Anatomics: Visual anatomic representation

An exploration into how complex visual information can be mediated using an interplay of artistic and scientific approaches in the investigation and creation of human anatomic representations

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Attestation of authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Signed: ………………………………………………………………… Richard John Carthew.

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Abstract

This project is concerned with visual representation of human gross anatomy[1]. The subject is complex because it derives from an intersection of artistic and scientific disciplines and is an active field of research. The overall aim of the project is to open up new ways of interpretation when engaging with complex visual representations of anatomy.

The project involves a consideration of the methods and models in which the communication of visually complex information is achieved by using a combination of artistic and scientific representation. It explores methods and techniques used in the creation of visualisations that are intended to convey scientific knowledge.

Literature and visual reviews were undertaken and these examined research material which informed the project's exploration. These reviews included texts that studied the historical development of anatomic representation and also contemporary visual material. Elements of cognition and perception and their relationship to visual communication were reviewed and considered in relation to the project's practical work. Wider socio-cultural contexts that affect pictorial style in anatomic representation were also reviewed and some relevant contexts are discussed within the exegesis.

Practical exploration included developing models of anatomy that combined elements from artistic and scientific approaches. For example, in some explorative work, the fine detail of traditional anatomic representation formed one section of a model and this was allied with another section that used a more scientific approach to isolate key structures by illumination.

The exegesis concludes with a summary of the project, conclusions arising from the research and an indication of potential areas for further study.

[1] For conciseness, all further references within the exegesis to *anatomy* and *anatomic representation* refer to *human gross anatomy* unless otherwise stated.

Part 1: Introduction

Today, visual anatomic representation draws upon a wealth of available resources and methods including illustrated texts, physical three dimensional models and computer generated representations. This material commonly possesses a high degree of visual, spatial and functional complexity within the relationships of their component structures. This richness (or denseness) of data can lead to confusion in understanding the information and key principles that are intended to be communicated and recalled.

This problem is recognised by Brenton, et al. (2007), in *Using multimedia and Web3D to enhance anatomy teaching*. They discuss the *brachial plexus*[2] and a student's response to its complexity of form: "The structure of the brachial plexus is very hard to remember, one student referred to it as 'like trying to memorise Clapham Junction train station', the busiest train station in the United Kingdom" (p. 42).

Currently there are many institutions worldwide engaged in developing improved methods and models to represent human anatomy, especially within virtual 3D space, with the aim to ease the difficulties in communicating visually complex anatomic information. To date, one of the most sophisticated representations available has been developed by the University Medical Center, Hamburg-Eppendorf (2007), and is called *Voxel-Man*[3] (p. 1). In this software, virtual 3D anatomic representation is presented stereoscopically to the viewer with physical feedback to the user's hands, thereby using a sense of touch (haptics) to better simulate surgical procedures. *Voxel-Man* combines "an onscreen anatomic representation with an external, tactile component that serves to better simulate the experience of working with physical bodies' and this is claimed to be 'a unique tool for training" (p. 1).

This project investigates the potential in using a combination of artistic and scientific approaches in communicating complex information, focusing on visual anatomic representation. In its final stages, the project shifted towards applying

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[2] A network of nerves originating from the spinal cord and extending via the arms to the fingers.
[3] This representation is based on data sets from the National Library of Medicine's (2003) *Visible Human Project* (p. 1), which is discussed later in the exegesis.

scientific visualisation strategies in the creation of works of art. The project includes both contextual research and practice-based, creative art work.

1.1 Overview of project

This project explores a combination of artistic and scientific approaches in the mediation of complex information, in particular, representations of human anatomy.

In an early practical experimentation, *Biocuboid* (figs. 5:1-5:2, pp. 41-42), materials were selected that could visually reference aspects of scientific presentation, for example, the creation of a 'laboratory aesthetic' using polycarbonate blocks, machined aluminium and cross-sectional images[4]. These materials were combined together in a specific design to visually refer to the natural science practice of collection, subsequent specimen isolation and its re-presentation.

The overall aim in experimenting with the above representation was twofold: firstly; to gain tacit physical experience working with new materials such as polycarbonate and develop a working knowledge for use in later practice work, and secondly; to create representations that visually occupy a middle ground between artistic and scientific processes. As such, these initial models can be regarded more as artful contrivances than as a vehicle to display accurate scientific data. They did however seek to lead the viewer to the conclusion that they were scientific representations, by using visual devices that referenced scientific equipment (including observable machined surfaces (fig. 5:2, p. 42)).

The notion of a 'scientific authenticity' engendered through a mode of visual representation was first explored here and was extended into *Holotype*, the next body of practical work (figs. 5:4, p. 44, & 5:7-5:10, pp. 47-50).

In *Holotype,* the process of specimen collection, classification and the resultant shift of its perceived identity (through iterative visual representation) in the natural sciences was further examined. *Holotype* was a series of sculptural works that began with an original standard (a *holotype*[5]), which served as the point of departure for increasingly derived representations. The increasing

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[4] The images for these transverse cross-sections were sourced from the National Library of Medicine's (2003), *Visible Human Project* (p. 1), by using the University of Maryland's (1996), V*isible Human Explorer* (p. 1).

[5] A *holotype* is defined by the International Commission on Zoological Nomenclature (2007), as "the single specimen upon which a new nominal species-group taxon is based in the original publication" (p. 1).

degree of abstraction through the series demonstrated a quality that can sometimes be found in the remediation of original scientific information, where iterative transmission and reinterpretation (using different modes of visualisation) can visually alter the interpretation of succeeding representations. This body of work furthered a familiarisation with the process of representing a core subject using different visual methods in depiction and also provided an experience in the nature of exhibiting practical work within a gallery context. This experience has better informed decisions in the strategy for presenting artwork at the final Postgraduate exhibition held in November 2007.

For the visual material included in the practical experimentation, I have drawn upon research in contemporary, computer mediated, scientific, artistic, and medical representation. This work has also been informed by historical developments and techniques in visual anatomic representation, from its origins in early anatomical investigations during Leonardo da Vinci's era in the 16th Century. Anatomical illustration before da Vinci's era was mostly based on "acquired medical knowledge" rather than the direct observation of a cadaver and they were "rough and crude" compared with da Vinci's representations (Pedretti, 2004, p. 112).

Some experiments during the thesis year used physical structures that operated in concert with a virtual component. *Inguinal Projection* (figs. 5:11-5:12, pp. 51-52), investigated the potential of using this dualistic approach; where the physical structure provided depth (indicating volumetric and spatial relationships) and the virtual component demonstrated aspects of temporal representation (including information revealed in successive stages of an animation).

The completed models were intended to be presented in various modes of display, as passive objects that could be regarded as static sculpture allied with a projected virtual animation and as more engaging work that requires some user interaction. This potential user interactivity, if thoughtfully designed and incorporated into the work, may promote the explication, understanding and retention of the key relationships that the representation is intending to convey. If badly utilised, it can degrade the user's experience and result in a poor understanding of the principle that is intended to be communicated.

Recent experimentation in the practical work has seen the discovery and evolution of a technique where discrete anatomic structures can be highlighted by illumination. This technique demonstrates potential in communicating the spatial relationships of particular elements of anatomy contained within visually complex representations.

The final artwork produced for this project, titled *Anatomics* (figs. 5:15-5:21, pp. 55-61), bought together prior discoveries that demonstrated effective potential (in anatomic representation) into a comprehensive sculpture. Anatomics featured in the Auckland University of Technology's Art & Design Postgraduate exhibition, November 2007 and incorporated interactive aspects designed to respond to the audience, potentially increasing their level of engagement with the artwork and its anatomic content.

The design, visual qualities and method of presentation in *Anatomics* took a more artistic approach (in the representation of scientific imagery) and signalled a focus shift away from creating didactic material (i.e. material designed for the purpose of instruction), toward fine art practice.

Part 2: Methodological approach, literature and visual review

2.1 Literature and visual review

A literature and visual review of anatomic representational material has provided a contextual background to the project and a source of ideas for further experimentation. The review included a consideration of historical texts and images of human anatomy beginning with the Renaissance period in the 16th Century, and continued up to contemporary material from artists, medical imagery and information design. Notable texts concerned with anatomic representation for this period included *Human Anatomy* by Rifkin, Ackerman, & Folkenberg (2006). This text is a comprehensive visual treatise that covers the past 500 years of anatomic representation and has valuable insights into the artists, anatomists and the developing technologies of visual reproduction they employed.

Spectacular Bodies by Kemp & Wallace (2000), probed deeper into the work of the principal historical anatomists responsible for developing representational styles in anatomic visualisation and also reviewed some contemporary artists in this field. *The Quick and the Dead* by Petherbridge (1997), expanded on the different thematic conventions used in anatomic representation and suggested that these were often affected more by the dominant socio-cultural forces at play, than their mediating technologies. This approach was reinforced by Sappol (2003), in *Visionary Anatomies and the Great Divide: Art, Science, and the Changing Conventions of Anatomical Representation, 1500-2003.*

In addition to these key texts, other research in anatomic representation via the internet revealed a vast body of resources including images, 3D representations, scholarly texts, electronic journals, and artists' material that operates within this field. For example the National Library of Medicine's (2003), V*isible Human Project* (p. 1), is a complete set of digital images (scanned from anatomical cross-sections of the human body) stored and available from their database. Cross-sectional images taken from the brain of the subject used in the V*isible Human Project* were downloaded using the University of Maryland's

(1996) *Visible Human Explorer,*[6] (p. 1), and used for the anatomic material in *Biocuboid* (figs. 5:1-5:2, p. 41-42).

A contemporary artist working with visual material from the V*isible Human Project* is Marilène Oliver (2001). In a similar structural approach used in *Biocuboid*, Oliver screen printed cross-sectional images onto acrylic sheets and re-assembled the entire body from the V*isible Human Project's* subject in a 1:1 scale sculpture entitled: *I Know You Inside Out* (fig. 4:7, p. 36). Oliver's intention in doing this and how it relates to *Biocuboid* is examined in more detail in part 4:2 of the exegesis, *Anatomical representation and the Visible Human Project data-set*.

For research on the communication of complex information in general and the relationship between artistic and scientific representation, Tufte's (1997) text, *Visual Explanations: Images and Quantities, Evidence and Narrative,* provides an analysis of a wide range of visual graphics designed to communicate information. Tufte assembled examples from different countries and included transport schedules, maps, multi-layered technical and scientific diagrams and anatomic images. In some cases Tufte presented the original diagram adjacent to his re-working of it (fig. 3:1, p. 20). His intention in using this method was to show how small changes could improve the effectiveness of visually communicating the intended principle. In my own practical work, *Inguinal Canal Region* (fig. 3:6, p. 28) similar techniques were used, such as using definitive boundary lines that delineate the edge of smooth colour gradations. This method improves the ability of a viewer to distinguish the boundaries between the complex forms of adjacent anatomical units.

Further insights into the ways in which images communicate meaning and how they operate in different social and cultural contexts were offered by Kress and van Leeuwen (1996), in their work, *Reading Images: the Grammar of Visual Design.* Key concepts examined included the effect of a viewer's personal background on their perspective when looking at visual work. This notion is relevant to the way an individual might regard the exhibition of a project's

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[6] A screen shot and brief description of this interface is given on page 32 of this exegesis.

practical work and is discussed further in part 3:3 of the exegesis, *Socio-cultural factors*.

Ka'ai and Moorfield (2004), examine within an Aotearoa/New Zealand context how messages are coded directly into visual work and require the reader to have an understanding of the cultural background to decipher their meaning. This notion correlates with a similar process in the understanding of some types of anatomical representations, for example X-rays where the technician relies on prior knowledge and experience to decipher the meaning visually present in the image.

Another key context for presenting and viewing art is the gallery or museum space. In examining exhibition practice, Hooper-Greenhill (2000), in *Museums and the Interpretation of Visual Culture* considers the role of exhibition curators and their approach or style of presentation as being able to influence the potential meaning of the exhibited material. According to Hooper-Greenhill a current trend in art museum display is to "leave the potential meaning open and ambiguous" (p. 4). This approach in using a minimum of supporting material influenced the exhibition of the *Holotype* series (figs. 5:4, p. 44, &. 5:7-5:10, pp. 47-50).

2.2 Methodological rationale

The exploration and production of creative work in this project has been systematically developed through a cyclic process of:

a) Research and investigation into existing resources such as visuals, models, texts and artworks positioned within the historical and contemporary science-art fields,

b) Informed experimentation in the practical realisation,

c) Reflecting upon the outcomes from this work and,

d) Using that evaluation to inform subsequent generative work.

The methodological process in this cyclic form of enquiry is described by Scrivener (2004), who formulated a model for working with creative production projects. He argues: "I have proposed that reflection should be central to the discipline of creative-production. This will involve recording creative production in a way that captures moments of reflection-in-action and-practice (*i.e.*, material for reflection on action and practice).” (p. 1). Scrivener’s suggested methods have been influenced by Schön’s (1983) text, *The Reflective Practitioner*: “I am persuaded that Schön’s (1983) theory of reflective practice provides us with ways of thinking about the nature of the creative-production process, the way past experience (both personal and collective) is brought to bear on it.” (p. 1).

Material developed during creative production was recorded within dialogic journals using annotated sketches (covered later in this section) and by other methods, including digital snapshots using a stills camera for static works and video files to record animated experiments. This repository of material was periodically reviewed and informed further work, in accordance with Scrivener’s suggestion. Scrivener also notes: “A creative-production project will be grounded in a practitioner’s current practice and realised in future projects. Consequently, it should begin with reflection on past practice. This will generate issues for further investigation, goals for future practice.” (p. 1).

For example, reflection on past practice resulted in changes for the final version of *Biocuboid* (figs. 5:1-5:2, p. 41-42). The first model of this series was designed as a cube that had equal external dimensions along all sides. It was intended for the interior volume to be seen as a cubic form, housing the cross-sections of the brain in locations equivalent to their position in the cranium. The refractive optical properties of clear acrylic, however, resulted in a ‘flattened’ internal cuboid (and therefore a brain that appeared oblate about its vertical axis).

As a consequence of this discovery, the second model was designed with acrylic slabs of greater thickness and hence longer vertical sides overall when assembled. This new design had the desired effect of presenting an interior view that appeared as cubic and therefore correctly displaying the relative locations of the brain’s cross-sections.

Other methodological approaches were assessed for their potential effectiveness in realising the aims and intended outcomes of the project, i.e. using experimentation to discover new ways of representation. In adopting this method of experimental approach to discover new ways of representation, a *heuristic* methodology appeared well suited to guide the overall exploration. Heuristics is defined as:

> A qualitative method of solving a problem for which no formula exists. It uses informal methods or experience, and employs forms of trial and error. Heuristics relates to the ability to find knowledge, patterns or a desired result by intelligent questioning and guess-work rather than by applying a pre-established formula. (Ings, 2005, p. 6)

In deciding on this approach, I recognised the central requirement of a cyclic process (of incorporating experience back into the project) already occurring in my early explorative work *Biocuboid* (figs. 5:1-5:2, p. 41-42). Kleining and Witt (2001), define qualitative heuristic methodology as having “rules which refer to the situation of the researcher, the topic of research, data collection and data analysis.” (p. 1).

Of these rules, one is crucial in maximising the potential for discovery by experimentation in this project and this is defined by Kleining and Witt: “The researcher should be *open to new concepts* and change his/her preconceptions if the data are not in agreement with them.” (p. 1). In the project’s experimental work, *Hand* (figs. 3:2, p. 21, & 4:4-4:5, pp. 33-34), the use of ‘illuminated layers’ visible in the demonstration of spatial anatomic relationships arose from an openness to the potential of an unpredicted outcome from an earlier experiment.

Dialogic journals were created, using annotated imagery (including process sketching and photography) to document the path of exploration and concepts emerging throughout the project’s progression. As well as providing a source for reflection and dialogue, these journals recorded material from the literature and visual review that influenced the project, such as other practitioners’ concepts and imagery.

Sections of these journals (fig. 2:1, p. 18), containing this material often became nodal points for the development of new work. For example, in the *Holotype* series (fig. 5:4, p. 44, & 5:7-5:10, pp. 47-50), conceptual ideas were developed by visually rendering them within the journal and this led to further development within practical experimentation.

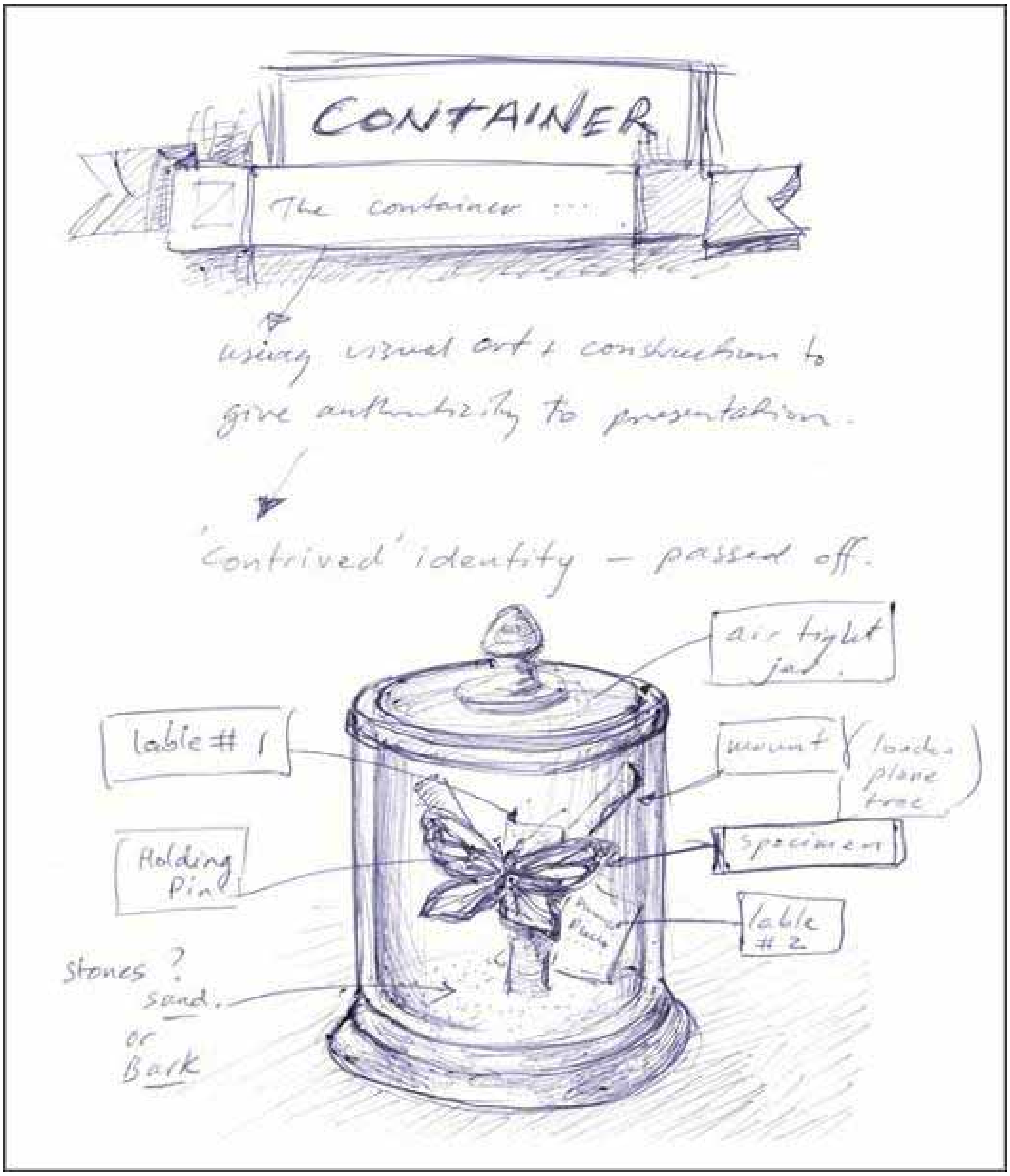

Fig. 2:1 Richard Carthew. *Untitled*. Detail. Scan from *Dialogic Journal No. 2.* 2005.

The image of the concept sketch within *Dialogic Journal No. 2*. (fig. 2:1, above), is typical of the rapid rendering style that exists in all three of the project's dialogic journals. This concept sketch informed the visual design of the first work in the *Holotype* series (figs. 5:4, p. 44, & 5:9, p. 49).

Overall, these journals served as an effective base for concept development, a place for reflection on experimental work, and as a central repository for other material related to the project.

2.3 Exegesis structure

This exegesis has six parts:

Part 1: Introduction

Part 2: Methodological approach, literature and visual review

Part 3: Charting the Map

This part introduces some historical and contemporary visual strategies used to communicate complex visual information. It highlights a stylistic shift that occurred in anatomical depiction after the Renaissance, and it considers the position of an audience in relation to their interpretation of visual material designed to communicate complex information.

Part 4: Communicating scientific information

The process of visual communication is examined in more depth here by examining strategies used to mediate visual complexity and focuses on a variety of visual anatomic representations and models.

Part 5: The interplay between Art and Science

This part considers artistic and scientific approaches to visual representation and the interplay at their intersection. It also covers further experimentation using techniques of illumination within anatomic representation.

Part 6: Conclusion

Part 3: Charting the Map

This section investigates some of the theoretical, philosophical and conceptual issues concerned with the visual representation of complex information. It also charts some of the defining visual developments in the history of anatomical representation still visible in representations today. This is important for the project as it contextualises the visual material developed in the practical work. The approach, style and rendering of anatomical imagery within the project's experimentation benefits from an understanding of the wider issues at work in representing complex information.

3:1 Cognition and perceiving visually complex information

There are qualities in the nature of human physiology and psychology directly related to sensory perception (hence reception) when interpreting visual representations of scientific information. Tufte (1997) notes:

> Many of our examples suggest that clarity and excellence in thinking is very much like clarity and excellence in the display of data. When principles of design replicate principles of thought, the act of arranging information becomes an act of insight. (p. 9)

Tufte (1997), illuminates this idea by explaining the principle of *smallest effective difference* in an image (p. 75). To do this, he shows us two adjacent visual representations of the same mechanical principle (fig. 3:1, below), the left hand diagram is the original as it appeared in *Handcuff Secrets,* Houdini (1909). Tufte redraws it (image on right in fig. 3:1) to better represent the main principle visually. His judicious use of grey scales results in the key component and its working relationship to the rest of the assembly being visually more discernable, therefore the communication of its specific function is more effective.

Fig. 3:1 Edward Tufte. *Smallest effective difference*. Printed image. 1997.
In Tufte (1997), Visual Explanations. (p.75)

I found Tufte's concept effective and translated it into *Hand* in a way I considered even more dynamic (figs. 3:2, below, & 4:4-4:5, pp. 33-34). In this experimentation, I designed the model to allow for selective highlighting of its plates, thereby revealing underlying anatomic structures. The concept was to illustrate their relative location to each other and to the surface morphology and therefore improve the potential for understanding their spatial relationships.

This principle is clearly demonstrated in a detailed view of *Hand* where two states of the model are compared (fig. 3:2, below). On the left is how the structures appear if they are all lit simultaneously and the right is when the layer representing the blood vessels lit independently. The visual complexity in the left image make the underlying individual structures difficult to distinguish. However, they can be more clearly visualised if they are highlighted individually as they are in the right image.

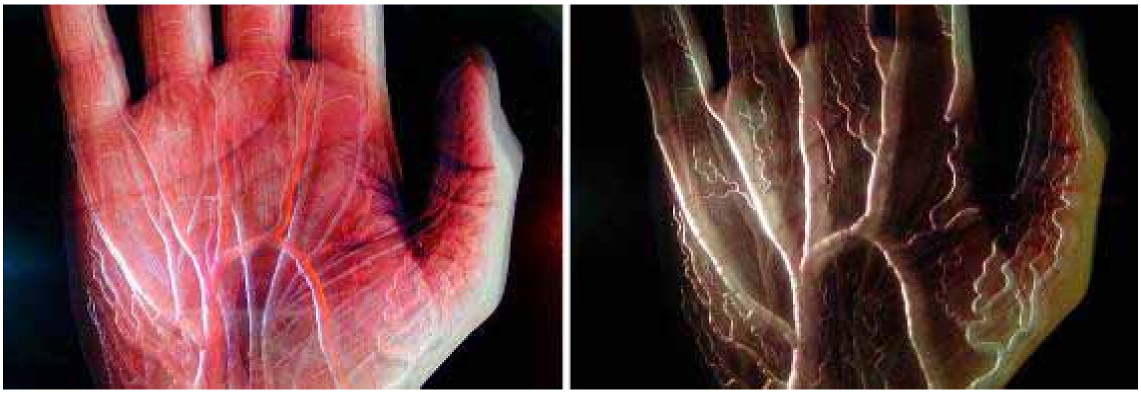

Fig. 3:2 Richard Carthew. *Hand.* Detail. Photograph of sculptural work. 2007.

This comparison demonstrates that the property of being able to visually isolate key structures is effective in resolving their relative positions and understanding their spatial relationships.

3:2 Historical modes of anatomic illustration related to current strategies

Tufte was not the first to use a method of visual highlighting when communicating an idea by visual representation. The employment of a similar technique, one of visually isolating key structures to effectively depict their relationship to other structures can be found in the Renaissance period when examining an example of Leonardo da Vinci's visual representation of anatomy (fig. 3:3, p.22).

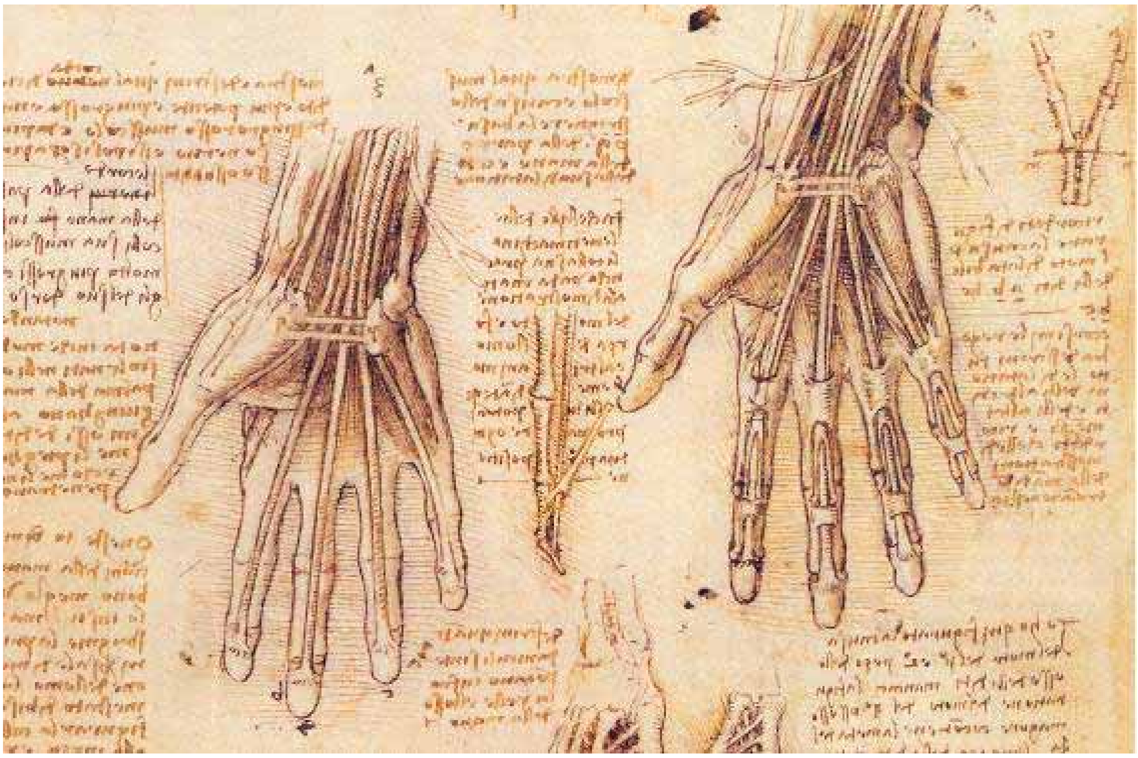

Fig. 3:3 Leonardo da Vinci. *Studies of the Hand*. [Online image]. 1510.
In Kemp and Wallace (2000), *Spectacular Bodies* (p. 26).

Kemp and Wallace (2000), consider da Vinci as one of the “great pioneers of what was possible in anatomical illustration” (p. 26), and support this opinion by outlining some visual techniques that da Vinci demonstrated:

> There are also views which display various kinds of section through the whole or parts of bodies. There are contrived, synthetic representations using such techniques as transparency and isolation, so that we can see, for example, a whole ‘tree of the vessels’ (Leonardo’s term). They exploit various kinds of diagrammatic and semi-diagrammatic modes to illustrate structural, mechanical and physiological principles. (p. 35)

Because each ensuing century saw the development of more innovative rendering the understanding of human anatomy advanced rapidly. Rifkin et al. (2006), state “Virtually every strategy that would later be used in the 21st century world of digital imaging to portray a 3D image on a flat surface was developed by artists working before the 20th Century.” (p. 319). In the project’s practical work, these historically developed techniques in anatomical illustration were reviewed and some were developed further. For example, elements from da Vinci’s approach in using ‘transparency and isolation’ to delineate anatomic units, were incorporated into the creation of the practical work *Hand* (figs. 3:2, p. 21 & 4:4-4:5, pp. 33-34), and the work *Corpus* (figs. 5:13-5:14, pp. 53-54).

In the mid 16th Century, approximately 30 years after da Vinci's *Studies of the Hand*, the anatomist Andreas Vesalius commented on the importance of illustration as a means for communicating visually complex information in O'Malley (1964): "…no student of geometry and other mathematical disciplines can fail to understand how greatly pictures assist the comprehension of these matters and place them more exactly before the eyes than even the most precise language." (p. 276). Vesalius however, did acknowledge the inherent limitations in illustration if that was the sole means of acquiring anatomical knowledge of the body:

> I believe it is not only difficult but entirely futile and impossible to attain an understanding of the parts of the body from pictures alone, but no one will deny that they assist very greatly in strengthening the memory in such matters. (p. 239)

It can be inferred from this commentary that Vesalius did not intend for his treatise to replace the direct experience of anatomic structures gained during dissection. The illustrations and text acted as explicatory and mnemonic devices to aid greater understanding and recall of anatomy during the practice of dissection and medicine.

In *Visionary Anatomies*, a major exhibition held at the American National Academy of Sciences in 2003, historical and contemporary anatomic representations were exhibited. An essay by the Curator-Historian, Sappol (2003), in the exhibition catalogue examines the major shift of anatomical illustration away from the embellished 'cadavers at play' common throughout the 16th and 17th Century representation into more factual, didactic modes of representation which persist today:

> Between 1680 and 1800 the conventions, meanings, audience, and uses of anatomical representation shifted. Anatomist's began to develop new criteria for what constituted acceptable scientific illustration. The artful representation of anatomical objects continued to be a crucial part of the science of anatomy, and anatomists continued to work with artists, and continued to value high artistry, but only of one type: the art of the real. (p. 5)

This shift in visual representation highlighted by Sappol can be observed by comparing two images from the 17th and 18th Century, (fig. 3:4, p. 24).

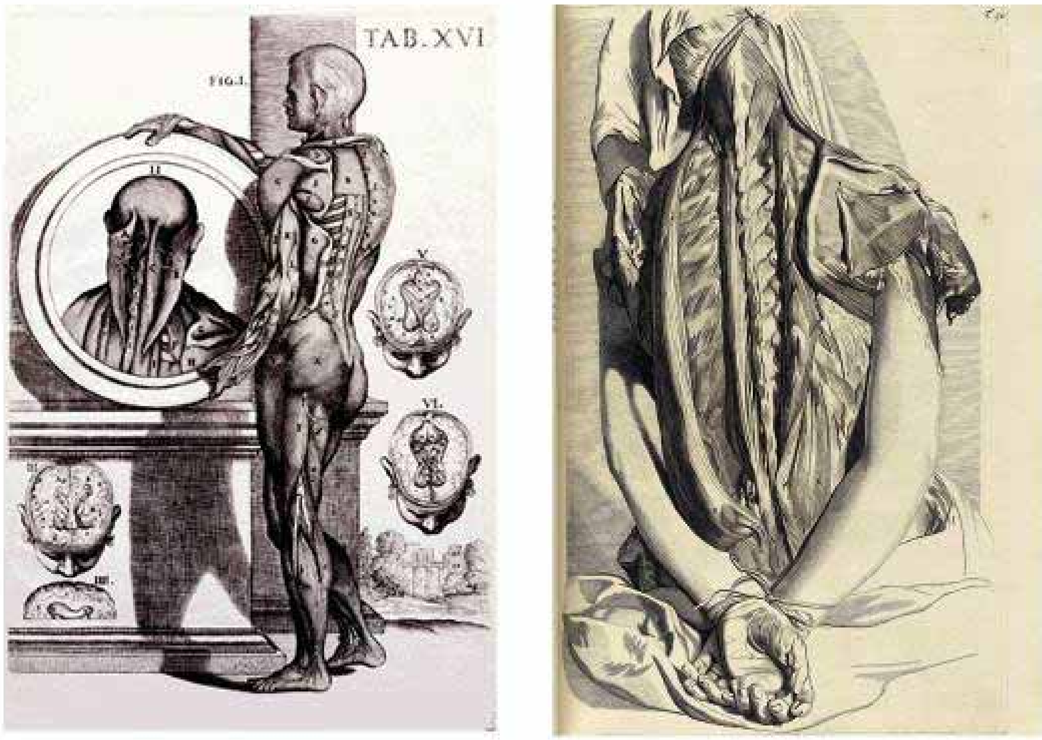

Fig. 3:4 Pietro da Cortona. *Tabulae anatomicae. pl. 16.* 1741. (left)., Govard Bidloo. *Ontleding des menschelyken lichaams, pl. 30*. 1690. (right). [Online images]. 2007.

The fidelity of visual detail is comparable between these two images, but they differ in their overall thematic style of representation. Cortona's image on the left visually depicts the 'cadaver at play' described by Sappol. This image, where the cadaver appears complicit in its own fate and is standing amidst decorative devices, is in strong contrast to Bidloo's 'realism' at right. Bidloo's copperplate represents a break from the tradition of placing anatomical figures in thematic landscapes. As Sappol states: "The stark dissection, with ragged flesh fully displayed and hands bound with a cord, signals a commitment to a higher level of realism. There is no fantasy landscape; the scene is the dissecting room" (p. 6).

In my own experimental work, *Vesalius-1* (figs. 5:5-5:6, pp. 44-45), I'm concerned with retaining this tradition of highly detailed rendering and Bidloo's style of realism, and hence I selected visually detailed historical material for contemporary experimentation. The high density of detail contained within a small area is an effective way to visually depict complex anatomic structures and their inter-relationships.

Throughout the history of anatomic representation, the quality of visual detail in the printed work can be seen to be of primary importance to the anatomists and artists producing the texts. New innovations in printing techniques were developed in the pursuit of better simulations of anatomy. The application of a newly developed technology for anatomic depiction, however, did not always result in greater realism or detailed work.

This is the case with the initial use of colour mezzotint[7], a new technique emerging in the mid 18th Century, where visual anatomic detail unwittingly lost some of its primacy in an anatomist's work utilising this technique. Stafford (1991), writes about this anatomist; Jacques Gautier d'Agoty and the emergence of his colour mezzotints and their early application in anatomic simulation. (fig. 3:5, p. 26): "Innovative multiple-plate colour mezzotints, or 'printed paintings,' were touted as bringing new precision and exactitude into medical and scientific texts. They reproduced objects in their natural colour without relying on hand tinting" (p. 76). The last sentence indicates that the presence of the artist's hand as an agent in the final work was undesirable.

There is some irony in this, as d'Agoty's final treatment of the prints was to hand varnish them in an effort 'to render the print surface lustrous' and this had the effect of degrading the visual detail so sought after:

> Dagoty's [sic] monumental plates (15 inches high by 12 inches wide) possessed neither the sharp clarity nor the transparent tinctures he desired. The use of varnish imparted, instead, a wonderfully dreamy and aqueous quality to the heroically scaled figures floating in the muted olive sea of the background. (Stafford, 1991, p. 78)

When developing innovations in the project's practical work and in particular when experimenting with the combination of several layers, care had to be taken in how the visual elements operated together. If too many structures were superimposed within the work, the effect was a degradation of the visual detail in a result similar to d'Agoty's experience. For example, the *Hand* model (figs. 3:2, p. 21 & 4:4-4:5, pp. 33-34), operates with a total of three layered structures and the addition of more layers with the same density of detail would result in the individual anatomic forms being obscured.

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[7] Colour mezzotint was a process originally invented in 1741 by Jacques-Christophe Le Blon, and used three colours in the printing process but was subsequently self-claimed by his pupil Jacques Gautier d'Agoty, who added a black plate to the process.

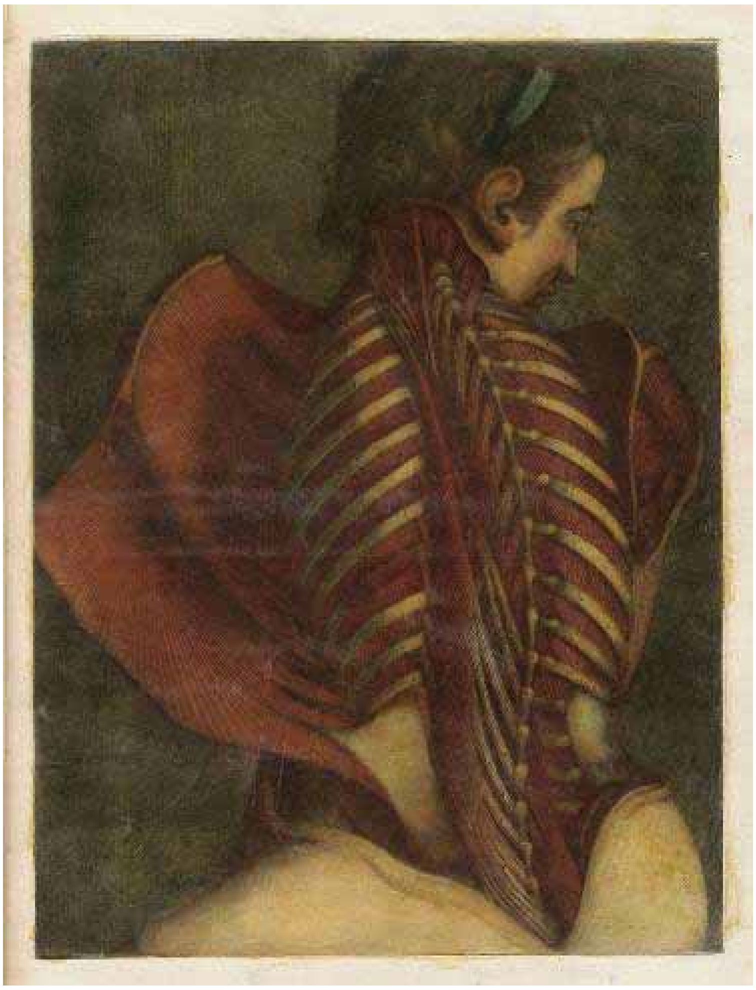

Fig. 3:5 Jacques Gautier d'Agoty. *Suite de l'Essai d'anatomie en tableaux imprimés, Plate 14.* [Online image]. 1745.

3:3 Socio-cultural factors

Kress & van Leeuwen (1996), in their text *Reading Images: the Grammar of Visual Design,* expand on some qualities of visual communication within the context of its supporting cultural framework. In particular they address the quality of inherent codification that resides in visual representations:

> Visual communication is always coded. It seems transparent only because we know the code already, at least passively- but without knowing what it is we know. A glance at the 'stylised' arts of other cultures reinforces the 'myth of transparency' we may see them as decorative, beautiful etc, but we cannot understand them as communication, as forms of writing unless we study and adopt the coded language of the culture. (p. 32)

Kress & van Leeuwen's idea can be translated into an Aotearoa/New Zealand context. For example, a person not versed in the coded visual language of the Maori cannot fully understand the intended meanings integral in their carvings. These carvings are embodied with cultural meanings mediated via the specific coded visual language of Maori, and the intended meaning is construed differently if that code is not known by the viewer.

Ka'ai, Moorfield, Reilly & Mosely (2004), support this idea in their text, *Ki te Whaiao: An Introduction to Mäori Culture and Society*:

> Although the Maori did not have a recorded history in the form of the alphabet and books, what many people fail to realise is that the carvings themselves are in actual fact recorded history. Every piece carved traditionally had a Kaupapa and everyone could read them. The shape of the heads, position of the body as well as the surface patterns came together in each piece to record and remember events. (p. 86)

Further more Ka'ai et al. (2004), state:

> Te moko tukupū wānanga are those carved patterns which were devised by carvers to give added meaning and strength to their work.' and 'The designs are symbolic of the first Korero and reflect the way carvings are created to 'speak' or pass on messages. (p. 118)

This does not imply that these works cannot be appreciated by the viewer, but it does mean that one of the intended purposes of the carvings (to visually record, store and transfer historical information) is lost on the individual who is not versed in the required 'code'. To a greater or lesser extent, this condition (the loss of intended meaning) must always occur when reading any visual work. This problem is discussed later in the exegesis using the *Biocuboid* models as a practical example (figs. 5:1-5:2, pp. 41-42).

Personal background and contextual environment of the work

> Because the success of information design is so context dependent there is almost no way to [accurately] predict scientifically for any particular setting what will work and what will not. Each design rises or falls according to factors that are difficult to replicate; the setting in which the transfer of knowledge [more accurately could be put as 'the transfer of information as a first stage of knowledge formation in the person engaged'] occurs, the individual involved, the medium or media employed, and the original and ultimate purposes of producers and consumers. (Jacobson, 1999, p. 3)

The personal and cultural background of the audience is a major factor in the reading of work. Education and professional experience will influence the interpretation of the work regarded and so will an emotional response. Consider the emotional response to the quality of colour mediated through cultural norms that Jacobsen (1999), outlines: "There is no direct [universal] correlation between colour and emotional content; the meaning of colour is culturally mediated" (p. 106). Bourges-Waldegg and Scrivener (1998) consider an example of colour in a cross-cultural context: "colours have specific meanings in specific contexts. Imagine a Chinese designer avoiding the use of black when designing[8] for Western users "because black is the colour of mourning". This would be inappropriate because in certain Western contexts, black can also signify elegance" (p. 303).

The surface colours in the anatomic representations created in my practice may be less prone to this type of cultural misinterpretation as they are based on 'natural' skin colours, or are depicted in greyscale. The underlying colours in these anatomic representations, however, do follow medical colour conventions and these are more abstracted to help isolate structures and/or show processes. For example in one of the experimentations designed to represent the inguinal canal, a painting was created, the *Inguinal Canal Region* (fig. 3:6, below). In this work, a major blood-carrying arterial pair are depicted as blue and red using anatomical colour convention.

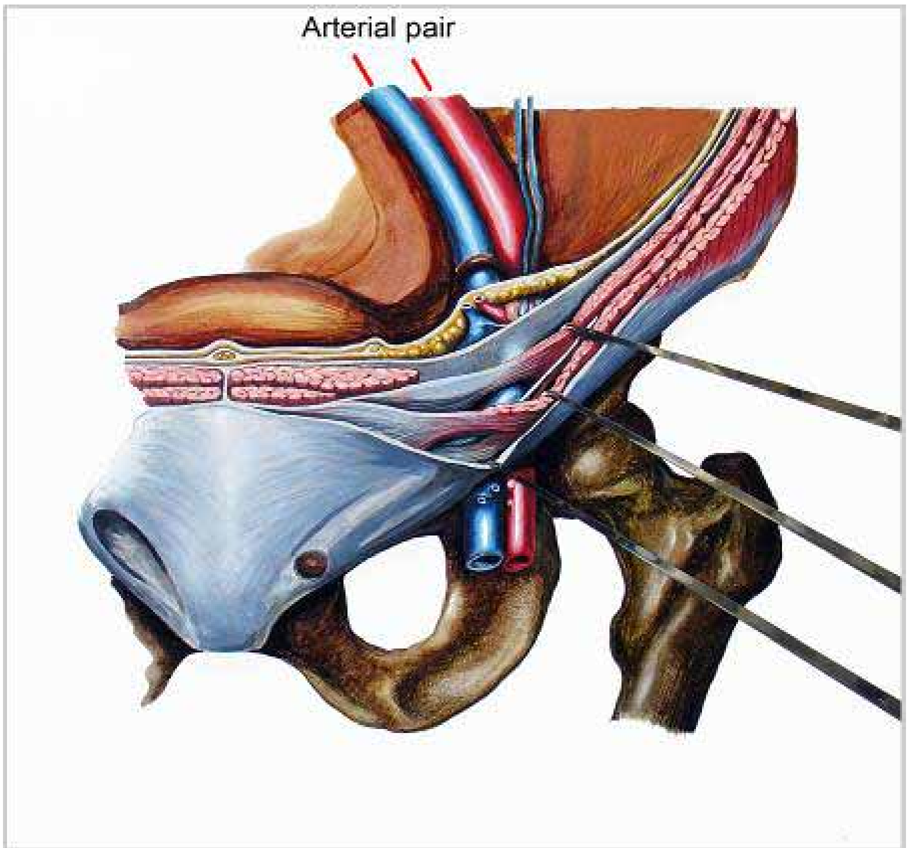

Fig. 3:6 Richard Carthew. *Inguinal Canal Region.* Photograph of acrylic painting, practical work. 2007.

The arterial pair indicated in fig. 3:6 have the same yellowish-tan colour inside the body, but in this anatomic representation, they are differentiated by the use of 'false' colouring to depict blood flow direction. Wilson (2001), addresses this

[8] For example, in designing a HCI: Human Computer Interface, i.e. a website or software CD-ROM interface.

issue, of an audience potentially misinterpreting an artwork, based on the premise that they most likely unfamiliar with its wider context:

> Art influenced by mathematics, science, and technology more generally confronts special problems of audience literacy. Much of its audience will be unfamiliar with the history, conceptual frameworks and discourse that shape thought related to the technological and scientific issues that interest the artist. (p. 335)

If the main purpose of the *Inguinal Canal Region* representation (fig. 3:6, p. 28) was to communicate the inter-relationships of the dominant anatomic structures, then the level of audience literacy required to achieve this would be high, as the painting was presented without any textual information. The various structures are depicted without any accompanying definitions, explanations or medical information. If the intended purpose of the painting was for it to be exhibited mainly an aesthetic artwork, then questions regarding the level of audience literacy take on different perspectives as the work can be appreciated in a more open way.

External factors in the contextual reading of an artwork exist as well, and these are dependent on the nature of the work itself and the approach taken in the exhibition strategy. This is discussed further in relation to the project's experimentation in *Part 5: The interplay between art and science* (p. 35, in this exegesis), where artistic and scientific approaches in making and presenting works of art are examined.

Part 4: Communicating complex anatomic information

4.1 Managing visual complexity

Photographic images of prepared anatomical specimens can be very complex in their form and thus complicate the process of visually delineating the structural components within the specimen. To aid the understanding of contemporary anatomic photographs, a simplified diagram/model is usually produced to accompany the image. Rifkin et al. (2006), gives an example of this:

> The complex nature of reality depicted in these photographs led to an interesting result, the photographs were often too cluttered with detail for students to be able to see their important features. Each photograph was often traced or accompanied by hand-drawn renderings of the same scene, in order to enhance or even allow for understanding. (p. 320)

Another example (where two images of the same subject have different modes of representation) are designed to complement each other can be seen online by visiting the State University of New York (SUNY)(2003), Health Science Center website (fig. 4:1, below).

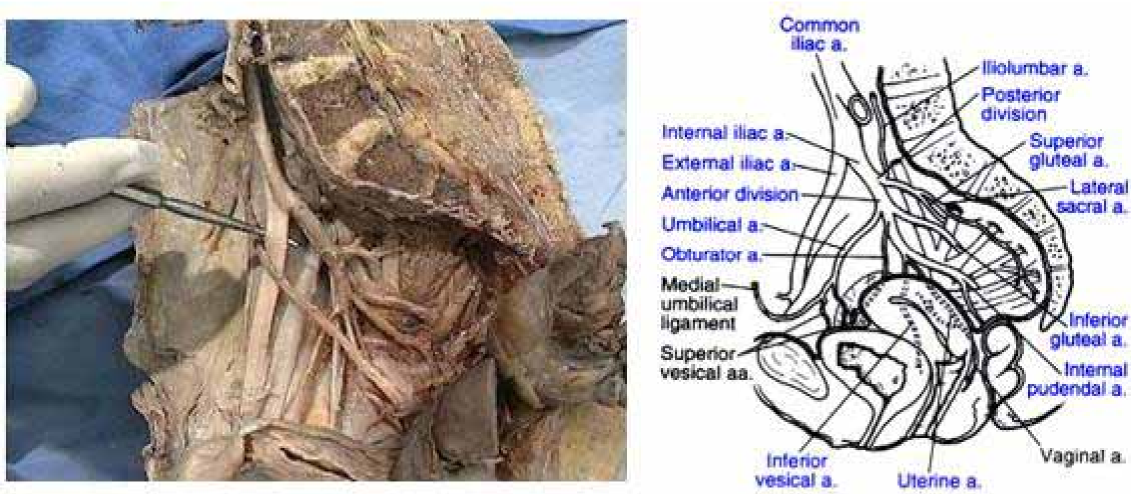

Fig. 4:1 SUNY downstate Medical Centre. *Human anatomy online:Fig 43.7* [Online image]. 2003.

SUNY's purpose in presenting two images side by side in their online anatomical resource is akin to Tufte's aim in his principle of *smallest effective difference*; i.e. the aim of communicating more effectively by bringing the viewer's attention to desired features, in this case the major gross anatomic structures of the inguinal canal region.

Another strategy to manage the visual complexity of anatomy is to commission a skilled medical illustrator to produce illustrations derived from the original anatomic image (e.g. a photograph) of the specimen. In this process, the desired features from the original photograph are judiciously translated by the medical illustrator into a representation that is easier to visually negotiate. Galison, in Jones and Galison (1998), considers the role of interpretation by medical illustrators:

> To be able to interpret was the key; judgement made it possible to sort the significant elements that 'justified the picture' from the background. Mere camera enabled naturalism was too blunt to reveal what the atlas makers and readers wanted to see (p. 346).

The *Inguinal Canal Region* (fig. 3:6, p. 28), was created to explore the potential of visual techniques in painting, such as smooth gradations of colour, in the effective representation of the membranes and arterial veins in this structurally complex region of the pelvis.

The use of colour to isolate anatomic structures and manage their visual complexity appears to be a very common technique after d' Agoty's work in 1745 (fig. 3.5, p. 26). An exception is *Gray's Anatomy,* first published in 1858, where his illustrations are created from woodcuts printed only in black (fig. 4:2, left image, p. 32). This method produced highly detailed illustrations with well defined lines and the overall effect was a sober presentation of descriptive anatomy. Kemp (2006), provides an evaluation of Gray's text and positions it squarely as a scientific approach to anatomical representation: "The whole book presents a heroically disciplined exercise in intellectual restraint, and unequivocally exudes the air of institutionalized science instruction in the mid-nineteenth century." (p. 277).

A series of images derived from *Gray's Anatomy*, have since appeared in Bartleby.com (2000, p. 1), with elements selectively coloured to isolate particular features (fig. 4:2, right image, p. 32). The greyscale component of this image is a copy from an original Grey's Anatomy woodcut print (fig. 4:2, left image, p. 32) and is coloured to show the two major arteries within the inguinal region. This basic technique is effective in demonstrating the 2D location of these primary arteries in the inguinal region, but does not offer the spatial inter-relationships that can be demonstrated in a 3D representation.

In the practical experimentation *Hand* (figs. 3:2, p. 21 & 4:4-4:5, pp. 33-34), the principle of isolating anatomic structures by colour is further developed into a 3D representation. The engravings that form the discrete anatomic units occupying this volume are illuminated with coloured light, thereby allowing their spatial 3D relationships to be distinguished more easily.

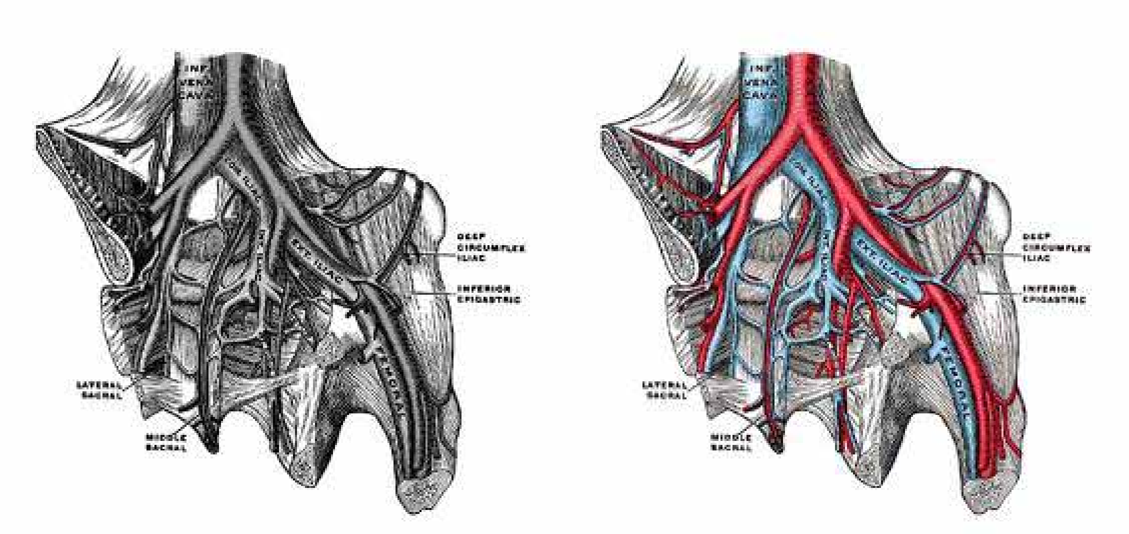

Fig. 4:2 Bartleby.com *The Iliac veins*. Detail. [Online image]. 2000.

Further back in history, other devices for making underlying anatomic structures visible were attempted in printed anatomic texts. An example is the creation of what Petherbridge (1997) terms '*flap anatomies'*, in (fig. 4:3, below):

> The Epitome (Vesalius,1543) was organised so that two of the plates could be cut out and reassembled over the skeleton figure as a 'flap anatomy'. In these, hinged cut-out sections can be picked up successively to reveal the serial stages of the dissected body underneath. The tradition survives today in popular paper anatomies. (p. 27)

Fig. 4:3 Andreas Vesalius. *Epitome*. Detail. Printed image. 1543.
In Petherbridge (1997), *The Quick and The Dead*. (p. 27).

The flap was lifted (in this case from the bottom edge) to reveal the anatomic structures beneath. This simple hinged device is loosely analogous to the process of dissection, where the outer layers are cut away to reveal the interior of the body. It also allows the reader to see the more familiar (and less visually complicated) exterior before examining its relationship to the underlying interior.

In an experiment with the practical work, *Hand* (figs. 3:2, p. 21; 4:4, below & 4:5, p. 34), further exploration into selectively revealing hidden structures was done by creating a work with three superimposed layers. The top layer is a true scale photographic transparency of my right hand[9]. Located underneath are two engraved polycarbonate layers, the uppermost layer is engraved with an approximation of the morphology of the carpal veins and the layer underneath represents the position of tendons in the hand[10].

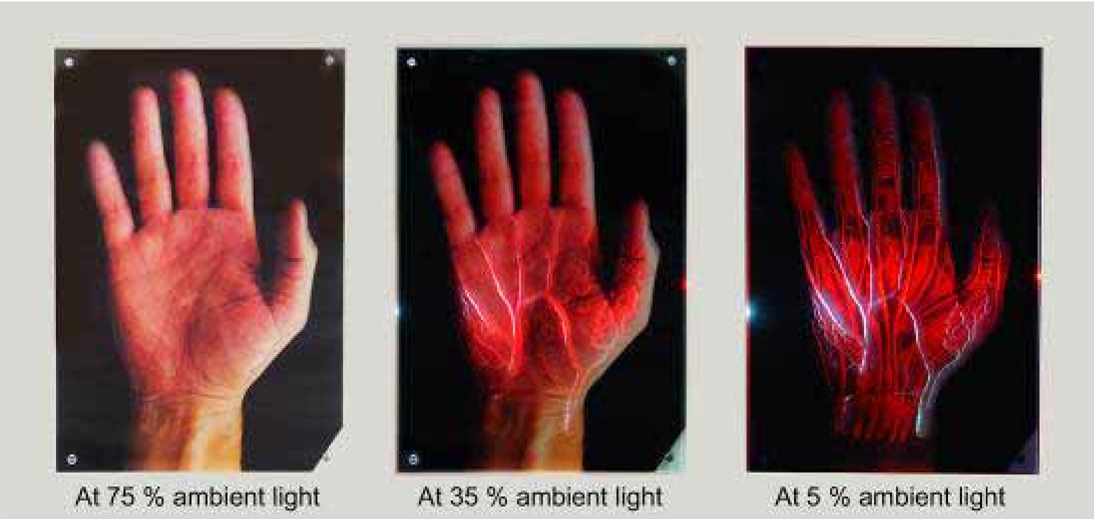

Fig. 4:4 Richard Carthew. *Hand*. Photographic series of practical work. 2007.

This experiment, where the stratified layers illuminate in successive stages, can be seen in operation in a video made as part of the documentation for this work. It is included on the DVD at the end of this exegesis.

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[9] This region was selected as its relatively thin body lends itself well to the concept for exploration and the physical logistics of the experiment.

[10] The guide for the position of these structures was derived from Netter's *Atlas of Human Anatomy* (1989, plate 439), and is an approximation of their respective locations.

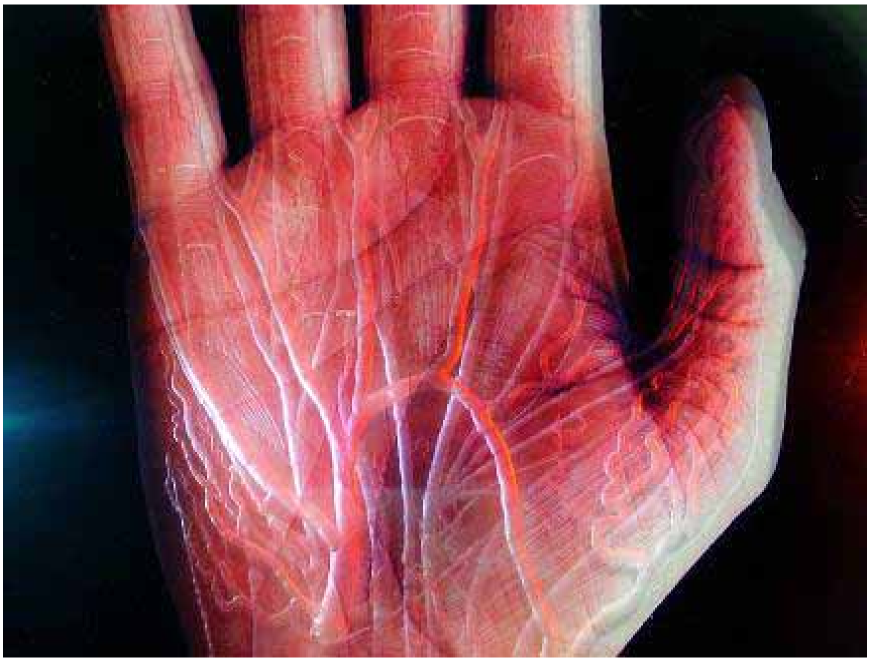

Fig. 4:5 Richard Carthew. *Hand*. Detail. Photograph of practical work. 2007.

The intended method of display is a progression that begins with a initial non-illuminated state (i.e. the left most image in fig. 4:4, p. 33). This is followed by the underlying (and visually obscured) structures being revealed successively by switching on their respective coloured illuminations (red light for the carpal veins, white for the tendons). This allows for each detailed form to be observed independently, or collectively (as seen in fig. 4:5, above) via user input. The observed result of the experiment demonstrated that this concept has good potential in communicating the spatial relationship of complex related units of superficial anatomic systems without the use of a computer mediated virtual model.

4.2 Anatomical imaging and the *Visible Human Project* data-set

Contemporary anatomical representation has an actively growing resource base with many new Human-Computer Interface (HCI) models being currently developed, including the University Medical Center Hamburg-Eppendorf's (2007), previously mentioned *Voxel-Man* (p. 1). The raw data for the creation of many of these resources is sourced from the National Library of Medicine's (2003), *Visible Human Project* (p. 1) data-set. The *Visible Human Project* was commissioned in 1986 by the United States government with the intention of providing an 'open source' comprehensive, high resolution, visual data-set from the cross-sectional scanning (in 1 mm increments) of a male cadaver. The first complete set was completed in 1994. The aim for the *Visible Human Project* is explicitly stated on its homepage:

> This is designed to serve as a common reference point for the study of human anatomy, as a set of common public domain data for testing medical imaging algorithms, and as a test bed and model for the construction of image libraries that can be accessed through networks. The data-set is being applied to a wide range of educational, diagnostic, treatment planning, virtual reality, artistic, mathematical and industrial uses by over 1,400 licensees in 41 countries. (p. 1)

A simple HCI presentation of the *Visible Human Project* data-set, provided online by the University of Maryland (1996), is the *Visible Human Explorer* (p. 1), which allows the user to view and download specific cross-sectional images from within the *Visible Human Project's* body, by using the browser to select their relative locations (fig. 4:6, below).

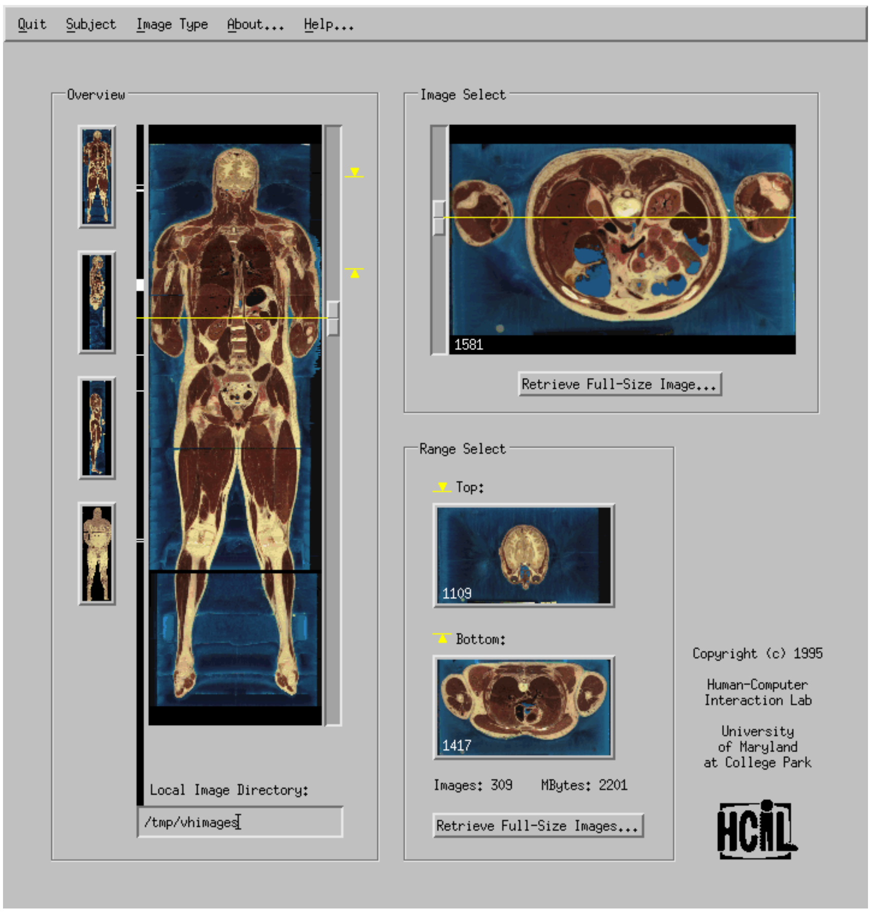

Fig. 4:6 University of Maryland. *Visible Human Explorer*. [Online image]. 1996.

To retrieve desired cross-sections, the user positions the yellow lines using the scroll bars at the edge of the images, sets the range and is presented with an option to download the high resolution data-set. This is a basic but useful mediation of the *Visible Human Project* data-set and was used to select the cross-sectional images to download for use in *Biocuboid* (figs. 5:1-5:2, p.41-42).

Rifkin et al. (2006), focus on some approaches taken in the creation of anatomical models from the *Visible Human Project* data-set and notes in one case, a reversal from 3D models back into 2D representation: "The *Visible Human Project* data-set was intended to be used primarily for 3D modelling in virtual space but several anatomists have adapted it to 2D illustrations." (p. 331). Visible Productions, a company within the Colorado State University also developed techniques to produce virtual 3D models from the data-set completed in 1994, and printed a 2D anatomical atlas from the results.

4.3 The *Visible Human Project* and an artistic approach

In an artistic response to the *Visible Human Project*, Artist Marilène Oliver (2001) downloaded the images from the *Visible Human Project* data-set and recreated a physical representation of the human subject by screen printing the cross-sections onto acrylic (fig. 4:7, below).

Fig. 4:7 Marilène Oliver. *I Know You Inside Out*. [Online image]. 2001.

Oliver states that her intention in doing this was to reconstruct a ‘analogue whole’ from a decentralised, digital and mass-less state:

> I downloaded images of his body and printed them onto sheets of acrylic and then ‘put him back together again’. In making *I Know You Inside Out,* Jernigan was relocated in time and space; returned from a digital to analogue state; no longer decentralized, fragmented and prone, but centered, whole and upright. (p. 1)

Oliver’s reification of virtual anatomic data into physical anatomic representations is a theme that is also central to the *Biocuboid* experimental work (figs. 5:1-5:2, p. 41-42).

In *Biocuboid,* the cross-sections are the physical result (from printing mass-less digital data) from the *Visible Human Project* onto transparencies and storing these at precise locations within the cuboid. The exploration of *Biocuboid* was intended to allude to some principles and qualities inherent in digital data, such as its storage. For example, the acrylic blocks that separate the anatomic representations are of solid, planar form and therefore limit the options (of where the cross-sectional biometric data can be positioned) to levels of integer values within the storage unit. The only other option in this decision is perhaps a binary one; is the cross-section to be included or not? The design of *Biocuboid’s* assembly also allows for this biometric content to be retrieved and exchanged with different data.

The other property in *Biocuboid* that references digital qualities is the relationship between the mass of the content (cross-sectional image printing ink) and the supporting architecture (aluminium and acrylic cuboid). While not zero (like data states), the mass of the printing ink used for the visually perceived brain is many orders of magnitude less than the mass of the supporting unit needed to store and view the data. In this sense, *Biocuboid* has qualities that are similar to the reference of digital and the physical properties in Oliver’s work.

Further comment regarding the potential of Oliver’s method in translating the virtual representations back into physical models that have ‘real’ volume is found on the Scicult (n. d.) website: “Translating flat or screen based medical imagery into a sculptural object allows the viewer to identify spatially with the imaged body as well as repairing its fragmentation/dislocation.” (p. 1). This property of the representation, one of allowing the “viewer to identify spatially with the imaged body” was a similar aim for the experimental outcome in *Hand* (figs. 3:2, p. 21 & 4:4-4:5, pp. 33-34). This is because it demonstrates potential for the viewer to make sense of the inter-relationships of the component structures, through being able to directly observe their spatial orientation in three dimensions.

Part 5: The interplay between art and science

This part considers artistic and scientific approaches to visual representation and the interplay at their intersection. It also reviews further experimentation with techniques in using illumination within anatomic representation.

5.1 The indistinct boundary between art and science

Deep cultural and philosophical issues surround the questions of what can be considered as art? What is science? And also, what can be used to distinguish between the two? Jones and Galison (1998) contextualise this question:

> Analytic attempts to distinguish 'art' and 'science' often founder at the boundaries drawn between them. Do the alligators that hang from the ceiling in the late Renaissance cabinet of wonders at Wurms form part of the history of scientific classification, or part of the history of aesthetics? (p. 1)

Kemp (2005) comments further on this topic by indicating the desired depth for enquiry into the relationship between art and science:

> We serve any enquiry into [the relationship between] art and science badly if our criterion is superficially the influence of science on art, or the influence of art on science. Deeper realms of enquiry concern complex dialogues centred on issues of cognition, perception, intuition, mental and physical structures, the communicative and social action of images, and the role of what we call the aesthetic as a shared instinct across the arts and sciences. (p. 308)

This is a profound question and while this project did not seek to provide solutions to it, an acknowledgment of these issues and the provision of a framework in which the project's experimental outcomes might be read, is necessary.

The project has approached this by considering the experiments as located within *artistic and scientific approaches* to visual representation. For example, qualities associated with the visual representation of science are examined in Kemp's 'issues of cognition' (using Tufte's concept of the *smallest effective difference* as a starting point (on page 20 of this exegesis)). Other considerations in the formal mediation of imagery focus on 'the communicative action of images' with reference to Kress and van Leeuwen in an Aotearoan/New Zealand cultural context (p. 26 & 27 of this exegesis).

5.2 Artistic and scientific modes of representation

Tufte (1997) examines techniques of relative measurement used in the depiction of quantities in images: "visual techniques for depicting quantities include *direct labels* (numbers and gridlines); *encodings* (colour scales, shadows and grey light shadows); *self representing scales* (objects of known size appearing in an image); and *areal extent* (surface coverage)" (p. 3). In the creation of representations that accurately convey the intended message and meaning, Tufte maintains that the creator should be asking themselves these questions: "Is the data carefully documented? Is the representation accurate? Do the methods of display avoid spurious reading? Are appropriate contexts and comparisons shown?" (p. 70).

In presentation of my research practice work *Biocuboid* (figs. 5:1-5:2, pp. 41-42), I did not provide a representative scale (Tufte's *encoding/self representing scales*) or any numbers, legend, or captions (*direct labels*) to frame the work and this led to some spurious readings. For example, I intended *Biocuboid* to represent the *human* brain in transverse cross-section, however chose to make the scale 1:2 for logistical reasons in production, as this model was an experimental prototype. Presenting the work without any of Tufte's visual cues defined previously, left the work open to wider interpretation and one individual enquired (because of *Biocuboid's* physical size) whether the cross-sectional images within the container were sourced from "the brain of a cat", (L. Antonczak, personal communication, May, 2005).

The nature and finish of materials used in *Biocuboid's* assembly (figs. 5:1-5:2, pp. 41-42), were selected to give the work a substantial mass and make it appear to have been machined with a high regard for engineering precision. For example, the highly polished acrylic blocks, milled aluminium square sections and stainless steel grub screws to lock the blocks in place give the appearance of industrial design. This is important if the work is to be regarded as originating from processes connected with science, such as specimen containment and deliberate measurement.

In a detailed view of *Biocuboid's* locking assembly (fig. 5:2, p. 42) further visual signals can be seen that allude to a scientific origin. For example, the machining marks on the work were designed to engender a sense of clinical detachment and an absence of a hand made aesthetic. The subject in this work was presented as a 'Laboratory prepared specimen' encased, untouchable and isolated inside its polycarbonate blocks. After further consideration and feedback, I realised that some concepts I intended to communicate through the work (such as deliberate measurement) were not entirely expressed.

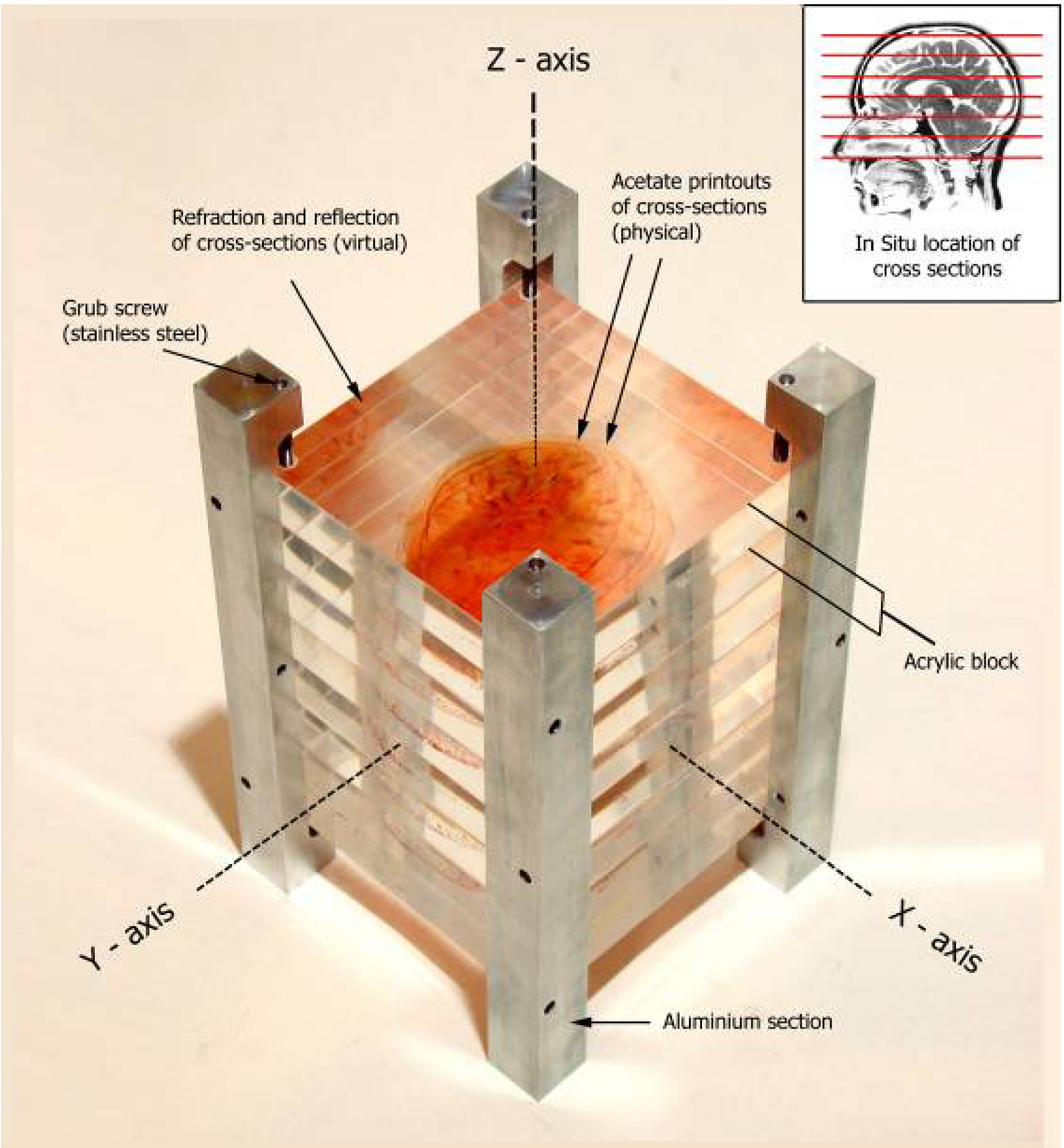

Fig. 5:1 Richard Carthew. *Biocuboid*. Photograph of sculptural work. 2005.

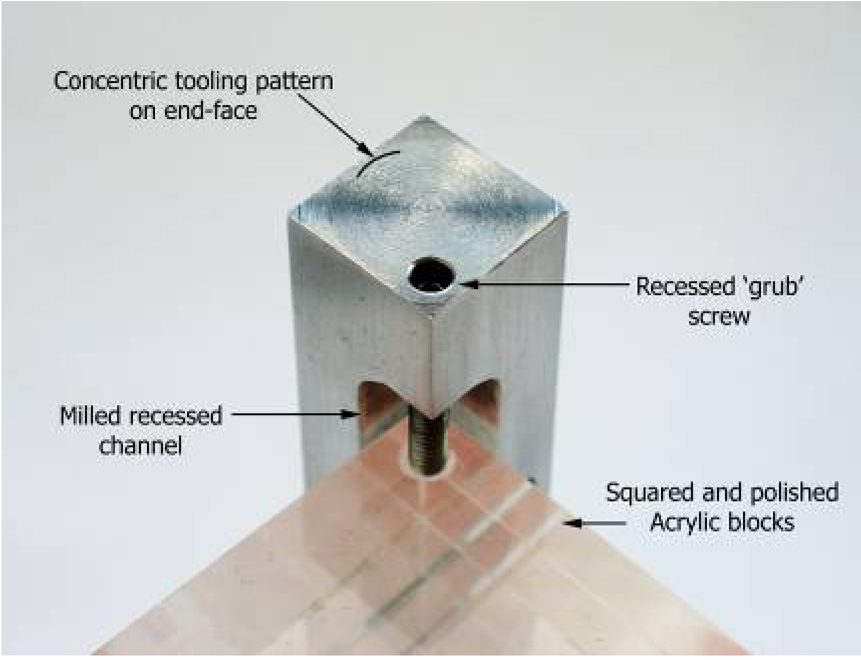

Fig. 5:2 Richard Carthew. *Biocuboid*. Detail. Photograph of sculptural work. 2005.

Tufte sees the inclusion or exclusion of scales, time marks, a key etc, as *quantification* or *dequantification* respectively. This may occur by unintended omission, as in *Biocuboid,* or as a deliberate act. A strategy using 'dequantification' is evident when examining the presentation of Maisel's (n. d.), visual work *Terminal Mirage 26*. (fig. 5:3, below).

Fig. 5:3 David Maisel. *Terminal Mirage 26*. [Online image] (n. d.).

Maisel, a contemporary American artist/photographer, “intentionally obscures the function, location, scale, and condition of his subject” and his reason for doing this is to engage the audience in “the beauty that dances across these large scale prints.” (p. 1).

There is a strategy at work when Maisel deliberately presents the subject in this way, that is not immediately obvious at the first viewing of the webpage. The image is actually an aerial photo of a biological weapons storage dump in the United States that is laid out in a precise matrix of storage units. There is a scientific aesthetic in the geometrical grid form, a product of the units being required to have a minimum distance of separation from each other. This context is only revealed when the viewer navigates further into the website and encounters the caption for this image. When Maisel presents his image this way, his strategy allows the work to be encountered as an aesthetic experience firstly (as he intends) and subsequently as a reference to science.

If this image were presented with the visual and textual information visible simultaneously, with scales, distances and a caption, the reading of the work would tend to be more toward the idea of documentation and scientific narrative, rather than being read as an aesthetic abstraction.

When presenting the first (of four) works in the *Holotype* series (figs. 5:4, p. 44 & 5:9, p. 49), a strategy of visual quantification was adopted. This first work was exhibited with the intention of referencing the scientific processes of collection and classification. Visual elements were included to signal this, such as taxonomic labels, catalogue numbers and the mounting via pinning of the specimen to a stand inside a airtight container. This artefact was placed centrally on a clean white pedestal with a polished aluminium plaque in front that stated: *Holotype*. The purpose of presenting the first work this way was to direct the viewer towards the idea that thematically, *all* of the artworks featured in the exhibit were commenting on scientific processes.

Fig. 5:4 Richard Carthew. *Holotype*. First in series. Detail. Photograph of practical work. 2005.

5.3 Revitalisation of historical techniques by new visual combinations

In an approach that brings together qualities of artistic and scientific representation, *Vesalius-1* (figs. 5:5, below & 5:6, p. 45), combines the highly detailed artistic engraving style of the 16th Century with a technique that uses an illuminated layer to reveal the content scribed within. When lit, this layer reveals an engraved scale model representing a skeletal form that was originally engraved by Vesalius, in Rifkin et al. (2006, p. 17). This is keyed to a second underlying image derived from another engraving by a lesser known anatomist, Joseph Maclise, in Rifkin et al. (2006, p. 289).

Fig. 5:5 Richard Carthew. *Vesalius-1*. Photographic series of practical work. 2007.
A combination of fine engraving skills, contemporary materials and selective illumination (right hand image showing illuminated skeletal form).

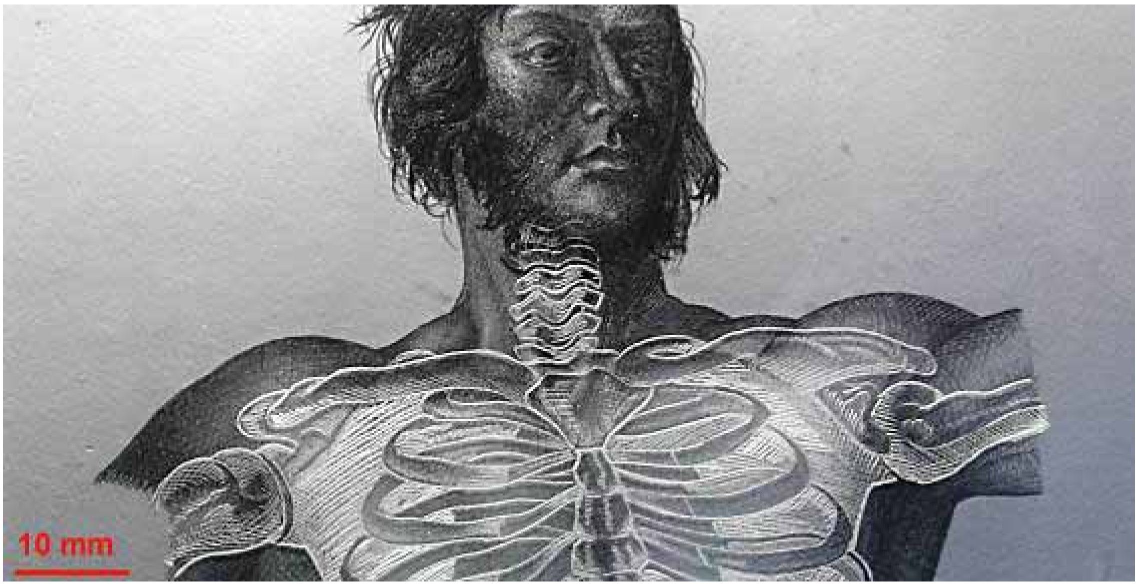

Fig. 5:6 Richard Carthew. *Vesalius-1*. Detail. Photograph of practical work. 2007.

The selection of these two original images to make a pair was primarily based on their complementary visual attributes, i.e. both were drawn from direct observation and from individual specimens.[11] These images were the product of fine engraving techniques and they both were drawn from the same relative perspective, hence were well suited for the overlaid, super-imposed relationship required for this experiment. This experiment was chiefly concerned with the result of the combination of fine engraving skills, contemporary materials and technologies when applied in an innovative way.

A secondary, unexpected feature of the work is that it can suggest an X-Ray-like property when the skeletal form is suddenly ‘revealed’ within the torso of the base level illustration.

The experiment resulted in outcomes that demonstrated good potential when using this technique to illustrate anatomy. In particular, the potential of being able to incorporate two superimposed levels of high detail was effective in communicating visually complex anatomic relationships.

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[11] Other anatomic images by different anatomists, e.g. Albinus, were idealised representations of the human form and were derived from a series of anatomic investigations on different specimens. In Rifkin et al. (2006).

5.4 Exhibition spaces: The museum and the gallery

Methods of display

Audience perception and their contextualisation of an artwork is in some degree influenced by the exhibition strategy used to present the exhibits. If an artistic exhibition is presented in a way which is similar to a didactic museum display, such as the first work in the *Holotype* series (figs. 5:4, p. 44 & 5:9, p. 49), then the audience might assume the exhibition content is designed to inform them of specific information, and perhaps conclude that the exhibit focuses on presenting aspects of science rather than that of art.

However museum display today is designed to be more open to audience interpretation. Hooper-Greenhill (2000) has reviewed the prevalent aesthetic styles in museum exhibitions over the last 200 years and notes this change and the inclusion of interactivity in the exhibits. The use of interactive mediums in representation is defined by Hooper-Greenhill as “Moving from a position of ‘didactic, authoritative display’ to a display that encourages active viewer participation (mutuality)” (p. 2), and currently:

> In museum exhibitions, curators, especially in art museums frequently prefer to leave the meaning potential open and ambiguous. Even where exhibition texts may indicate intended readings of exhibitions, as in science museums, this by no means guarantees a unified way of responding to the experience of the exhibition. (p. 4)

The method of display (or exhibition strategy) played a central role in the desired interpretation of the *Holotype* series exhibition in 2005, (figs. 5:4, p. 44 & 5:7-5:10, pp. 47-50). Four individual but thematically connected works were exhibited in series and these were intended to be ‘read’ left to right (thus following the increasing levels of abstraction of the central subject/holotype).

Fig. 5:7 Richard Carthew. *Holotype*. Series of four works. Photograph of practical work. 2005.

In this early work, I intended to explore the formalised natural science concept of a Holotype and its subsequent abstraction into Paratypes. In the biological sciences, a *Holotype* is defined by the International Commission on Zoological Nomenclature (2007) as “the single specimen upon which a new nominal species-group taxon is based in the original publication.” and a *Paratype* is “each specimen of a type series other than the holotype.” (p. 1).

There is a central theme to the ‘progression of derivation’ through the four works. The central subject in all work is the monarch butterfly with the first in the series (figs. 5:4, p. 44; 5:7(no. 1) above & 5:9, p. 49), containing the actual specimen, which serves as a ‘fake’ holotype (by the holotype definition there can only ever be one primary ‘formal’ specimen designated as a holotype in taxonomy), hence this is the first level of abstraction. The illustrative shellac ink painting (fig. 5:7(no. 2) above), is derived from this specimen and is the second abstraction, moving away from the scientific style of the first work, into a more artistic style.

The third work edges back into a scientific, specimen-like representation (fig. 5:7(no. 3), p. 47), and is a stratified polycarbonate block containing a translucent, printed monarch and the last abstraction (figs. 5:7(no. 4), p. 47; 5:8, below; 5:10, p. 50), is a greatly reduced print (15 x 13 mm) that is only visible through a 20 x 15 mm port leading down a 200 mm solid section of polycarbonate. This work relies on an optical illusion created by the internal refraction of light to produce a matrix of monarchs. This virtual collection of butterflies has notions of display similar to that encountered in 18th and 19th Century museums where specimens were laid out in rows inside vitrines.

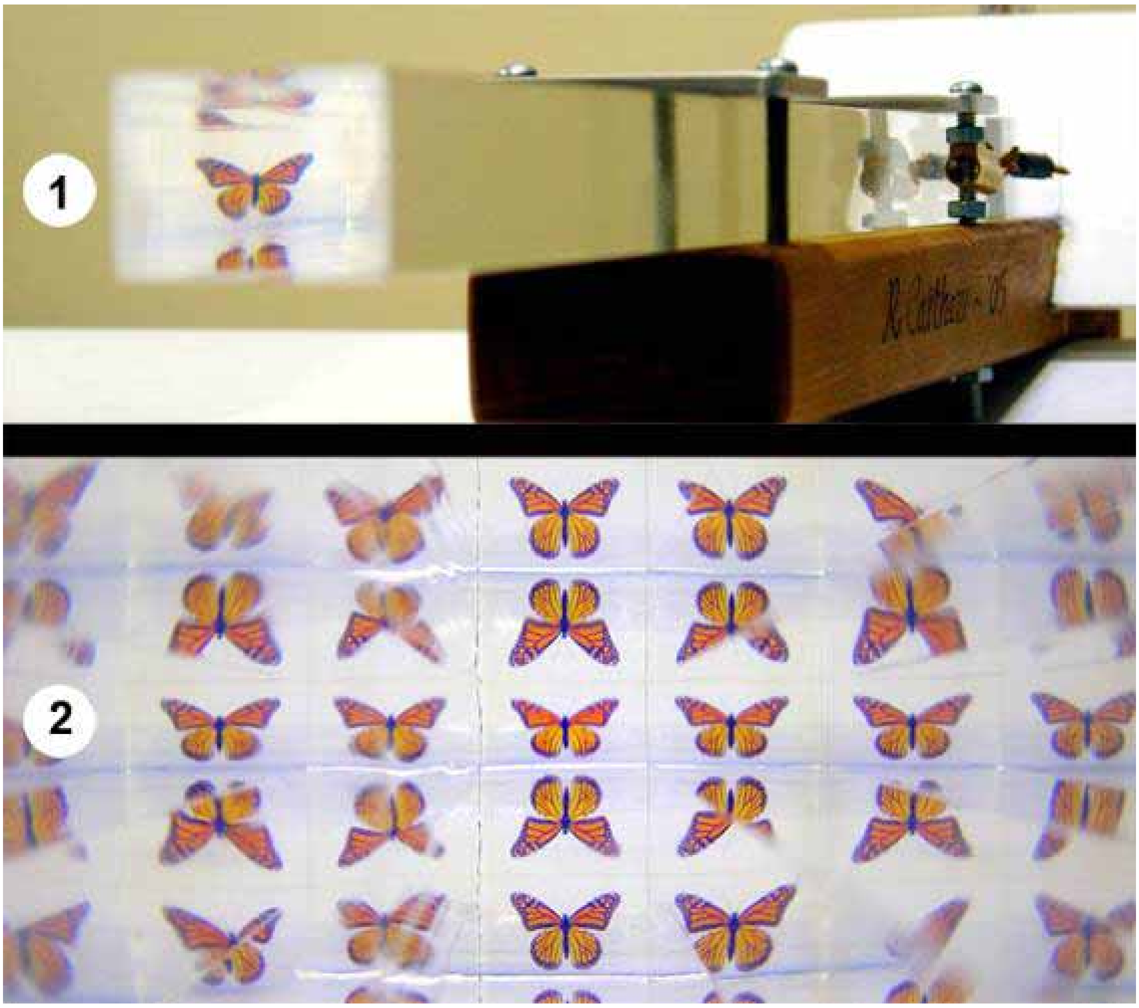

Fig. 5:8 Richard Carthew. *Holotype*. Fourth in series. Detail. Photograph of practical work. 2005.

The viewer is required to actuate a small switch which causes a small light to turn on and provide illumination to create the effect. Image 1 shows the polycarbonate section assembly from an oblique angle and the image of a butterfly can be seen. Image 2 is how the illusion appears when the viewer positions their eye to look down the section. (There are similarities in the illusion produced by a matrix of virtual copies surrounding the central figure within *Biocuboid*).

Overall, the central monarch in each work becomes increasingly synthetic and removed when moving through the series and the viewer's available angles to scrutinise the butterflies diminish (they range from a spherical volume of many metres around the first work, to a 20 x 15 mm aperture in the last work). I was experimenting with a didactic mode of presentation in the first work, creating a mounted, carefully labelled and numbered specimen housed in a sealed glass jar that used these aesthetic devices to re-enforce the authenticity found in typical 19th Century museum displays (figs. 5:4, p. 44; 5:7(no. 1) p. 47 & 5:9, below).

Fig. 5:9 Richard Carthew. *Holotype*. First in series. Detail. Photograph of practical work. 2005.

I intended the visual and physical characteristics throughout the series to move forward from this scientific style of representation and invite more activity on the viewer's behalf, in the way Hooper-Greenhill touches upon above (p. 46 of this exegesis). The last work in the *Holotype* series, to be viewed the way I had intended, relied upon the viewer to get involved, position one eye at a very precise location and then press a micro-switch to the operate the illusion (fig. 5:10, p. 50).

The *Holotype* series was engaged by the gallery visitors at the exhibition, from many angled pathways and not primarily in the left to right sequence as I had envisaged. Had their path been orchestrated to ensure their progression was from left to right in viewing the sequence, there is still no guarantee that this defined order would have produced the intended reading; one chiefly of increasing abstractions in the work and one of increasing control over the position of the viewer. One approach that may have helped to create this appreciation would have been to provide more textual material leading into these concepts or more proactively, designing a visible pathway to be followed.

Fig. 5:10 Richard Carthew. *Holotype*. Fourth in series. Detail. Photograph of practical work. 2005.
Last work in series. A switch actuated by this viewer powers an LED to view the illusion.

Anatomics and exhibition

Anatomics was the final artwork produced within the scope of this project and featured in the 2007 Auckland University of Technology Art & Design Postgraduate Exhibition. The work consisted of three main components housed in a free-standing sculpture designed to be encountered in a predefined sequence in a similar strategy to that employed with *Holotype*. The strategies and methods used in the exhibition of this work and the audience response are covered in more detail in *5.6 Anatomics: A more artistic approach to anatomic representation* on pages 54-61.

5.5 Projection illumination and reflection in anatomic representation

A larger scale experimental work, *Inguinal Projection* (figs. 5:11-5:12, pp. 51-52), was created to explore the potential in projecting an animation (virtual component) onto a three-dimensional surface to effectively communicate spatial relationships.

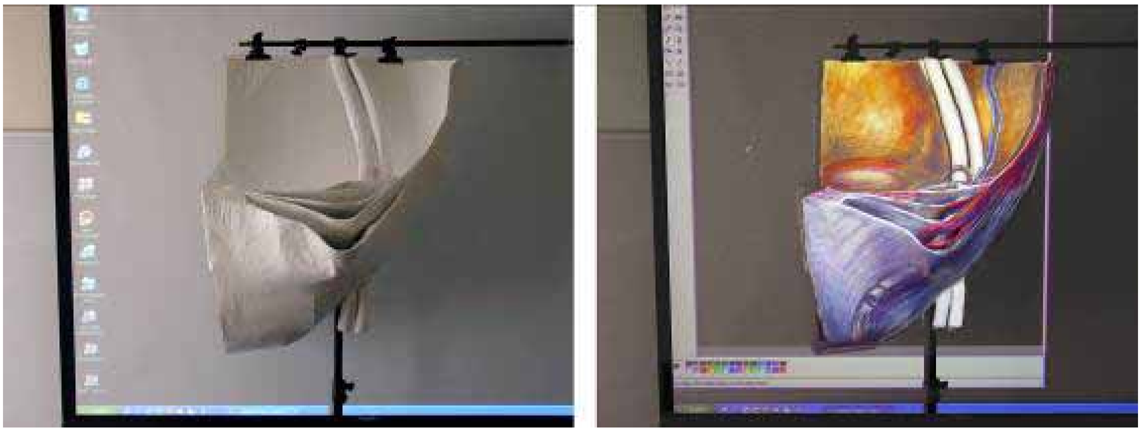

Fig. 5:11 Richard Carthew. *Inguinal Projection*. Photographic series of practical work. 2007. This model is seen without the projection on the left and with the projection on the right.

To produce the physical structure, first it was necessary to interpret the spatial relationships of the main anatomic structures within the chosen region (the Inguinal canal). This was done with the aid of Netter's (1989) *Atlas of Human Anatomy* (plate. 439), and direct consultation with Dr. Phil Blythe, an Anatomy lecturer at the University of Auckland Medical Sciences Learning Centre (personal communication, October, 2006), and Heather Clark, Physiology lecturer, AUT. (personal communication, November, 2006).

A wire-frame model was then fashioned which provided a base for the overlying papier-mâché screen. Further adaptation of the initial virtual projected image was necessary for it to be visually cohesive with the physical model[12]. The projected component issued from a single point source and this resulted in differential illumination across the curved surface.

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[12] A video demonstrating the projection in operation can be seen on the DVD in the back of this exegesis.

During the design phase of this experiment it was known that areas at 90 degree angles or greater to the incident light would not receive any illumination. It was decided to proceed with the experimentation allowing for this and should the combined effect have potential in demonstrating anatomic relationships, the introduction of a second projector could be considered. The result when the model was operated served to give a sense of spatial depth across the inguinal structure, but in comparison with other practical work previously covered, had less richness of detail within the structure (fig. 5:12, below). This loss of detail can be attributed partly to the technical limitations of the digital projector where limited resolution introduced pixel artifacts, reducing the clarity of focus in the image.

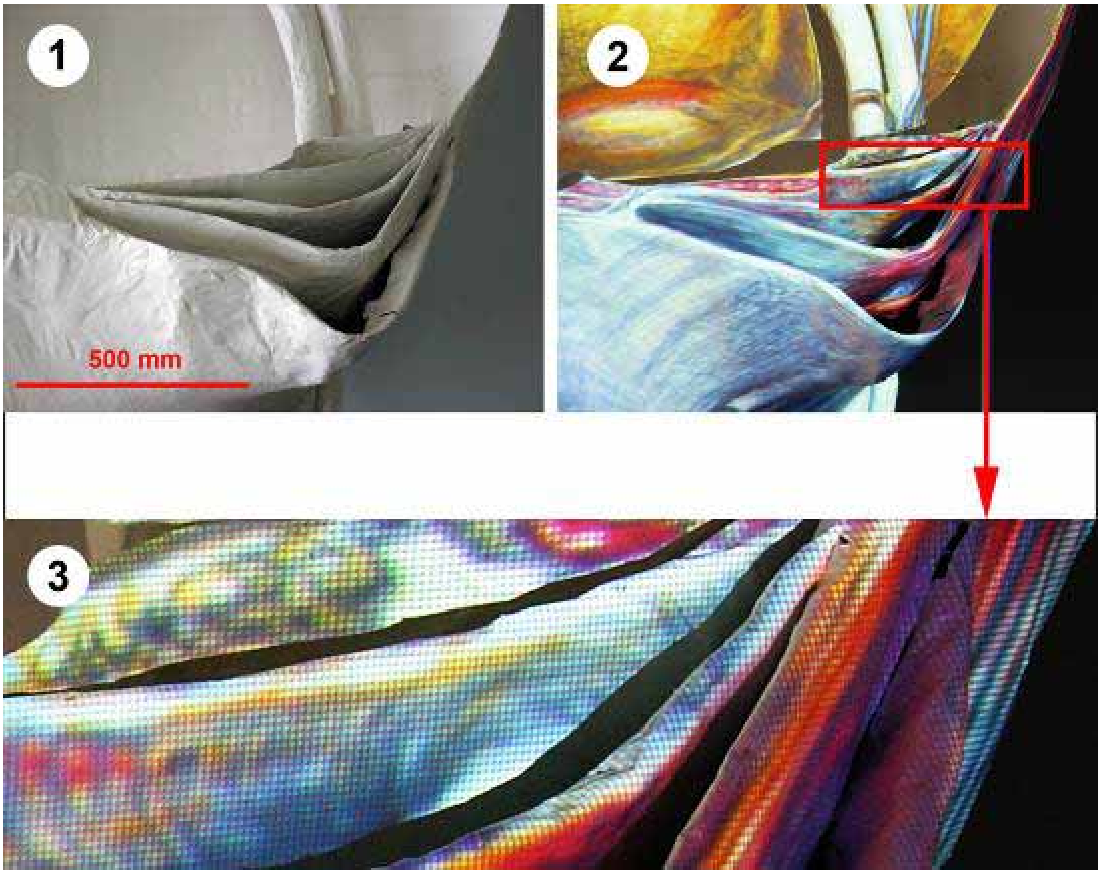

Fig. 5:12 Richard Carthew. *Inguinal Projection*. Detail. Photographic series of practical work. 2007.

Image 1 is a close-up of the wireframe and papier-mâché structure, and Image 2 is the projected animation. While the model provided a sense of spatial depth, the loss of detail due to the limited resolution of the projector, can be seen in image 3, (detail of area within red square in image 2). Image 3 appears to be out of focus, but the areas in deep shadow have sharp boundaries, indicating in this image that the loss of clarity is a property of the projection.

Overall, the potential of the work to display anatomic detail could be improved by using two data projectors with greater resolution. However, it was decided to conclude the experiment at this point, because the physical qualities of the model (fragile, cumbersome and of limited morphological detail) made the potential gain minimal in comparison with some other experimental approaches that showed more promise.

Illumination and reflection in anatomical representation

In more recent experimental work, *Corpus* (figs. 5:13 below & 5:14, p. 54), an on-screen animation via a laptop computer was designed to provide the potential for changeable content that is seen via reflection in a dark tinted sheet of polycarbonate. Set in behind this reflective base are two superimposed sheets. The top layer is a deeply engraved representation of the human brain in sagittal cross-section and the layer fixed behind is a smaller engraving of the Corpus callosum[13].

The engraved forms are not visible initially, but can be revealed or hidden when desired. This is achieved by switching on LED's situated at the margin of the acrylic sheeting which illuminate the engraved structures within. The entire assembly is designed to be housed inside a controllable lighting environment set with low ambient light. The position of viewing aperture ensures that the animation is correctly positioned over the cross-section.

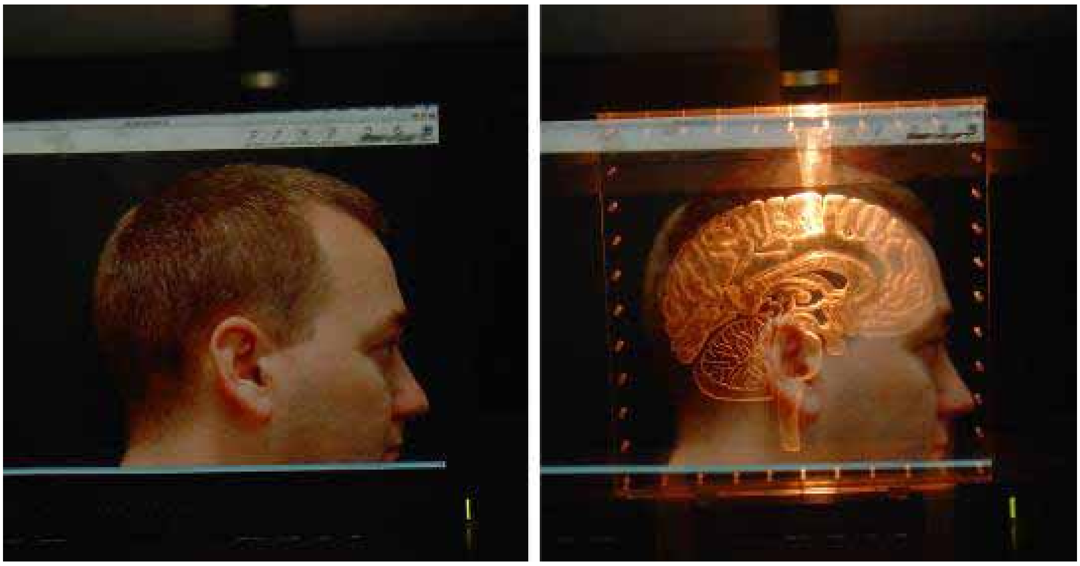

Fig. 5:13 Richard Carthew. *Corpus*. Photograph of practical work. 2007.

[13] The Corpus callosum is a structure that connects the left and right cerebral hemispheres.

Reflected animation begins the work with the integral component at rest (left image), and continues with an illumination at an appropriate time (right image).

In *Corpus* (figs. 5:13 above & 5:14, p. 54), the principle of timed illumination to reveal the underlying anatomic structures behind the image is similar to the principle used in *Hand* (figs. 3:2, p. 21 & 4:4-4:5, pp. 33-34). It builds from this earlier work however, by using animated images for the reflected component. In addition, it has the potential for a selected structure within the engravings illuminate at appropriate times based on the animation's narrative. For example, when an explicit reference is made to the Corpus callosum, this structure can appear illuminated in-situ within the profile of the head (fig. 5:14 below).

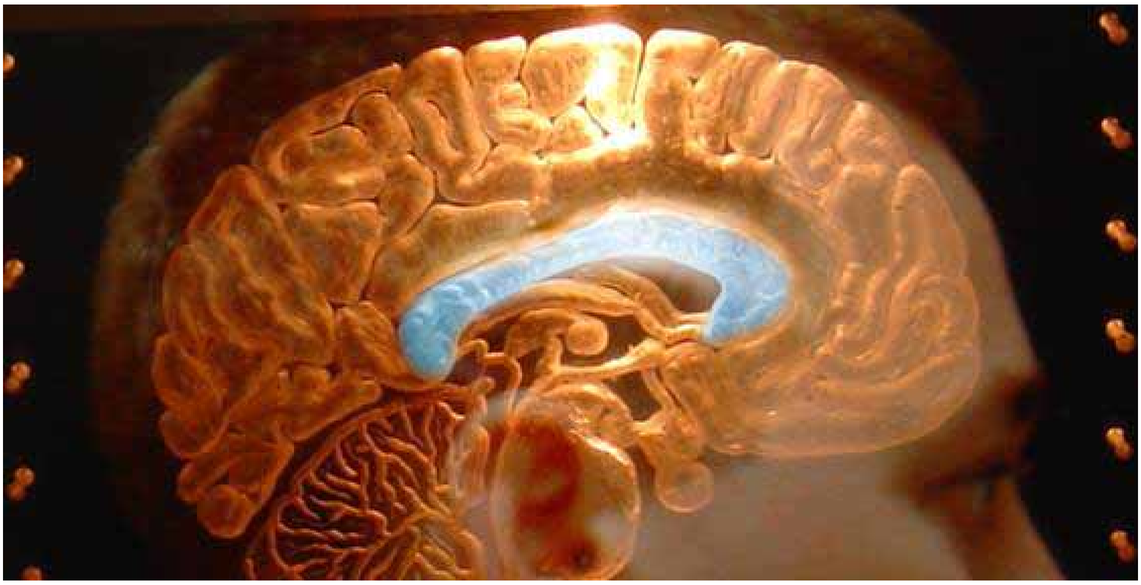

Fig. 5:14 Richard Carthew. *Corpus*. Detail. Photograph of practical work. 2007.
The Corpus callosum is the structural feature highlighted in the central blue illumination.

The physical component of this work exhibits a quality that becomes evident if compared with animated work that is displayed on-screen only; the ability for the viewer to perceive physical structures within the cross-section as stereoscopically three dimensional. This has the visual effect of promoting the spatial relationships in a more accessible way than a flat, on-screen representation.

5.6 *Anatomics*: A more artistic approach to anatomic representation

Overview

Anatomics (figs. 5:15-5:21, pp. 55-61) was the final work produced within the timeframe of this project and was exhibited at the Auckland University of Technology Postgraduate Exhibition at the end of 2007. This sculpture developed into the most complex, highly finished and largest scale piece produced during the entire project, being 2000 mm tall, 666 mm wide and 500 mm deep.[14] One motive in producing the artwork to such a large scale (relative to previous experimental work) was to impart it with a greater potential 'presence' when viewed, given the knowledge that it was to be exhibited in relative isolation due to the generous gallery space available.

Fig. 5:15 Richard Carthew. *Anatomics*. On exhibition site. Photograph of practical work. 2007. The work is seen here from the frontal elevation and 'at rest' (i.e. the interactive elements are awaiting activation by the viewer). The step on left activates the backlighting for the cross-sectional representation of the brain.

The complexity in *Anatomics* arose from the combination of: (i) The desire to further develop and integrate effective qualities discovered in earlier experimental work such as *Holotype*, *Biocuboid*, *Hand* and *Corpus* in tandem with (ii) Designing the work to include some form of appropriate interactivity to respond to passive and active viewer intervention (with reference to the

[14] Dimensions for the total height of the anatomic representation match the height (1872 mm), of the subject used in the *Visible Human Project* (2003).

principle expressed by Hooper-Greenhill of "active viewer participation" on page 41 of this exegesis).

High production values were applied throughout the creation of *Anatomics* as this piece was intended to represent the summation of the effective concepts and techniques developed over the entire project.

Main structural features and experiences

Anatomics possesses three distinct regions of experience within its structure that are designed to be seen in this order:

(1) A frontal anatomic representation of the superficial muscles and veins in the head and upper torso region (fig 5:16 below); (2) A side mounted cross-sectional (sagittal) representation of the central nervous system (figs. 5:17, p.57 & 5:18 p. 58) and; (3) A keyhole simultaneously allowing two perspectives: the foreground, revealing a discrete part of the interior of *Anatomics;* and the background, where part of the gallery is visible through the reverse side of the frontal representation (fig. 5:21, p. 61).

This sequence, if followed was designed to give an overall encounter with anatomic representation that lead from superficial anatomics through to deeper structures and concluded with a visual metaphor of the subject itself with reference the key anatomists influential throughout the project. (fig. 5:20, p. 60).

The frontal anatomic representation (fig. 5:16 below) further developed the layered illumination technique first discovered in *Hand*, extending the format 10 times in areal extent.

Fig. 5:16 Richard Carthew. *Anatomics*. Detail. Photograph of practical work. 2007.
The frontal anatomic representation reveals itself, illuminated by the viewer's proximity. The right-hand image clearly shows the two anatomic features (muscles & veins) and 'additive colour mixing' of the blue and red light that produces a magenta hue .

This increased size was very effective in engaging the audience, but it did result in greater additive colour mixing between the layered red and blue engravings, creating areas of magenta (fig. 5:16, right-hand image, p. 56). The representation was set to illuminate when the viewer approached to within about 2 metres via a passive Infrared detector (P.I.R.). When this is considered in a scientific context, there is a temporary cyclic process of electromagnetic exchange operating at this time: The viewer closes the circuit when their body heat transmits electromagnetic I.R. waves which are detected within *Anatomics*, triggering illumination of the body that in turn propagates electromagnetic light waves back to the viewer. During the exhibition, the IR detector demonstrated some operational foibles which could be overcome by using a different method of proximity detection, such as laser range finding.

The side mounted cross-sectional (sagittal) representation of the central nervous system (fig. 5:17, below) expanded qualities discovered in the Biocubiod experimentation. A human sized 1:1 scale model was created using image data sourced from the *Visible Human Project* (National Library of Medicine (2003)).

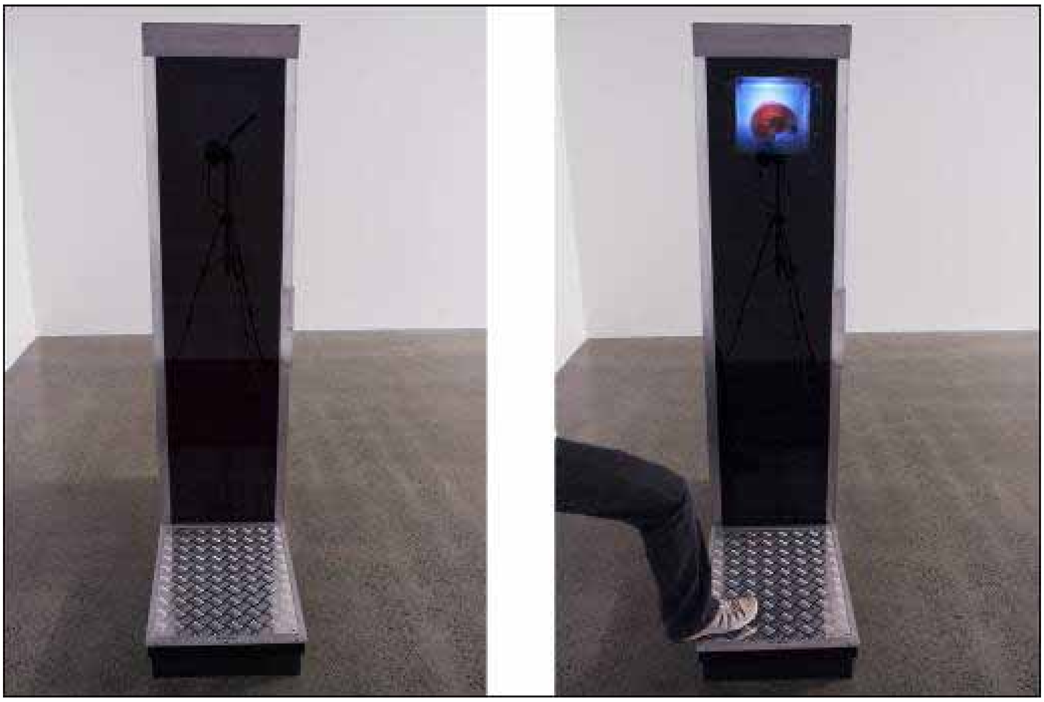

Fig. 5:17 Richard Carthew. *Anatomics*. Photograph of practical work. 2007.
Side mounted cross-sectional model of the brain. Pressure on the step activates the backlight for this representation and also allows viewers of average height to have a view perpendicular to the stratified cross-sections as intended.

This model was vertically mounted according to its correct relative position to the frontal representation.[15] This required the inclusion of a step into *Anatomics'* overall design thereby allowing a viewer of average height to see through the cross-sections at an angle of 90^0 to their planes as intended.

Visual cues encouraged attendees to stand on the step, thereby activating a pressure switch backlighting the representation of the brain.

A secondary illumination (within the cross-section) is activated by sound waves and visually locates the auditory processing area within the temporal lobe of the brain.

[15] Using the total height (1872mm) of the subject used in the *Visible Human Project* (2003).

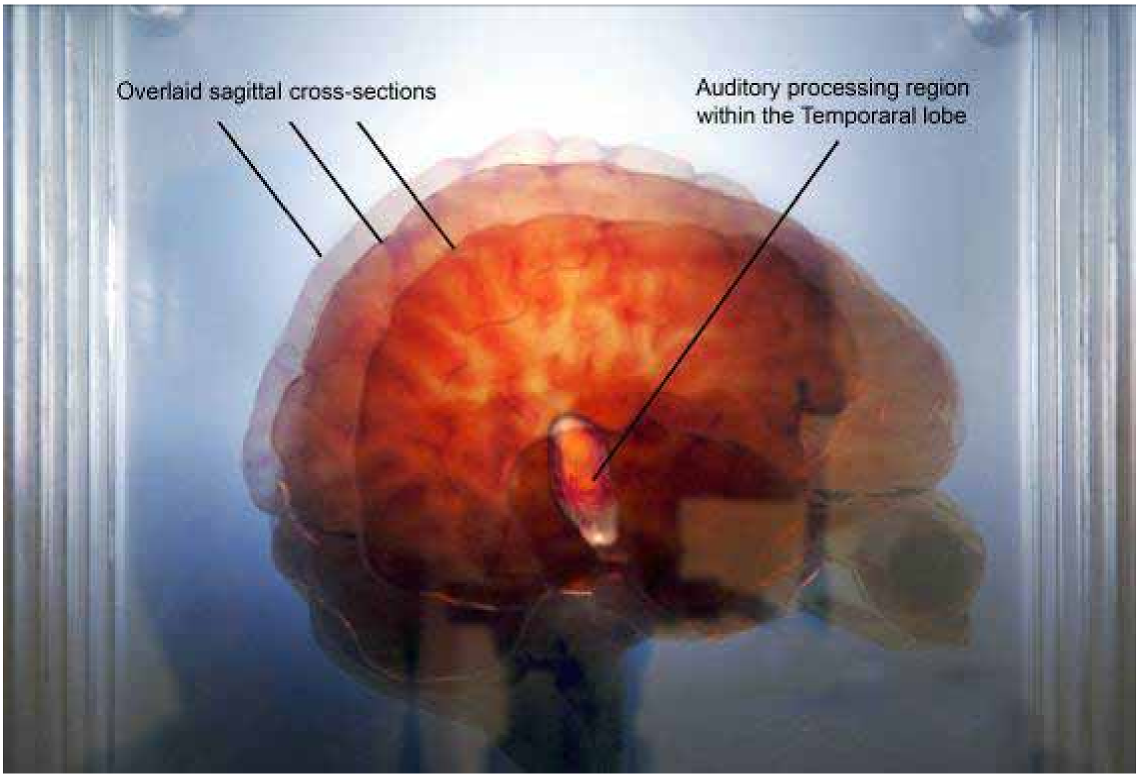

Fig. 5:18 Richard Carthew. *Anatomics*. Detail. Photograph of practical work. 2007.
Side mounted cross-sectional model of the brain. One of the cross-sections contained an engraved structure (indicated) that is activated by sound causing it to illuminate. This shows the approximate position within the CNS of the auditory processing region.

The intention of including this visual device is to demonstrate functional anatomic regions at greater depths within the body than the frontal representation. This feature of illumination responding to the viewer's input seeks to create a sense of mutuality with the viewer. In addition to this, its operation can be seen to approach a technological mimesis of the biological process it represents.

Access to the third experience offered by the artwork is signalled by a small plate titled *Anatomics* with a keyhole at its centre designed to incite the spectator to peer through it. A keyhole can be regarded as a transitional portal or boundary between two adjacent but physically separated regions. In the context of *Anatomics*, it serves as a visual allegory for the boundary existing (pre-20th Century) between visual external and internal anatomy. Looking through it reveals the internal properties of the work otherwise hidden from view and a reflection upon the foundations of the project.

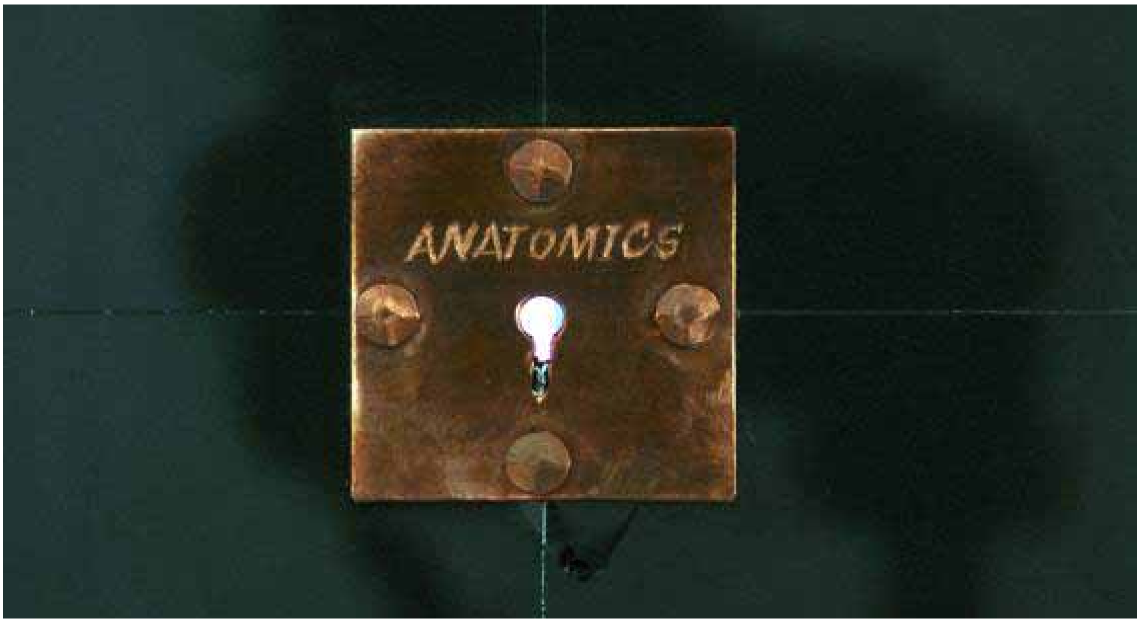

Fig. 5:19 Richard Carthew. *Anatomics*. Detail. Photograph of practical work. 2007.
Title plaque and keyhole mounted on the rear. Copper was used to reference the historical background of this project in union with a graphic timeline inside charting key historical anatomists (fig. 5:20, p. 60).

Progressing to this stage, the anatomic material represented has quickly shifted from the superficial to the very deep. Consequently, the third component to avoid repetition did not portray more anatomic structures of a similar character. This provided an opportunity to incorporate material of a different nature and resulted in a reflection upon some of the contexts surrounding visual anatomic representation and the project itself. For example, when looking through the keyhole, the foreground reveals a graphic timeline that contains references to key anatomists' work featured in this exegesis and which influenced the project's practical experimentation. This is an adaption of an earlier concept involving a timeline projecting across the gallery floor from the frontal elevation that proved impractical to implement.

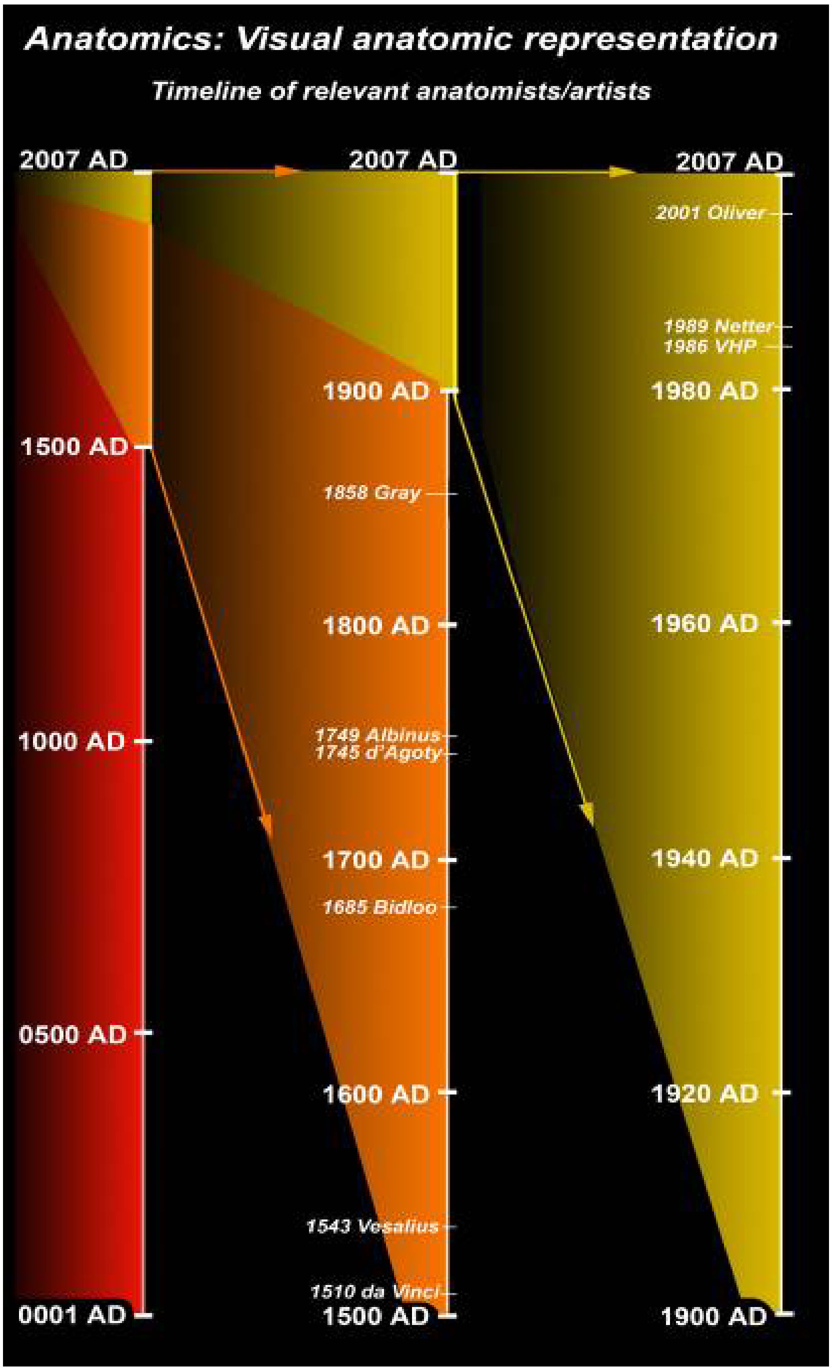

Fig. 5:20 Richard Carthew. *Anatomics*. Detail. Image of practical work. 2007.
Graphic representation indicating key anatomists and their respective dates of publication for their influential work.

Also visible through the keyhole (in the background) is the approach path taken by the exhibition attendees through the gallery entrance toward *Anatomics.* When observing attendees from this viewpoint, occasionally one will position themselves in front of the work in a location where the magenta vertical line (representing the edge of the medial sagittal plane) appears to overlay and bisect their body (fig. 5:21, below).

Fig. 5:21 Richard Carthew. *Anatomics*. Detail. Photograph of practical work. 2007.
View through *Anatomics'* keyhole. The anatomists' timeline graphic (fig. 5:20, page 60) is located in the foreground and in the background is the gallery with a viewer visible midway between the gallery entrance and the translucent (from this perspective) *Anatomics'* frontal acrylic plates.

The visual perspective of this particular viewpoint can be perceived as one offering a 'mirror-image, reversal or a loop back' from the viewer's initial, exterior perspective when viewing *Anatomics*.

Overall, *Anatomics* appeared to work well in engaging the audience as an exhibition piece and arousing people's curiosity[16]. It was especially interesting to see the feed-back loop develop, where the viewers would interact with the work and subsequently modify their actions based on *Anatomics'* response.

[16] There is a video of *Anatomics* operating in the gallery, which includes a small clip from the exhibition. This can be viewed on the DVD at the end of this exegesis.

There was a slight operational issue with triggering the frontal illumination by using the infra-red system. The detector tended to illuminate the frontal representation in response to an approaching viewer, but the duration of its visibility tended to be too brief, with the LED lighting assembly switching off after approximately 1 second. A small change of design could resolve this issue and one possibility would be the incorporation of a laser range finding unit which could be set to keep the frontal component visible until the viewer moved out of range.

Part 6: Conclusion

This project has been an exploration into the methods and models in which the communication of visually complex information can be achieved by a combination of artistic and scientific approaches in representation. Visual anatomic representation has been an ideal subject to explore as it is positioned at the intersection of these two modes of depiction. Anatomic representation combines elements of scientific information with artistic interpretation and form to mediate complex biological knowledge.

Theoretical material was researched from a range of sources to provide an informed starting point for concept development and further practical experimentation. Included was an investigation into historical methods in anatomical representation, from which much imagery necessarily survives in contemporary methods of anatomic representation.

Products from modern medical imaging such as the *Visible Human Project* and work derived from it were critically examined to determine their approach in anatomic modelling. The *Visible Human Project* also provided material for further experimentation developed using cross-sectional modes of representation and this is evident within the final exhibition work, *Anatomics*.

The practical outcomes of the project have been realised from a series of experimental works created using an artistic and scientific approach. From this approach, some experiments were devised that used forms of imagery contained in layered polycarbonates. The central principle in these experiments; of selectively revealing key structures within the models, helped communicate their individual morphologies and also their inter-relationships to their surrounding structures. This technique of ‘isolation through highlighting’ is an effective strategy in overcoming the visual complexity that can arise when viewing complex, layered scientific imagery.

The final artwork produced within the project, *Anatomics,* signalled a shift of focus in the overall visual mode used for anatomic representation. The anatomic material was exhibited with a distinctly artistic approach to its presentation, one concerned more with aesthetic experience than depicting scientific accuracy. This was intentional and appropriate given the environment of the art gallery where the work was exhibited.

Further directions for practical experimentation with anatomic representation will continue with this approach, i.e. using scientific imagery and strategies of representation to inform fine art practice. Current experimentation is underway to investigate the potential of user-programmable micro-processors for controlling elements of desired interactivity in artworks. For example, the Italian produced *Arduino Diecimila* (2008), is the micro-controller board forming the platform for the current experimental work. This unit has input and output pins designed to connect to sensors, motors and lighting assemblies etc. The unit is sold with a software application which allows the user to create uniquely coded programs that, when downloaded to the board, will interface with physical elements connected to it by the artist. Once the program is downloaded to the micro-controller's memory, the unit can be disconnected from the computer and run independently (connected within a sculpture) using a 9 Volt power supply.

A simple example of a possible application of this unit could be to set it up within an anatomic sculpture and program it to detect (and respond) to an approaching viewer. This would be achieved using sensors connected to the input pins, so as this hypothetical person advanced, different events, such as a series of illuminations, could be made to appear in sequence depending on the viewer's relative position.

In conclusion, this level of customisation, of being able to embody unique interactive experiences within detailed, multilayered, sculptural works, could show great potential in developing engaging artwork that enhances anatomic visualisation.

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