrated (Thompson 1917: 740-1).' D'Arcy combined Dürer's techniques with those of René Descartes, using his method of co-ordinates to turn Dürer's proportional drawings into scientific diagrams. By applying a Cartesian grid to the form of an animal or a part of an animal, and subjecting it to increasingly complex mathematical transformations, he was able to demonstrate that laws of growth rather than evolution could be used to explain the different forms of related species (Figure 3).

Most of these famous diagrams (along with many others in *On Growth and Form*) were the work of two women who worked closely with D'Arcy, Doris Mackinnon and Helen Ogilvie. Doris Mackinnon came to University College, Dundee in 1909 as assistant lecturer in D'Arcy's department, having graduated from Aberdeen three years before. She became renowned for her work on parasitic protozoa and during the First World War was employed by the War Office to work on the diagnosis of amœbic dysentery and intestinal protozoal infections. After D'Arcy left Dundee in 1917, she ran the department herself for two years before moving to King's College,

London where she succeeded Julian Huxley as Professor of Zoology in 1927, a position she held until her retirement in 1949.

Helen Ogilvie studied at Dundee Training College before becoming a student of D'Arcy's at University College, graduating in 1908. She then studied in Oslo where she became an expert on marine phytoplankton. She returned to Dundee in 1912, joining the teaching staff and assisting D'Arcy in his role as Scientific Adviser to the Scottish Fishery Board. In 1926 she moved to the Aberdeen Marine Laboratory where she spent the rest of her career, retiring in 1946.

The diagrams that Mackinnon and Ogilvie created under D'Arcy's direction have, like many other aspects of the book, gone on to have a considerable influence in other fields. For much of the twentieth century, however, D'Arcy's ideas seemed to run counter to biology's increasing focus on evolution and genetics. A few key followers continued to champion his importance, including Julian Huxley and C H Waddington, but it was only with the rise of evolutionary-developmental biology (or evo-devo) in the 1980s, coupled with the development of computer-based mathematical modelling techniques, that D'Arcy's work began to find its way back to the biological mainstream. D'Arcy had been all too aware of the limitations of the mathematics of the time to undertake the task he had begun. Richard Dawkins has noted that 'It is one of the... tragedies of biology that D'Arcy Thompson died just before the computer age, for almost every page of his great book cries out for a computer (Dawkins 1996: 200).'

In fact, the development of the computer owes not a little to D'Arcy's work – by showing how complex biological systems can be understood by fundamental mathematical principles, *On Growth and Form* provided an important basis for the development of modern systems theory. Alan Turing's experimental thinking

machines rely on similar ideas, and in the early 1950s Turing turned his attention to biology with his landmark paper 'The Chemical Basis of Morphogenesis' (Turing 1952), beginning an investigation into animal coat patterning that D'Arcy had briefly introduced at the end of the second edition of *On Growth and Form* with a study of the zebra's stripes. Turing's work demonstrated how mathematical equations applied to different chemicals in the body that he called morphogens could create visual patterns such as this. In 1988 his ideas were taken further by James Murray in his celebrated paper 'How the Leopard Gets its Spots' (Murray 1988), which proposed that a single mathematical model called reaction-diffusion could possibly explain most if not all of the wide variety of animal coat markings found in nature (Figure 4). More recently, in 2012 researchers at King's College London provided the first experimental evidence to confirm Turing's ideas, identifying the actual morphogens involved (Economu et al 2012).

D'Arcy's influence has gone far beyond biology. His importance to systems theory was also recognised by Norbert Wiener, the pioneer of cybernetics, acknowledged in his landmark 1948 book *Cybernetics or Control and Communication in the Animal and the Machine*. It also proved an inspiration to the anthropologist Claude Lévi-Strauss, who refers to D'Arcy in his important 1963 book on *Structural Anthropology*, and many anthropologists today continue to view *On Growth and Form* as an important source text.

In architecture and engineering, *On Growth and Form* has inspired creators and practitioners from Le Corbusier and Mies van der Rohe to Norman Foster and Cecil Balmond. Perhaps most notably, D'Arcy's work on the mechanical efficiency of soap bubbles and the structural tension of dragonfly wings helped to inspire the

development of lightweight structures such as Buckminster Fuller's geodesic domes and Frei Otto's Olympic stadium in Munich.

Many of these influences relate as much to the text of *On Growth and Form* as its images, but the latter (particularly the transformation diagrams) have either directly or indirectly inspired a variety of scientific visualisations since the book's publication.

One clear visual affinity is with Wilder Penfield's iconic cortical homunculus drawings (1937-50), though whether there is a direct connection here is unknown.

Penfield was a Canadian neurosurgeon who pioneered a new surgical treatment for severe epilepsy by stimulating patients' brains with electrical probes while they were conscious on the operating table. This allowed him to pinpoint the specific areas of the brain affected by their epileptic seizures and target these during the surgery. The technique also allowed him to create maps of the sensory and motor cortices of the brain, and these form the basis of the cortical homunculus, a diagram of the human body distorted according to the way it is perceived by the brain – transforming parts of the body according to specific data in a way that is clearly analogous to D'Arcy's transformation diagrams.

The same ideas can be seen in the algorithms used to create the Worldmapper series of cartograms, first published in 2007 based on a process developed by Mark Newman and Michael Gastner (Gastner & Newman 2004). These are a way of visualising data on land area, population, world poverty and health (for example allowing viewers to see the world according to the GDP wealth of its various countries and compare that with its available water resources). Each time the original is distorted according to specific mathematical transformations dictated by the scientific data.

Forensic anthropology also draws on D'Arcy's diagrams, for example in a procedure developed by the Centre for Anatomy & Human Identification at the University of Dundee. Forensic teams often work on disaster scenes where they find skeletal remains that have been distorted by fire or building collapse and it is often very difficult to distinguish human from animal remains. By using a 3D version of the transformation diagrams, they can create models to predict different distortions caused by different circumstances, and thus aid in identifying the remains.

These are just a few examples of the scientific influences of D'Arcy's work, but one of the most notable features of *On Growth and Form* is its on-going influence in visual art – indeed artists were much quicker than scientists in recognising the potential of D'Arcy's ideas as part of a wider fascination for natural science and mathematics that had a great impact on the development of modern art (Juler 2015; Henderson 2013). The sculptor Henry Moore discovered *On Growth and Form* as a student, and the influence of its illustrations can undoubtedly be seen in the series of 'Transformation Drawings' that he created in the early 1930s, which use overlapping pencil lines to depict organic forms apparently in the act of morphing from one state to another. These drawings then informed the sketches Moore created while working out ideas for his sculptures, and similar transitory biological forms can also be seen in his early print work.

The second edition of *On Growth and Form* was enthusiastically taken up by a group of students at the Slade School of Fine Art in London in the 1940s, including Nigel Henderson, Richard Hamilton, Eduardo Paolozzi and William Turnbull. In 1951, Hamilton staged an influential exhibition called *Growth and Form* at the Institute of Contemporary Arts, to accompany the Festival of Britain. This was one of

the first installation art shows in Britain, entirely comprised of scientific imagery and models, many of which were drawn directly from the illustrations in D'Arcy's book.

Along with another D'Arcy enthusiast, Victor Pasmore, Hamilton would go on to become an important teacher at the Department of Fine Art in King's College, Newcastle. The new Basic Design Course they introduced proved to be hugely influential on art schools around the country, and it included many exercises drawn from *On Growth and Form*. Pasmore was also a key member of the post-war Constructionists, whose work spearheaded a growing interest in the use of mathematical patterns to generate art, something taken further by the Systems Group founded in 1969.

Meanwhile early pioneers of computer art such as Roy Ascott and Desmond Paul Henry saw *On Growth and Form* as a key prefigurement of their work, and one can trace a direct line of descent from D'Arcy through Mandelbrot's work on fractals to the computer-generated imagery of Pixar and others today. A notable example from this artistic and conceptual journey is Andy Lomas, who works as a special effects designer on major Hollywood blockbusters (for example as a CGI supervisor on *Avatar*) but also works as a practising fine artist, generating work using computer algorithms, directly inspired by D'Arcy's work (Figure 5). Also of note here is the work of contemporary Japanese artist Macoto Murayama, whose print series *Inorganic Flora* presents minutely detailed illustrations of plant specimens in the form of engineering blueprints.

Coded Chimera is a fascinating example of an interdisciplinary project involving art, science and illustration, led in 2010-11 by sculptor Bruce Gernand. A senior research fellow at Central St Martins in London, Gernand's interest was in the process of form-making as much as its final outcome. D'Arcy's transformation

diagrams became the starting point for a project to use computer modelling techniques to morph different animal forms as a way of exploring sculptural form-making, using the ancient idea of the chimera as a way of linking art and biology. Rather than revealing the mathematical relationship between two related forms, Gernand sought to use animals that were culturally rather than taxonomically connected, such as tortoise and hare, or cat and crocodile. The project involved both the physical and the virtual – taxidermied museum specimens were scanned in 3D and the digital forms subjected to various computer morphing techniques, which in turn generated rapid prototype models of particular stages in the transformation process (Figure 6).

Gernand's work was exhibited at the University of Cambridge in 2011 then at the University of Dundee in 2012. The latter exhibition was one of a series staged by the author to accompany a project funded by the Art Fund's RENEW scheme to build a collection of art inspired by D'Arcy's work, one of the principal aims being to encourage artists to visit the D'Arcy Thompson Zoology Museum in Dundee and respond directly to his original collections. Since the museum moved to its current location in 2008, the collection has been used regularly by both professional artists and students. In 2010 level three Illustration students from Duncan of Jordanstone College of Art & Design (DJCAD) undertook a project researching D'Arcy's ideas and collections, resulting in an exhibition of their work in the Bradshaw Art Space at DJCAD (Figure 7). In 2012 an artist in residence programme was introduced, initially in collaboration with the Bards Graham Charitable Trust and the Royal Scottish Academy. The first artist selected, Lindsay Sekulowicz, had a particular interest in memory and neuroscience, spending time working with scientists at Ninewells Hospital in Dundee and the Sea Mammal Research Unit at the University of St Andrews. The body of work she ultimately produced explored the fact that much of

D'Arcy's original museum collection was lost when the museum was demolished in the 1950s. By drawing representative specimens and creating sculptural pieces that symbolise others, her intention was to create a system that would help to re-create the extent of the original collection in people's minds: "the drawings became a memory map, that when viewed together, begin to speak about archives, collecting, the individual and collective memory (personal communication)."

In 2013, artist Gemma Anderson also approached the collection from an illustrative standpoint (Figure 8). Gemma is currently undertaking a PhD exploring what she calls Isomorphology, looking at shared patterns across different natural forms, and the role of the artist in helping scientists to understand these via her illustrations. She explains: "As a holistic and visual approach to classification, Isomorphology runs parallel to scientific practice while belonging to the domain of artistic creation. It is complementary to science: addressing relationships that are left out of the scientific classification of animal, vegetable and mineral morphologies (Anderson 2013: 4)."

It is hoped that, through initiatives such as this, D'Arcy's work will continue to inspire science, imagination and the illustration of knowledge for years to come.

The waves of the sea, the little ripples on the shore, the sweeping curve of the sandy bay between the headlands, the outline of the hills, the shape of the clouds, all these are so many riddles of form, so many problems of morphology, and all of them the physicist can more or less easily read and adequately solve: ...but it is on another plane of thought from the physicist's that we contemplate their intrinsic harmony and perfection and 'see that they are good' (Thompson 1917: 7).

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Illustrations:

Fig 1 – Nassellarian skeleton from *On Growth and Form*, first edition, 1917 (Cambridge University Press)

Fig 2 – Haeckel Radiolarian model from D'Arcy Thompson's collection (copyright University of Dundee Museum Services)

Fig 3 – Transformation diagram from *On Growth and Form*, first edition, 1917 (Cambridge University Press)

Fig 4 – Standing-wave patterns generated on a thin metal plate to demonstrate the process of animal coat markings (courtesy of Dr James Murray)

Fig 5 – *Aggregation 24* by Andy Lomas, 2005 (copyright the artist, courtesy of University of Dundee Museum Services)

Fig 6 – *Coded Chimera* by Bruce Gernand, 2010 (copyright the artist, courtesy of University of Dundee Museum Services)

Fig 7 – *D'Arcy Thompson* by Chloe Brown, 2010 (copyright the artist, courtesy of University of Dundee Museum Services)

Fig 8 – *Five Fold Symmetry* by Gemma Anderson, 2013 (copyright the artist, courtesy of University of Dundee Museum Services)

Biography

Matthew Jarron is Curator of Museum Services at the University of Dundee, which includes the D'Arcy Thompson Zoology Museum. He is the author of several publications relating to the museum collections including *D'Arcy Thompson and his Zoology Museum in Dundee* (2010, co-authored with Cathy Caudwell) and has edited or co-edited issues of the *Journal of the Scottish Society for Art History*, *Museum Management & Curatorship* and *Interdisciplinary Science Reviews*.

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