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THESIS

THE AESTHETICS OF REPRODUCTIVE MORPHOLOGIES

By
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Statement

This volume is presented as a record of the work undertaken for the degree of Doctor of Philosophy at Sydney College of the Arts, University of Sydney.

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Acknowledgements

This project would have not been possible without the unconditional support of many individuals who believed in the merit of my research and encouraged me to do so. Even though it is my research, the scope of my project and its ambition would have not been able to be developed without collaborating with other artists, academics and technicians. I would firstly like to thank my supervisor Ross Gibson, who kept me on track for four long years, always keeping the big picture in mind. He guided me in a field unknown to me: academic writing. Thanks to his insights I was able to tame my enthusiasm and deliver a proper thesis. I want to thank my editor Ross Harley, who helped me on the last stretch to get it into a tight form. Thanks to Sue Linsday, microscopist at the Australian Museum, who encouraged me to pursue my dream to make 3-D models out of electro-microscopic scans, and had the patience to sit with me and scan miniscule specimens multiple times until we achieved the results we wanted. Thanks to Andrew Simpson from Vert Design, who was not afraid to experiment with me to achieve what no one had achieved before in 3-D modeling, and who found the talent and technologies to do it. Thanks to Matt Booth, for his great eye and technical skill in computer modeling, and for taking the risk of tackling this subject matter. Thanks to Valerie Odewahn, Tony and Johnathan at Sydney College of the Arts, who helped me 'make things', and answered technical questions absolutely every day I was on campus. There was so much to learn from them. Thanks to Nick Greenwich, from the 2-D Digital Lab at Sydney College of the Arts, with whom I learnt to work in 2-D digital image printing. Thanks to Allan Jones at the Centre for Microscopy at Sydney University. Thanks to Mark Elliot for lending me his flame glass skills to make some beautiful objects. Thanks to Gary Warner for the thoughtful and effective museological design, display case design and object support, and especially for the beautiful miniature lighting he did for the show at Cockatoo Island. I enjoyed working with him making every decision a thoughtful one. Thanks to Philip Sticklen for his beautiful craftsmanship of the display cases. Thanks to Bill Eberhard for his generous comments, and for letting me use his drawings as inspiration for many of my artworks. Thanks to the Australian Museum for giving me access to its microscopic collection of animal genitalia, and for lending me some Harvestman specimens for the exhibition at Cockatoo Island. Thanks to Sydney College of the Arts, who gave me access to fabulous facilities and a beautiful environment in which to study and make art. Thanks to Sydney University for the UPA Scholarship, and thanks to Arts NSW for their generous support for the exhibition of my project at the 18th Biennale of Sydney. Thanks to the Biennale of Sydney for lending me Building 123 at Cockatoo Island and for an audience of over 600,000 people. Thanks to Catherine de Ziegler and to Gerald McMaster, curators of the Biennale, for inviting me to participate. Thanks to Emma Watts for her thoughtful documentary *The Wonderful World of Professor Cardoso* produced by ABC TV Artscape, which followed the project prior to the exhibition at the Biennale, warming the audience to the show at Cockatoo Island, and presenting my

perspective as a woman artist to the public. And lastly, I would like to acknowledge and thank all the many volunteers who gave me at hand with the installation and de-installation of the project on the island.

List of Illustrations

Summary

This thesis is about the diversity and complexity of genitalic morphologies. It aims to answer two interrelated research questions: What contribution can visual arts research and practice make to a general public's understanding of complex scientific phenomena, and what strategies are most effective for representing these phenomena in a way that honours that complexity and engages the viewer comprehensively and with well-informed affects, beyond the simple provision of verbal information?

I have approached this research as an artist, from a visual and sensory perspective. I have made original images and objects that stand on their own as artworks, at the same time that they communicate scientific concepts that are difficult to convey to a general audience. The thesis aims to understand the science behind the general question of morphological extravagance, and to create 'plastic' forms that can engage meaningfully with a general audience.

My two research two topics focus on the complex forms and competing theories that are currently put forward to explain the incredible extravagance of animal genitalia. Through my practice as an artist, I show that an artistic/museological mode of communication is an effective means of generating and disseminating the inter-disciplinary knowledge that I synthesise here.

The thesis investigates the complex and various morphologies of selected animal genitalia, placing the scientific understandings of their form and function into a cultural context (that of the museum). My artwork comments on how museums of natural history have had a general and continuing influence on how the public engage with 'artful science'. This project provides a new and original understanding of the aesthetic, pedagogic and communicative possibilities of the museum as an art form.

The research also draws upon established biological pathways (including 'biophillia' and 'formaphillia') that shape emotional and aesthetic affinity for biological form and novelty. I also mobilise non-literary forms of communication, such as three-dimensional displays, audio-visual information, and limited written text to engage the general public and specialised audiences alike. And finally, I use the allure of sexual selection, what we might call 'aesthetic selection', to seduce large audiences and to trigger a sense of curiosity, awe and wonder.

Introduction

> …. from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.[1]
>
> Charles Darwin (1859)

So it ends the famous naturalist Charles Darwin in his ground-breaking study, *The Origin of Species*. Darwin's insights into the evolution of natural life forms have proven central to my research, providing a way into thinking about the complexities and intricacies of natural history. Indeed, this thesis is about those *most beautiful and most wonderful* and most complex genitalic morphologies that are constantly evolving in the natural world that surrounds us and that we are a part of.

My interest in this thesis is on genitalic form. The reproductive morphology of a great many species changes so quickly that evolutionary biologists can measure significant change and differentiation in a matter of a few generations. In terms of evolutionary biology, we can safely say that animal genitalia evolves *rapidly and divergently*, which is to say that it evolves faster than any other anatomical feature or characteristic. This is why, unknowingly, taxonomy has used genitalia as a taxonomic tool to identify species for the past three hundred years. Also unbeknown to taxonomists were the causes of genitalic extravagance, or complexity. As an artist, this subject matter provides an endlessly fascinating and engaging series of morphologies that provide the central thread throughout my work here.

This dissertation is about the aesthetics of reproductive morphology. My aim is to discover why is there is so much diversity and complexity in copulatory organs, and to find the best way to present my findings to the public. I will do this by way of a studio-based research that makes a contribution to our understanding of complex natural forms that are routinely studied by evolutionary biologists. As a contemporary artist concerned with the relationship between the human and natural world, I ground my research squarely in the naturalist tradition, focusing my attention on the ways that early collections of natural history and taxonomy help us to investigate this topic in a rich and complex manner.

My research also belongs to the tradition of comparative anatomy, which studied patterns of form and of embryology, which studied the development of form. Comparative anatomy studies the development of morphology, and the anatomical and scientific models developed by this field provide excellent examples of how science and art were once fully integrated. The research conducted in this PhD therefore belongs to the tradition of evolutionary theory, which seeks to explain the origin and purpose of genital form and function. The

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[1] Charles Darwin, *The Origin of Species by Means of Natural Selection : or the Preservation of Favored Races in the Struggle for Life* (Cambridge, Massachusets: Harvard University Press, 1859; repr., 1964). 490.

fact that animal genital morphologies are used by scientists to understand the dynamics of evolutionary forces such as of sexual selection, places my arts-based research at the cutting edge of evolutionary biology.

My interest in the complex organs of sexual reproduction began many years ago in an artwork that I created about fleas. The work involved the transcription of what to me was an incredible quote about fleas onto a didactic wall panel, presented as a blackboard with white chalk hand-writing. It's worth including the full text here, as it will give an insight into the core of my dissertation:

> Genitalia are confined to the last two segments of the abdomen, and flea copulation has been hailed as one of the wonders of the insect world. The male, normally much smaller than his mate, slides beneath her from behind, embraces her back-to-belly with his antennae and softly caresses her genitalia. Then his tail curls up like a scorpion's and he penetrates her with what Brendan Lehane calls "the most elaborate genital armature yet known." The male, he writes, "posesses two penis rods, curled together like embracing snakes. Inside his body, the smaller rod moves outwards lambently, catching delicate skeins of sperm and moving it into a groove on the larger longer rod. Then the whole phallic coil slides out from this sensitive rear, the large rod enters the female and guides the thinner along beside it." The thin rod continues inwards, eventually depositing its sperm and withdrawing. "Any engineer looking objectively at such a fantastically impractical apparatus would bet heavily against its operational success," writes entomologist Miriam Rothschild. "The astonishing fact is that it works." Mating fleas remain locked in this improbable embrace for several hours, meanwhile feeding away. Fertilized eggs are laid within a few hours of copulation, and the mating pair may repeat the whole operation. Throughout the mating ritual, the pair continues eating and defecating at an accelerated rate in order to provide food for their offspring.[2]

I was fascinated, intrigued and amused by this text, especially by the wild claims that fleas have "the most elaborate genital armature yet known", and that "flea copulation has been hailed as one of the wonders of the insect world". Hyperbole is great material for the flea circus, which I was researching at that time and which I eventually developed into a 'real live flea circus', the Cardoso Flea Circus (1994-2000); but I was most surprised by the language that scientists used to describe the flea copulation. I was also shocked to learn that fleas were so remarkable at sex.

The power of this quote over my imagination lay not just in the hyperbole of the scientific manner of re-describing these 'flea facts'. Reading and re-reading this passage, I found that it was not only the sexual life of the fleas that was astonishing; it was the description, the endorsement, and the writing itself. What fascinated me about this passage was not just that serious scientists would spend hundreds of hours observing and studying in such detail the sexual behavior and the reproductive anatomy of such a seemingly insignificant creature. I became interested in the idea that the description and comments revealed as much about the humans as it did of the animal. It was the gaze of those scientists, engineers

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2 Des Kennedy, *Living Things we Love to Hate*, second ed. (Pownal, Vermont: A Storey Publishing Book, 1993). 28-29.

and writers that intrigued me. And of course, as a flea trainer in progress, I was interested the sense of scale, that of looking at the edge of perception.

Why do these humans look with so much attention at other species' private parts and their most intimate moments? What can we learn from a study of the reproductive morphologies of invertebrates and of other small creatures that feature in my dissertation? This became a thread that runs throughout this current investigation, which aims to unite the scientists' gaze with the artist's ability to create two- and three-dimensional forms that can convey the kind of complex information contained in the long quote above.

The limited knowledge that exists about the extraordinary diversity of life on Earth, and in particular on the area of animal reproductive morphology was one of the things that attracted me even more to this subject matter. It had what show business calls a 'novelty' factor; in academic terms we tend to think of this as a gap in knowledge. The current project seeks to unite the two approaches in a *museum as artwork* that presents my findings in a highly developed aesthetic framework.

The Museum of Copulatory Organs (MoCo) is the practice based artwork that provides the embodied knowledge of aesthetics and form that I will describe and analyse throughout this written component of the PhD. The written thesis will take the reader along with me on my quest to find out about the diversity and complexity of genitalic morphologies, and the answers I have found for my research questions: What contribution can visual arts research and practice make to a general public's understanding of complex scientific phenomena, and what strategies are most effective for representing these phenomena in a way that honours that complexity and engages the viewer comprehensively and with well-informed affects, beyond the simple provision of verbal information? They will take the reader with me in my quest to find the best and most innovative ways to present my findings to a large and popular audience.

I have approached this subject matter as an artist, from a visual perspective. I have made and used images to explain concepts, but I want to clarify from the outset that I am not a scientist. My aim is to play a generalist role, to understand the science behind my questions and to give them plastic form. So, I am not presenting a 'science thesis'. Nor does the thesis claim to present a comprehensive history or survey of museological practices, past and present. Rather, to be precise, it seeks out the most appropriate and effectively 'idiosyncratic' museological modes for presenting and interrogating the morphological wonders that I am spotlighting throughout the doctoral research.

As Darwin powerfully suggests, form and beauty are almost synonyms. Throughout this thesis, I take 'beauty' to mean the satisfying refinement of symmetry and pattern-presentation in all the stimuli and materials available in nature and culture. In this regard, I am using the popular-vernacular connotations of ‘beauty’ in order to speak of various museological strategies and ‘attractions’. My thesis is not an analysis of ‘beauty’. Important as such research is, it is not my topic.

Chapter One

Identifying Genitalic Extravagance and Imagining a Museum as a Means of Investigating and Communicating Strangeness in Animal Reproductive Morphology

> The common-sense function of male genitalia[3] is that of gamete transfer: in one way or another the male places his sperm inside the female, where they can then fertilise her eggs. But when one looks at the extraordinary complexity of male genitalia of a species like the chicken flea … for example, this simple explanation seems inadequate. In many species the male genitalia are structurally the most complex organs in his entire body; in some they are also incredibly large, as in some nematodes and flies, whose intromittent organs are longer than the rest of the body. It is just too fantastic to believe that such complicated machinery is necessary only to perform a mechanically simple function.[4]

William Eberhard is an evolutionary biologist currently employed at the Smithsonian Tropical Research Institute. He is an expert in the field of genitalic morphology and evolution, and his work (including generous correspondence from him)[5] has been a strong influence on my doctoral research. Eberhard coined

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3 Eberhard, W. G. (1985). Sexual Selection and Animal Genitalia. Cambridge, Mass., Harvard University Press.

For this dissertation I have used Eberhard's definition of genitalia:

Male animals employ a remarkable assortment of structures in sperm transfer. I use the term male genitalia in a broad sense to include all intromittent structures on the male body as well as the packages of sperm (spermatophores). …In many species males have additional structures (claspers) for holding the female during copulation. ...I will include as genitalia all male structures that are inserted in the female or that hold her near her gonopore during sperm transfer. I exclude other reproductive organs such as testes, accessory glands and so on that are not normally in direct contact with females….In keeping with the definition above, I will consider as genitalia those parts of the female reproductive tract that make direct contact with male genitalia or male products (sperm, spermatophores) during or immediately following copulation. Specifically excluded are those structures higher up, such as ovaries and others not in direct contact, such as accessory glands, shell glands and such. P.1-2.

4 ibid.

5 Eberhard, W. (2012). PhD Art and Science in Sydney. M. F. Cardoso. Email.

Dear Maria Fernanda,

Thank you very much for the message. It has made my day. The homage you are making is, of course, to the powers of sexual selection to create beautiful objects and movements, not to anything I have written. That message about sexual selection is of course classic, but you are taking it to a context that for most people is completely new and esoteric. You are doing for genitalia what others in the past did for peacock tails and bird songs (how even more impressive it would be if we could communicate effectively about tactile sensations - the tickling vibrating sensation that a female stick insect must feel with a male quivering on her back, the feel of the gentle periodic rubbing with his genital claspers). This is a wonderful area of biology in which to combine science and art. I only wish that more people (biologists included!) had the patience you obviously have to really carefully observe and appreciate what you are seeing.

Thank you again for the message, and congratulations on your work.

Best Regards,

Bill Eberhard

the term “genitalic extravagance” in his 1985 book *Sexual Selection and Animal Genitalia,* published by Harvard University Press. This publication contains a few scientific illustrations that quickly demonstrate why he used that term.

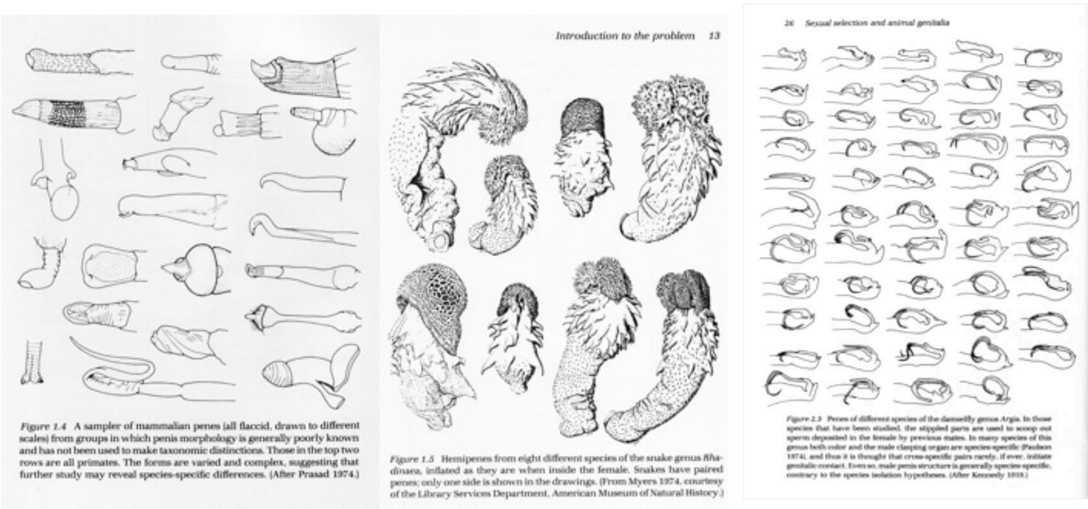


Figure 79 Mammalian Penes, Hemipenes of Snakes, and Damselfly penises, from Sexual Selection and Animal Genitalia, Eberhard (1985), with permission from William Eberhard.

One and a half centuries earlier, Charles Darwin similarly had been intrigued by gender-differentiated appearances and anatomies of particular animal species. While looking at the exuberance of the male peacock tail, for example, Darwin exclaimed: "It is incredible that all this display should be purposeless”.[6] That purpose was then defined as the theory of sexual selection, which for Darwin, aimed to explain extravagant and ornamental displays such as bird feathers, bird song, or deer antlers that didn’t make pragmatic sense from the point of view of his theory of natural selection. Such elaborate and extravagant displays made the males too conspicuous for their own sake in a world full of predators.

There had to be some other reason for extravagant appearances in general, which he proposed was sexual selection, based somehow on criteria that are aesthetic or pleasure-based. But it was not until Eberhard’s book that anyone had asked why genitalic extravagance in particular exists. Eberhard proposed that genitalia were subject to the forces of sexual selection, and especially subject to what he called “cryptic female choice”. (At this point, while I am outlining the general shape and trajectory of my own thesis, I won’t explain Eberhard’s and other scholars’ more

Eberhard, W. (2009). 8 Great iPhotos. M. F. Cardoso. Email.
Those are extraordinary photos! I love how you have been so very careful to align them perfectly, to allow their exotic forms to shine through. That snail takes the whole idea of excessive complexity up one level. I am very excited to see these. If I can help you in any way from the scientific side, please let me know.
Yours,
Bill Eberhard

6 Darwin, C. (1871). The Descent of Man, and Selection in Relation to Sex. London, William Clowes and Sons, Limited.

recent theories that aim to explain genitalic extravagance, but will describe them later in the dissertation.)

As I was conducting my initial research and when I look now at some of the specimens I have imaged (in both two- and three-dimensional forms), I ask myself a question similar to the ones evolutionary biologists have asked — but I ask it from the point of view of an artist: "Why is there so much complexity and diversity in animal genitalia?" This was and remains my initiating question, the one that prompted me into doctoral research. As I began to find ways to answer that first question, I was led to my second question: "How can I best present my findings to the general public?"

In this dissertation, with these two research questions in mind, I will proceed to describe my investigative process as an artist/researcher. I will show how, as part of the same process by which I have discovered the right images and words for understanding the science and cultural significance of animal genitalia, I have also investigated and developed an effective new way to use images, objects and words to convey my findings (not only to a specialist audience of academic scholars, but also to my artistic peers and to an informed and curious general public). In offering here an account of the development and delivery of the art project that communicates the results of my research, I can also show how I have developed not only an enhanced understanding of reproductive morphologies, but also a fresh and effective means of deploying museological conventions and media to represent and offer explanations of some of the wonders of genitalic morphology in a select group of animals.

As is often the case with any research enterprise, be it in the sciences or in creative arts, my project commenced with a sense of wonder and fascination: in other words, my investigation commenced with a profound curiosity. As I will outline more fully shortly, it was through my research into the art and science of the flea circus that I had my first encounter with the intriguing world of animal genitalia. In 1994, I made my first artwork on this subject matter, simply by copying a quote about flea copulation from Brendan Lehane onto a vinyl blackboard using white chalk. This was my first 'educational artwork', as it made reference to school and chalk blackboards from my childhood. Later, in my 1998 flea circus performances, I included a flea wedding as well as a slide show with a section on their genital structure and mating habits. This was my way of sharing with the public some of the wonder and startling facts associated with flea anatomy.

Through the Cardoso Flea Circus project, I learnt that in each of the societies where I staged the circus, the general public had a hunger for arcane scientific facts. Exploiting this discovered proclivity in the audience, I manipulated special biological facts concerning fleas into an art form through a slide show and lecture that appealed to the audience's sense of wonder and readiness for astonishment. As I began my doctoral research on animal genitalia, I sensed that, for the purposes of organising and communicating whatever knowledge I generated throughout the research, I could continue to expand upon such techniques developed in the context of the 'educational' aspect of the Cardoso Flea Circus — but this time for the educational purposes of a Museum of Copulatory Organs (MoCO).

So, from the start, I was researching two topics — not only the forms of and the reasons behind the extravagance of animal genitalia, but also my hypothesis that an artistic/museological mode of communication would be an effective means of generating and disseminating the inter-disciplinary knowledge that I was aiming to synthesise as I investigated the morphologies of selected animal genitalia.

Here in this first chapter of the dissertation, I will concentrate mainly on this latter hypothesis concerning my investigation into the museological 'knowledge-transfer' that has been the outcome of my doctoral research. My research has developed an interdisciplinary scope as it has led me into the investigation of social conventions as well as museological practices, artistic media and methods, biological behaviours and reproductive morphologies. Throughout the full extent of the dissertation, I will reflect on what was learned in each of these research domains. In this initial chapter I will ground the entire investigation in an account of the work that I completed and the discoveries that arose as I developed a museological method of arranging and displaying the results of my research. By showing how my doctoral investigation evolved, step by step, to become MoCO, I can offer an account of the incrementally emergent knowledge-generation and synthesis that occurred for me in the inter-linked fields of museological practices, artistic media and methods, biological behaviours and reproductive morphologies as they were brought together by the museological design of the entire investigation.

The idea for MoCO — imagined as a museum in the tradition not only of educational displays but also of 'cabinets of wonders' and dime museums — was first conceived in 2004. Now, eight years later, MoCo has been born. It is finally a reality, an outcome of my doctoral research. I want to start my dissertation here by emphasising the chronology and the process involved in the making of this project, as it sheds light on the difficulties and insights involved in using art-making as a research process.

In 2003, having stopped performing the flea circus after a sold-out season at the Sydney Opera House in 2000, I was looking for new subject matter for my next body of work. I asked myself: "Are fleas the *only* genitally extraordinary creatures in the animal kingdom, or are there other animals with elaborate genitalia?" This question was swiftly answered after a summer spent at the research libraries of the Australia Museum. It became clear that that there was plenty of diversity and complexity across the animal kingdom, but not much in the way of images; nor was there extensive research about them. What images did exist were of a low quality, and suggested that more work could be done to improve the way in which a wide variety of genitalia are imaged. I photocopied all the images I could find in the existing literature, and, aware of copyright law, I then conceived of re-making those images myself so they could become artworks in their own right. I set myself the task of finding, collecting and making those images, with the aim to present them to the world as an art project. In this fashion, I managed to identify a gap in knowledge, and a promising field of research.

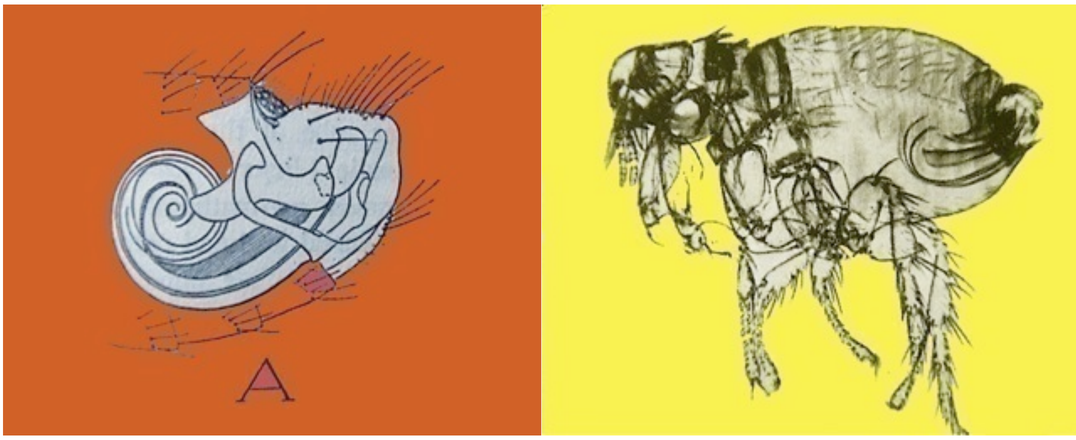
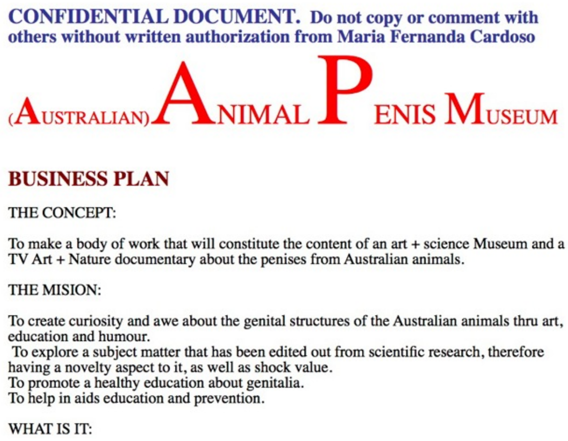


Figure 80 "The most elaborate genital armature yet known." Coloured scientific illustrations of the flea genitalia from the Cardoso Flea Circus Lecture 1998-2000.

Imagining a Museum

In 2003 I presented the findings of my preliminary research into the wonders of animal genitalia in an illustrated lecture at the Museum of Contemporary Art, Sydney. The slideshow was entitled *Penises of the World*. I had a full house for that single test-case lecture. Here, I learned that there was an appetite for the kind of information and visual presentation I was offering. But I also discovered that the title alone discouraged many people in the general public. Both curiosity and fear were triggered by the same word: *penis*. This experience has been consistent throughout the development of my project.

During my early years of research, I did not find many images of female genitalia. They were even more obscure and elusive than images of the male genitalia. So originally, my project was called the Australian Animal Penis Museum (now MoCO has evolved to include female anatomy, as well as other structures used in copulation). At this starting point it was specifically Australian creatures that featured in the project, as it aimed to present the uniquely bizarre examples of marsupial and monotreme anatomy.



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(AUSTRALIAN) ANIMAL PENIS MUSEUM

BUSINESS PLAN

THE CONCEPT:

To make a body of work that will constitute the content of an art + science Museum and a TV Art + Nature documentary about the penises from Australian animals.

THE MISION:

To create curiosity and awe about the genital structures of the Australian animals thru art, education and humour.
To explore a subject matter that has been edited out from scientific research, therefore having a novelty aspect to it, as well as shock value.
To promote a healthy education about genitalia.
To help in aids education and prevention.

WHAT IS IT:

Figure 81 (Australian) Animal Penis Museum Business Plan, confidential document, by Maria Fernanda Cardoso, 2004.

In 2004, to help clarify the project in my mind, I wrote a Business Plan, mimicking the style of a start-up enterprise. There was humour in it, and a sense of absurdity: I am not a business woman, I'm an artist. At the time, I assumed that the idea of a Penis Museum was not going to be supported by Government funding. I thought that I might have a better chance of success if I looked for private funding. I dreamt of being able to generate profit enough to make the project a reality as a form of 'edutainment'. From day one, I wanted my project to exist in the world independent from the art gallery system where I was mostly exhibiting at the time. I wanted to create a real Museum-Art Project, and a self-funding one at that. If I failed, the Animal Penis Museum Business Plan could at the very least become a conceptual art piece.

So, why did I want to make a real museum, and not a fictional one, as have been created by many artists in the past? Ever since I defined myself as a 'materials based' artist (in terms of the process and making of my sculptures and installations since 1985), I chose to work with 'real materials', and not with materials specially made for the purposes of art making. By 'real materials' I mean substances and objects that you can find in nature, in homes, backyards, supermarkets, hardware stores — places where 'real people' gather and operate. I wanted to show the wonder and potential in these ordinary things.

During the period (1992-2000), I imposed on myself the task of using actual living fleas and to make a real Flea Circus. It took two years of research and six years of development, and continued until I stopped performing in 2000. I mention the long time frames that I work with in order to explain the coherence of my own set of rules for art making. In the same fashion, if I wanted to make a genitalic museum that exists in the 'real world', (not exclusively in the abstracted or fictional space created by the Art Museum, the Art Gallery, or a Performance Space), I knew that I had to work with rules, expectations and conventions that apply outside the art world — and all this without disregarding or disrespecting my artistic methods and training. That included persistent fundraising and grant writing, unsuccessful proposals to institutions such as the Australian Museum and events like the Venice Biennale; even the commencement of my PhD candidature was conceived as a 'real space' where I could pursue the subject of my research — the science of genital morphologies and evolutionary biology — as well as new techniques of imaging and object making that would be appropriate for the rigour of scientific processes and research frameworks.

As I aim to show in this dissertation, the academic approach has been productive. Developing my art project under the umbrella of a PhD has granted me access to the collection of the Australian Museum and to their microscopy unit. It has also allowed me access to the Sydney University microscopy unit, access to research-active scientists, and most importantly, it has given me the intellectual structure and credibility to pursue subject matter that is still taboo in many parts of society. The structure of the PhD has enabled me to keep the academic rigour of my work central to the project, and has allowed me to be taken seriously in several sectors of society, and not just the art world. The scale of my pursuit has transformed me into a qualified artist/researcher, which is similar to the manner in which I became a self-taught flea trainer and flea impresario.

One specimen at a time, I started to create the MoCO collection. As I researched the available literature more deeply, I began to understand the context that most suited MoCO. I began to emphasise the usefulness of my role as an artist capable of interrogating, conversing and collaborating with scientists in a surprising, productive and mutually informative manner. I also began to assemble the collaborative community of artists and scientists with whom I felt an affiliation and from whom I might receive information and inspiration — artists and scientists, in other words, who might be role models and guides for me in my inter-disciplinary artistic and scientific quest. In this respect, it was a great breakthrough to receive the endorsement of William Eberhard via a series of email exchanges.

My research questions guided the early investigation and helped me refine the MoCO mission and collection. Seeking to align my research questions to the 'mission statement' of MoCO, I set about fashioning a language and a way of thinking that could reach out beyond the art world and the scientific communities into other regions of the cultural, commercial, and educational sectors. Accordingly, I decided to write and distribute a press release about my enterprise.

The generic conventions of the press release required me to set the tone and scope of the project outside narrow or esoteric parameters. Without abandoning my scholarly intent, I aimed for this project to resonate and to have significance farther afield than solely the academy: I wanted it to have a meaningful existence across several disciplines, institutions and communities.

Given the way the press release was shaped by my research questions, it has served as a vision or mission statement, and it has stayed consistent as a set of aims and principles throughout my doctoral research. (I have updated it here so that it refers to the realisation of the project at the 18th Biennale of Sydney, 2012.)

The press release ran like this:

A Museum is Born —Press Release
MoCO
Museum of Copulatory Organs

Maria Fernanda Cardoso, the creator of the Cardoso Flea Circus (1994-2000), and her team of collaborators are pleased to announce the extraordinary premiere exhibition of MoCO, the Museum of Copulatory Organs science and art project. Open daily from 10-5pm, from June 26th until September 16th 2012 at Cockatoo Island, MoCo is part of the 18th Biennale of Sydney.

Inspired by descriptions of the anatomy of the male flea, Colombian/Australian artist Maria Fernanda Cardoso decided to investigate the anatomy of the private parts of small creatures. The morphologies she found were so unusual and diverse that she thought they were worthy of becoming artworks and having their own museum. Now a real museum, MoCO's aim is for the entire world to learn about the reproductive wonders of the small.

In order to pursue this obscure subject matter, Cardoso had to earn her credentials and become an expert in animal genitalia. So she enrolled into a PhD program at the University of Sydney's College of the Arts, and she can now talk with evolutionary biologists in their own language. Already holding an MFA degree in Sculpture from Yale University, soon she will be Doctor Cardoso, a specialist in art, science and sex.

MoCO's first exhibition focuses on invertebrate genitalia. Among the highlights of the exhibition are the exquisitely made insect penis micro-sculptures made in bronze, glass and resin. Electron microscope micrographs depict the most extravagant and complex organ ever seen, the phallus of a local (hermaphrodite) snail, a resident of the Sydney Harbour mangroves and salt marshes; earning the prize for the most convoluted reproductive female anatomy is a female fruit fly, the *drosophila bifurca*. An insect sex video shows the transfer of a pink spermatophore between male and female stick insects, an event recorded for the first time ever.

As an ongoing project, MoCO is seeking collaborations and contributions by scientists as well as sponsors. MoCO holds a growing collection of anatomical micro-sculptures, drawings and micrographs of copulatory organs across the animal kingdom.

MoCO will be available for touring from 2013 onwards.

Public of all ages are welcome, in the company of adults.

* Copulatory organs are defined as any structure involved in the process of gamete transfer in sexual reproduction, both in animals and plants. i.e. male and female genitalia, spermatophores, genital claspers, pollen, etc.

AIMS of the MoCo Museum:

- To build an ever growing collection depicting extravagant genital morphologies, available for exhibition and research.

- To research sexual reproduction and its impact on the shaping of life on earth.

- To pursue excellence in the artistic representation of copulatory organs and processes.

- To make public the extravagant beauty, diversity and complexity of genital morphologies, in particular of small creatures.

- To trigger further biological and cultural research and understanding of the forces of sexual reproduction.

- To find a permanent venue for MoCO's collection, and to make it an art and science destination, becoming part of city life.

- To tour the collection until we find a permanent home.

- To provide matter of fact education about the wonders of reproduction. This is *Sex Education for the 21st Century*.

End Press Release

MoCO Timeline: an idea in time

As the vision has gradually developed and evolved, it is important to understand that this project has been eight years in the making, four of them full-time as a PhD candidate. I have prepared a time-line of the project, to help the reader to see how a long-term 'trial and error' process (encompassing periods of self-doubt, real world rejections and necessary adaptation) has been a crucial aspect of the research. Considered alongside the press release, the time-line gives the reader an introductory overview of the entire project which we will go on to examine in detail throughout this dissertation.

Before enrolling as a PhD Candidate

1994 "Flea genitalia is considered one of the wonders of the insect world." Quote read.
1995 Made Flea Copulation blackboards, the first artwork in the collection.

1998 Cardoso Flea Circus exhibition at the Museum of Contemporary Art Houston. The curators ask me not to exhibit the Flea Copulation Blackboards as they would have to make a public disclaimer about sexual content, which would discourage families from seeing the rest of the show.
1998 Incorporated a 'Flea Wedding' to the newly expanded Cardoso Flea Circus performance
2000 Added an educational section to the flea circus, a lecture and slide show featuring flea genitalia and copulation among other flea-facts.
2003 Research at the Australian Museum libraries looking for images of genitalia. Identified a lack of images, but a promising field of research.
2003 Gave a lecture "Penises of the World" at the Museum of Contemporary Sydney, simultaneous to my solo exhibition titled "Zoomorphia", at the MCA. It gets a full house, but schools discouraged from visiting the show.
2004 Wrote the Business Plan for the Animal Penis Museum and started fundraising
2004 Proposed the Animal Penis Museum to the Australian Museum. I won the ground support from the scientists but not from the administrative directors.
2004 Proposed the Animal Penis Museum to the Venice Biennale Pavilion with Elizabeth Ann Macgregor as curator.
2004, 2005, 2007, 2008 Unsuccessful Australia Council grant applications for the Animal Penis Museum.
2006, 2007, 2008, 2009 Unsuccessful grant applications to the Guggenheim Foundation for the Animal Penis Museum
2006 Tired of waiting for a grant or an exhibition opportunity, I try to get funding to do a documentary about the subject matter. With my own resources, I produce a documentary 'teaser' about my project. With Alan D'arcy Erson as co-producer and co-director, we win an ABC documentary development grant. The press wants to interview me the next day but I refuse to give interviews. The grant falls through as Darcy takes a job at the ABC and has a conflict of interest. In the process of filming I collect my first specimen, the spiral organ of a male emu, which I have freeze dried and now sits in storage. The dissection is performed by a bird veterinarian Michael Cannon, and filmed in HD with me getting an anatomy lesson from him. The raw footage never gets edited, nor has it been presented to the public to date. A proposal to show this work is rejected from the Art Gallery of NSW's special projects program. People close to me advise me against showing this video for fear of a negative reaction from the public, as it graphically depicts the flesh and blood of the emu under dissection.
2006 "Mating in the American Lobster" (Prototype for a bedspread), a playful artwork, with an idea of the kind of merchandising I wanted to make for the 'Museum shop.'
2007 I come to terms with the reality that the only way to develop this project is within academia. I apply to UTS for a PhD with the new title of Museum of Reproductive Morphology, I am accepted, but fail to get a scholarship.

Work Conducted during PhD Candidature:

2008 Start a PhD on the Museum of Reproductive Morphology at SCA with Ross Gibson as supervisor. This time I get a three-year scholarship from the University of Sydney.
2008 Start collaboration with Sue Linsday, microscopist at the Australia Museum. Now that I am a PhD candidate I have access to the Australian Museum collection. In the microscopy collection there are existing specimens of a snail, harvestman and microbats, which we proceed to image in the electron microscope for my own purposes.
2008 Start collaboration with Vert Design to make 3-D computer models of the Harvestman genitalia. We experiment for a whole year until we find animation software that has the results I want.
2008 Residency at GRAPHICSTUDIO at the University of Southern Florida, where we experimented using photogravure to make electromicroscopy prints, as well as 3-D printing of my first computer model developed by Vert Design which looks very stiff and inorganic.
2008 I do printing tests of high resolution 3-D printing technologies in several businesses. Found technology at a rapid prototyping company based in Melbourne, who can successfully print my objects. The first 4 digital sculptures are exhibited at the Hong Kong Art Fair, but no works are sold.
2008 I collaborated with SCA glass MFA candidate to make blown-glass domes in the shape of condoms to protect and display the 3-D models, but end up commissioning glass artist and master craftsman Peter Minson to make them using flame glass techniques which are more accurate than blown glass.
2009 Experimented with MicroXCT scanning with Professor Allan Jones, at the Microscopy department at Sydney University.
2009 Collaborated with Mark Elliot, flame glass artist, to make the scorpion spermatophore models, using flame glass techniques.
2010 Experimented with bronze clay, polymer resin, wax, and shrink plastic to make models and drawings.
2010 Continued to collaborate with Vert Design to make computer models of Love Darts, but can't afford to print them.
2011 Exhibit "It's not Size that Matters, it is Shape" at Arc One gallery in Melbourne from April/May 2011. Nine Harvestman suite of objects is finished. Display techniques for digital prints using presentation boxes are resolved. Large computer renders are displayed on the walls. This exhibition becomes a test case for my project. I conclude I need to show the real specimens to contextualise the objects and images presented. There are no sales. Is it the economy or the subject matter?
2011 ABC Artscape sees my press release and visits the Arc One gallery show and artist talk, deciding to make a half hour documentary dedicated to my research project.
2011 Exhibition at SCA Galleries of the video Stick Insects Most Intimate Moments, made in collaboration with Ross Rudesch Harley. Initially shot in 2006, edited in 2011.
2011 Invitation to present MoCo Museum at the Sydney Biennale in 2012 Get $15,000 budget from the Biennale.

2012 Arts NSW Grant for $60,000 for the presentation and production of MoCO at the Biennale of Sydney.
2012 Commissioned artist and museologist Gary Warner from CDP Media to make the museological design for the exhibition at the Biennale of Sydney.
2012 Continued collaboration with Matt Booth from Vert Design to make more digital sculptures of pollen, female tracts and spermatozoa.
2012 ABC TV Documentary "The Wonderful World of Professor Cardoso" goes to air on April 24. Lots of press surrounds its screening. Around 300,000 viewers watch the live to air program, with many thousands more viewing the program online after its release.
2012 Museum Display Cases are commissioned and built by Phil Sticklen, designed and lit by Gary Warner. The brief is to be able to display and light small, fragile and valuable objects and small specimens to an expected audience of 500,000 visitors over a period of three months without any security. The location assigned to my project, building 123 at Cockatoo Island, is a large old shed used in the past for hardware storage. There is no lighting, nor environmental controls. The building is full of dust, and possible leaks. We can't touch any of the building as it is heritage-listed.
2012 Biennale of Sydney opens June 26 and we are receive an average of 3,000 visitors daily over three months, a 25 % increase from the previous biennale in 2010, which received 500,000 visitors. The show will go onto storage after September 16th 2012.
2012 Commissioned MoCo website to Adnan Lanani from Forays for you, based in the UK, and will display documentation of the show. Kathryn Bird designed the MoCo typographic identity.
2012 PhD Examination in October 2012

This first chapter has provided a schematic overview of the some of the key ideas that have pre-occupied me during my doctoral studies. I have laid these out in a chronological fashion in order to give the reader an overview of the development of this project, and to emphasise the continuity it forms with my art practice over a good many years.

With this general overview in mind, I will now turn to an account of the manner in which I went about establishing the Museum of Copulatory Organs as an expression of my own individual research, and as an embodiment of the ideas and questions that animate this thesis. I will also outline how this individual artistic expression also finds form in the 'institutional shape' of a museum, as this is central to my aim of communicating my research findings to a broad and popular audience (and not just the more rarefied art world).

Chapter Two

How to Make Your Own Museum

When I first began to make this body of work about animal genitalia, I experimented with numerous titles: Australian Animal Penis Museum, Penis Museum, Cardoso Penis Museum, P-Museum, Museum of Animal Genitalia, Museum of Reproductive Morphology and finally Museum of Copulatory Organs (MoCO). The word 'museum' was essential, as it instantly defined the project, locating it in the lineage of cultural and natural history I wanted to be associated with. As an artist, I had previously created an artwork/cultural institution that enjoyed great success (a circus, with real live performing fleas). It seemed obvious to me that the museum as institution and framework for my physical artworks (sculptures, videos, drawings, photos, and prints) provided an extremely fertile ground to explore.

In order to better understand the objects of art and science, one needs to understand their contexts; and in order to innovate, one needs to experiment with contexts and frameworks for the effective communication of original ideas that can be expressed through objects and other aesthetic components. The concept and the 'template' of the museum provided me with the first and most fundamental elements of the context I needed.

My research involves an investigation into several different traditions: not just museums and collections, but also the traditions that have sometimes connected and sometimes divided art and science. I have also investigated the history of three-dimensional (physical) scientific models, and the knowledge to do with animal genitalia and sexual selection. In order to synthesise and communicate any knowledge I have generated during my research as effectively as possible, I had to understand the history (as well as the most up-to-date innovations) relating to museological display. For this reason, I also explored new technologies and several different modes of representation to convey an aesthetic experience of my subject area as well as the science behind the art works included in the displayed collections.

A complete and comprehensive study of the tradition of museums and museum collections is beyond the scope of this thesis. However, for strategic and pragmatic purposes, I have chosen to include three specific museological examples that I will refer to in this chapter. Each of these examples embodies a crucial aspect of museum history, forming the background to the efficacy, cogency, and appeal of my own museum. In this chapter I will use the examples of Madame Tussaud's 18th century Wax Museum, P. T. Barnum's 19th century American Museum, and the contemporary Museum of Jurassic Technology as background and foil to a wider discussion of natural history display and the attraction of popular museums.

The early museums are significant to this study for several reasons. When they were established, they were mostly not considered to be serious institutions, and were generally thought of as mere commercial enterprises. Despite this, their proprietors claimed their aim was to educate and to instruct audiences — at the same time that they were expected to make money. Natural history museums can be considered to be the last remnants of a long tradition of 'educational entertainments' that arose during the Enlightenment. During the late 18th century, a rising pre-literate middle class audience, eager to improve itself, was willing to pay money to better themselves. They were a ready audience for enterprises such as Madame Marie Tussaud's Wax Museum and later, P. T. Barnum's American Museum. Barbara Maria Strafford argues that the birth of popular education as amusement, or what we might now call multimedia edutainment, comes back to the pre-literary period of the Enlightenment:

> Telling the story of the beginnings of mass literacy by focusing on the eclipse of visual aptitude is to introduce fresh materials, new conceptual models, and forward-looking technology into traditional accounts… I experiment by focusing on representative moments in the singular transit from an oral visual culture, to a literate one, to the uncanny recurrence of pictures ever more lifelike within vivid multimedia performances.[7]

The early museum examples we will consider here relied on a vivid visual language to communicate the news of the day, technological and natural novelties, and a variety of strange oddities. These popular museums were extraordinarily successful, and the techniques they utilised were attuned to the pre-literate mass audience. I look to them for clues and inspiration for highly effective modes of communication. As Barbara Maria Strafford puts it,

> visual education … arose in the early modern period. Significantly, it developed on the boundaries between art and technology, game and experiment, image and speech. The exchange of information was simultaneously creative and playful. We need, therefore, to get beyond the artificial dichotomy presently entrenched in our society between higher cognitive function and the supposedly merely physical manufacture of "pretty pictures." In the integrated (not just interdisciplinary) research of the future, the traditional fields studying the development and techniques of representation will have to merge with the ongoing inquiry into visualisation.[8]

My own work aims to integrate sophisticated cutting-edge scientific understandings of the world of animal genitalia into display methods and techniques in order to make them accessible to the general public (of all ages and professions). My project has all the characteristics necessary to awaken the public's curiosity, and has deep resonances with the traditions and techniques of the 18th and 19th century museums under consideration here: novel information about obscure subject matter; fascinating scientific facts; natural beauty; and technical skill.

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[7] Barbara Maria Stafford, *Artful Science : Enlightenment, Entertainment, and the Eclipse of Visual Education* (Cambridge, Mass.: MIT Press, 1994). xxii.

[8] ibid., xv.

These early museums were all owned privately, and the languages of display and representation they developed (precisely because they relied on a fee-paying audience) placed them within the context of a disreputable world of commercial pseudo-science and entertainment. However, historian Kate Berridge asks whether

> instruction and amusement [can] be mixed? Were crowds compatible with culture? Were the barbarians getting too close to the gate? The debate touched Marie [Tussaud] and all those who were part of a growing phalanx of entertainers making fortunes from middle-class taste. They trod a precarious path between being taken seriously for their educational aims and being dismissed as tacky money-grubbers.[9]

I propose that some of the techniques they mastered can be analysed and revived in a contemporary context of art, science and museology. I also want to suggest that their contribution to the making of culture is yet to be fully recognised and understood.

A significant aspect of these early museums concerns the central role played by the personality of the owner/director, which was in turn intrinsic to the identity of the museum. Both Barnum and Madam Tussaud created fictionalised versions of their own biographies. Being sole proprietors gave them a distinctiveness (or perhaps a kind of 'charisma'), as well as the freedom to experiment whimsically and sometimes even perversely — a liberty that is almost impossible within large corporatised institutions of today. According to cultural historian Philip Kunhardt, a showman such as Barnum used his distinct personality "to create charisma and crowds" by way of an "injection of sheer personality".[10] Both Tussaud and Barnum understood that their personal role was as important as the exhibitions and materials they were presenting to the public.

As the contemporary field of animal studies shows us, it is problematic to separate nature from the human. This is what interests me about these popular museums of the 19th century: the relationship between human and animal was often centre-stage. This has had an impact on my own practice. When I created the Cardoso Flea Circus, I understood that you cannot separate the animal from the trainer, and so my role as circus-owner 'Professor Cardoso' was as important as the fleas themselves. For MoCO, the relationship between myself and the specimens I make and display should be visible to the public. I aim to highlight that relationship through the media interviews I give in support of the project. (For instance, a 30 min documentary "The Wonderful World of Professor Cardoso"[11] by ABC Artscape was aired in April 24 2012, and it is now online. The documentary follows the making of MoCO, and presents it from the perspective of the Museum's creator.) Like Tussaud before me, my personality as a woman,

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9 Kate Berridge, *Madame Tussaud: a Life in Wax* (New York: Harper Perennial, 2007; repr., 2006). 289.

10 Philip B. Kunhardt, Kunhardt, Peter W., *P.T. Barnum: America's Greatest Showman*, 1st ed. (New York: Knopf, 1995). 36.

11 Emma Watts, "The Wonderful World of Professor Cardoso," ABC TV Artscape, http://www.abc.net.au/arts/artists/maria-fernanda-cardoso-the-museum-of-copulatory-organs/default.htm.

artist, mother and wife, concerned with my own imperative to reproduce lies at the centre of the project. I will discuss other tactics I have used to reveal these relationships to the audience later in the thesis.

In the following section, I want to account for the general influence and role of museums in the popularisation of science and art within the framework of public education and forms of entertainment. Terrence Whalen's description of the Barnum Museum provides a good place to start:

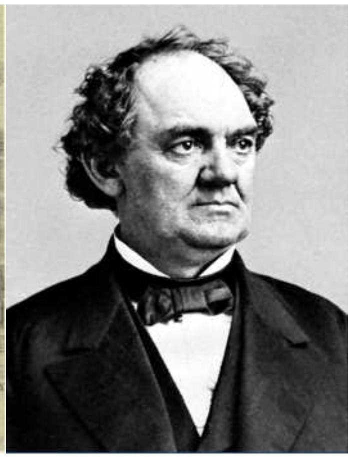

Figure 82 Barnum's American Museum 1853 on Broadway and Ann Street, New York
Figure 83 Portrait of P.T. Barnum

> Located at the corner of Broadway and Ann Street in New York, the American Museum was a five-story building whose collection had been built up by John Scudder, taxidermist and naturalist. After Scudder died in 1821, the museum had gradually fallen upon hard times. Barnum, who sensed an opportunity, acquired the museum at the end of 1841 through an imaginative credit arrangement, flimsy collateral, and fast double-dealing. The museum was trumpeted as "a vast National Gallery" containing "a million of things in every branch of Nature and Art, comprehending a Cyclopaedical Synopsis of everything worth seeing and knowing in this curious world's curious economy".[12]

Barnum's American Museum ran from 1841 until 1868. It burned down in 1860. Barnum rebuilt it in nearby location, but it too mysteriously burned down again some years later. Coincidentally it was only a year after the second fire in 1869 that the American Museum of Natural History of New York was founded, ushering in a new era of museums. The Museum of Natural History idea that replaced Barnum's model was a 'serious' institution, as opposed to the show business framework that Barnum created. Barnum's museum offered both strange and educational attractions. It was an affordable and safe entertainment for families, single women, children, and the broader general public alike. Whalen notes that Barnum's museum used a variety of performative modes:

> Barnum also added live entertainment, such as exotic animals, exotic human beings, carnivalesque sideshows, and, perhaps most important, stage shows in an auditorium called the "Lecture Room." Such rooms were a common feature of museums during this

[12] Terence Whalen, "Introduction," in *Barnum, Phineas T. an Autobiography* (Urbana: University of Illinois Press, 2000), xxii.

period, and as their name indicates the rooms were designed for educational presentations on science and history. Barnum retained the original name, but under his management the Lecture Room was used less for education than for entertainment.[13]

The lecture room is a feature, which I believe can be effectively incorporated into the structure of my MoCO project. During the Biennale of Sydney, I presented a number of lectures and tours of MoCO for the general public. Lecturing is a very effective mode of teaching and communicating knowledge. I have accumulated so much knowledge about animal genitalia, that it is impossible to make enough artworks to communicate it. By lecturing, I can communicate a lot of my findings within one single format, over a short period of time.

With my experience teaching and performing for the Cardoso Flea Circus, I have developed talks and lectures to accompany the MoCO exhibition — a hybrid of teaching and performance art. This is another way to bring my persona to the forefront of the public awareness.

In its heyday Barnum's American Museum received 15,000 visitors per day,[14] and over its entire life span the American Museum received about 38 million visitors — more than the entire population of the USA at the time, which was 32 million people. Many scholars claim that Barnum was a central figure in the emergence of mass entertainment.[15] To cater for such massive audiences, the layout of his museum was designed to accommodate audiences of different genders, classes, and levels of education. For a very small amount of money (initially a dime, then 25 cents) audiences got considerable value for money. Barnum's model was a democratic ideal of a museum, accessible to all.

> The process of uniting individual amusements and marketing them as a single, "walk-through" entertainment, suitable for the entire family, was what made the dime museum novel. In a sense it was a so-called environmental entertainment, among whose fixed exhibits mobile spectators could organise their own journey.[16]

According to Andrea Stulman Dennett, it was through his American Museum in New York that Barnum earned his reputation as the father of American show business. His museum and related entertainments were the prototype that all later museums followed.

> [Barnum] created the first reserved seats; the first matinee shows; the first celebrity marketing campaigns; the first venues with national audiences; the first three-ring spectacles; and the first corporate models. It was Barnum, in other words, [who] built much of what scholars now call the "culture industry".[17]

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13 ibid.

14 Tina Kelley, "A Museum to Visit from an Arm Chair," New York Times, http://www.nytimes.com/2000/07/01/nyregion/a-museum-to-visit-from-an-armchair.html?pagewanted=2&src=pm.

15 Including Andrea Dennett, James W. Cook, and others.

16 Andrea Stulman Dennett, *Weird and wonderful : the dime museum in America* (New York: New York University Press, 1997). 5.

17 James W. Cook, ed. *The Colossal P.T. Barnum Reader : Nothing Else Like it in the Universe* (Urbana: University of Illinois Press, 2005), 1.

The following quote, from the definitive biography of Barnum, expresses the care and consideration the impresario took in all aspects of his Museum, including the architecture that housed the exhibits. The quote is lengthy, but it's worth including here as it explains Barnum's resilience and ingenuity as he set about injecting fresh energy and identity into his newly acquired venture at the outset of his directorship of the American Museum:

> The museum Barnum now presided over had long since lost its sparkle. To create charisma and crowds its new owner developed a threefold plan: renovation, a massive publicity campaign, and the injection of sheer personality. He began by concentrating on the huge drab, marble building itself. His first innovation was a lineup of colourful world flags along his rooftops, their flapping visible from over a mile way as they gave the museum an international air. Along the second floor of the building exterior, Barnum installed a wraparound balcony, upon which guests could take in the air and at the same time inadvertently lure other customers in. Always interested in the latest technology, Barnum went onto install a huge lighthouse lamp on his rooftop, the city first spotlight. Retractable and stored inside a parapet by day, the diamond-shaped "Drummond Light" possessed a powerful, moving reflector beam designed to sweep up and down Broadway by night, lighting the whole area, Barnum liked to boast, "with unaccustomed glare".
>
> But the most striking transformation of the building's exterior occurred following weeks of secret preparation. Then, on a single night, Barnum's crew installed a series of large oval colour paintings between all of the nearly 100 windows along the museum's upper stories. Suddenly, from the front of the museum, loomed polar bear and elephant, ostrich and giraffe, tapir, pelican, eagle and gnu. There was a lion, a kangaroo, a peacock, and an elk, a rattlesnake, a tiger, a fur seal and a cormorant. The impact was startling, transforming a large but ordinary building into a dreamlike emporium.[18]

Making a museum a landmark and a destination, a fun place to visit rather than a dusty repository of objects, are lessons worth noting. By promising the weird and wonderful, as well a diversity of experiences, Barnum created a great deal of excitement before the public actually made it to the steps of the museum. This was partly done by publicity, but it was also achieved through the physical experience of the building — both from the outside, and by the exhibits housed inside.

> The success of the American Museum owed much to Barnum's innovative use of advertising and humbug. The museum itself was covered with posters and flags, and many empty walls in the city were employed for the same purpose.[19]

I set the above quote aside several years ago and eventually re-invented these ideas for the staging of MoCO. For the Cockatoo Island installation of MoCO, I wanted to dress up the building with banners, Barnum style. (Unfortunately, for a variety of reasons outside my control, I was not able to realize this vision.) The installation of MoCO on Cockatoo Island did have its own free-standing building with signage naming promising what was inside. Being part of the Biennale of Sydney's Cockotoo Island experience makes the project part of a family-friendly and festive event. As I write, we had record attendance: 6,000 visitors on Saturday

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18 Kunhardt, *P.T. Barnum: America's Greatest Showman*: 36.

19 Whalen, "Introduction," xxxiii.

21 July 2012, and a record 8,200 visitors on Sunday 22 July (the last day of school holidays), and average of 3,000 visitors per day during the week. I accepted the challenge to exhibit at Cockatoo Island with the difficulties that the site presents, because I knew we would get this kind of audience. I also knew that we would have our own building, which I could name, even if it was only for three months. It is my aim that the City of Sydney will adopt the project as its own, and make it part of the cultural life of the city — a tourist destination. Until that happens, I plan to tour the project.

At many levels, Barnum, innovated in terms of 19th century museology. In a modest way, by offering diverse mediums of representation (including video and digital screens, the latest 3-D modeling technologies along with old fashioned glass, bronze and drawings), MoCO aims to have enough variety to sustain the general public's interaction with the art work, and to engage an attention span that is greater than 30 seconds (which is the average time spent viewing any artwork at a public museum).[20] As MoCO grows, I plan to add more and more exhibits, using even more diverse mediums and innovative technologies.

> My travelling museums of natural history have been the largest and most interesting ever exhibited in the United States, and no author, or university even, has ever accomplished as much in the diffusion of a knowledge of the varied forms and classes of animal life. These, with my museums in New-York, Philadelphia, and Baltimore, have been one of the chief means by which I have instructed the masses.[21]

So wrote Barnum. Yet, he was not in the business of educating. He was in he business of entertaining, even though he owned what was in essence a natural history museum. Where others saw the museum as a stuffy repository of valuable yet boring cultural relics and natural history specimens, he saw *attractions*. I see the same potential for MoCO. He lived on the intersection where Museums of Natural History had lost their glamour, and become impossible to run. Jane Goodall talks about Barnum's Museum strategy:

> What was new was the balance of priorities, which gave much greater emphasis to entertainment and especially performed entertainment, while maintaining a prominent investment in quite large-scale formal natural history collections… He established a modernised version of the museum 'as' theatre.[22]

MoCO's Biennale exhibit, and the Sex Education for the 21st Century lecture aim to capitalise on the same fascination for natural wonders in order to educate a broad public in a range of subjects such as biodiversity, evolution and sex. As a

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[20] Jeffrey K. Smith and Lisa F. Smith, "Spending Time on Art," *Empirical Studies of the Arts* Volume 19
, no. 2 (2001): 229-36.
According to Jeffrey K. Smith and Lisa F. Smith in their article "Spending Time on Art", the public spend an average of 27.2 seconds, with a median time of 17 seconds viewing an individual work of art.

[21] Whalen, "Introduction," 400.

[22] Jane Goodall, *Performance and Evolution in the Age of Darwin: Out of the natural order* (London: Routledge, 2002). 36.

retired flea trainer I have witnessed the public fascination with arcane facts and natural history, and I have also encountered a similar fascination on the part of the public in their desire to understand more about the scientific facts behind the art works that they have encountered.

Barnum was an innovator on many other fronts. He made his name, and his life history, into what would now be considered to be an international brand of lasting power: the name Barnum would attract audiences even a century later with the Barnum and Bailey Circus. He recognised that his showmanship and personal charisma as part of his success and this remains true for both for the American Museum and for the Circus.

He used the public fascination with difference and with natural wonders to his advantage. His art was manifest in the way he connected audiences to the exhibits. According to James Cook in *The Colossal P.T. Barnum Reader*, Barnum also created the first mass media spectacle with the invention of the Three Ring circus. Thanks to the use of an emerging technological and innovative system — the newly laid railroads — alongside his use of the printing press (another technology he used to his advantage), he would cover the city in mass-produced posters and handbills. He wrote articles for the newspapers, paid for printed advertisements, published his letters outlining his scouting for novelty acts overseas as a form of pre-publicity and published his autobiography many times.

For MoCo, Barnum's tactics provide great lessons. Drawing upon my experience as an artist and flea circus impresario, I am aware of the power of PR to have a considerable impact the reception of a work of art. The press releases and relationships with media are critical to gaining attention, and to get inside people's imagination. An engagement with the popular media is essential if one wants to become part of popular culture. Taking great care with my first press release for the test-case exhibition 'It's not Size that Matters, it is Shape', at ARC1 Gallery in Melbourne in April 2011, was crucial, as it generated the interest of ABC Artscape producer Emma Watts, who went on several months later to direct the 30 minute documentary mentioned in the previous chapter. With it, came publicity, and as a result MoCo was featured in the *Sydney Morning Herald* and the *Telegraph*, among other popular media outlets. This pre-publicity created a public ready for the exhibition at Cockatoo Island at the Sydney Biennale (which also had a PR machine working to promote the work).

Another important aspect that gave Barnum an edge was his particular use of language and narrative. He understood that exhibits alone could not speak for themselves, and that they needed to be talked about. For Barnum, exhibits needed to be contextualized and interpreted with language, and ideally they needed to be debated. To amplify debate, he chose many controversial exhibits and invited the public to come and to judge with their own eyes. The later model of Natural History exhibits tended to minimise the use of language and relied more on visual language assisted by the terse 'label' and prosaic and dispassionate gallery guides.

Barnum's use of language provides an important lesson that has been incorporated into MoCO exhibits.

Both Barnum (1810 -1891) and Madame Tussaud (1761-1850) created lasting brands using their own persona as the centre of the brand. Madame Tussaud used a fictionalised version of her own biography, told in wax exhibits of herself featuring the main events of her life. She claimed to have worked for the royalty prior to the French Revolution, also claiming she was forced to make death masks of all the guillotined heads of the revolution.

> Of far more interest than her claims to have known virtually the entire cast of the French Revolution is why she made such claims and why she told her tory as she did. There is in fact no evidence to support most of her assertions about her early life. Many of them may not be true. Yet this hardly matters. The creation of the myth is an achievement in itself, just as the success of her exhibition is incontestable evidence of her commercial acumen, her understanding of the market for her works, and her brilliance as a cultural innovator.[23]

Packaging knowledge into 'titillating' forms that were particularly popular with the expanding middle class had been Madame Tussaud's aim and achievement, but many were dismissive.[24] That debate still goes on between the scientific community, and popular science. What I have to say is that popular science, and the historical forms of popularisation of knowledge are very important in the diffusion of knowledge, as they encourage innovation. They enrich what we can learn from the communication pathways they use, and they show us how to apply their communicative ruses and methods to our contemporary contexts.

One of the main differences between Barnum's American Museum and Madame Tussaud's Wax Museum was that Barnum was encyclopedic in his approach to curating his Museum exhibitions. Madame Tussaud stayed firmly anchored in the mastering of one technique — that of wax portraiture. While he was a promoter, and a curator of sorts, she was an artist. But she also knew how to promote. To add excitement, she would use wax portraiture in the same way that news media use photographs and video nowadays: to give currency to her exhibits, she represented the news of the day. Hers was a time when photography was still in its infancy, a time when many people still were not able to read. Her uncanny resemblances have been unsurpassed in terms of 3-D representation. Even though in the last decade we have had an explosive growth in 3-D computer animation, it is still confined to 2-D screen based representation. For centuries, wax casting and modelling have been the ideal medium to represent the texture and glow of skin. It is also unsurpassed in the depiction of anatomical features, and for this reason became popular for the teaching of medicine. The technology was cutting edge at the time of Madame Tussaud. The pioneer of wax modeling, Dr. Phillippe Curtius, presented his first exhibition in 1770, while the first public display of the anatomical models at La Specola in Florence were presented in 1775. Those were the 'gold standard' for anatomical models for centuries. Only recently have the wax anatomical figures of La Specola had been surpassed by the

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23 Berridge, *Madame Tussaud: a Life in Wax*: 320-21.

24 ibid., 311.

development of plastination by Dr. Gunther von Hagens who patented plastination in 1977 and founded an Institute of Plastination in Germany.

Figure 84 Wax self portrait of Madame Tussaud, guillotined heads she was 'forced' to make during the French revolution, and self portrait as a young lady, in her own tableaux autobiography (in wax). She was the art teacher for the sister of Louis XVI prior to the French Revolution.

It is not a coincidence that Madame Tussaud was trained in the craft by a medical doctor, Dr. Curtius, in whose house she lived as the daughter of his housekeeper. Dr Curtius learnt his craft by making *moulages*, which are pictures of diseases in wax. The particular realism of *moulages* results to a large extent from their production using a particular technique called the reverse casting method, which

> could reproduce organic textures in a more lifelike manner that had ever before been achieved in three dimensions. The realistic colouring as well as the insertion of natural products, such as hair or scales, and artificial items such as glass eyes, underscored the main intention of the *moulage* only to give a picture of the living original. Thanks to its malleability, but also its ability to resemble the translucency of skin and muscular tissue, this technology allowed highly-skilled wax-workers to make accurate three-dimensional representations of the human body.[25]

Under her vision and technical mastery, knowledge was transferred from the field of anatomy to the fields of figurative art, representation and popular culture. Jane Goodall, who has written about the role of *Performance and Evolution in the Age of Darwin,* suggests that the

> potential for theatricalising anatomy displays was recognised by a number of entrepreneurs in the mid-nineteenth century. Madame Tussaud was one of the first to move in this direction, with her technically meticulous wax renditions of the guillotined heads of French revolutionaries.[26]

Her exhibitions are interesting to look at from my point of view as an installation artist/performer. Replacing living actors with wax ones, her tableaux and the use of visual narratives became very theatrical. Goodall tells us that the exhibition of human bodies, "subjected to violence in dramatic settings with atmospheric

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[25] Thomas Schnalke, "Casting Skin: Meanings for Doctors, Artists, and Patients," in *Models: the Third Dimension of Science*, ed. Sorraya de Chadarevian and Nick Hopwood (Stanford: University Press, 2004), 233.

[26] Goodall, *Performance and Evolution in the Age of Darwin: Out of the natural order*: 33.

lighting transformed the Chamber of Horrors into a kind of theatre."[27] Madame Tussaud's business was to tell stories.

Goodall writes on the transition between the cabinet of curiosities and the Museum of Natural History from the perspective of performance:

> The precursor of the modern scientific collection was the cabinet of curiosities or Wunderkammer. These collections were often referred to as 'theatres of nature'…[28] When the principle of singularity — of the curiosity as a bizarre or wonderful object, something out of the order of known objects — was replaced by the principle of comprehensiveness, the collection became legible to scholarship in the new scientific mode practiced by the Royal Society. The spectator seeking to be fascinated by an exhibit in its own right was to be superseded by the scholar who set out to read the system. Over the next two centuries, the cabinet of curiosities with its display of singularities gave way to the scientific museum as 'Classifying House,' and an intrinsic theatricality gradually disappeared from natural history collections.[29]

Not only did that loss of theatricality distance museums and the science behind them from the general public, but it made the Museum of Natural History a musty repository of dead objects where taxonomical classification took over (at the expense of the narratives that the objects in the collection had the potential to release). What my research offers is an attempt to again unite the use of taxonomy with the narratives of evolution. By revealing those grand narratives of love and pain, of sexual attraction and deceit, I aspire to deliver a Museum whose content is fascinating to the general public. As science helps us reveal the epic tales of survival and reproduction, I want to bring them to the fore of public attention, without leaving behind the systematic study of form and classification (which is the taxonomical research at the foundation of genitalic research). Morphology, or the study of form, is as important to the study of biology as it is to the arts and to aesthetics. MoCO presents morphologies and tells the stories behind them. My aim is to create a balance of priorities, to show beauty and form, and to narrate all that we know about why these genitalic morphologies exist in such complexity and diversity.

Like Barnum, Tussaud used technological innovation and technical virtuosity to attract a fee-paying public and to create a business. But it was not skill alone that she wanted to show, nor was she solely interested in educating the general populace about anatomy; her business model was theatrical and narrative, and she was also able to show the news and gossip of the day. Under her command, the technology (which preceded photography and the moving image) had a role that anticipated many of the popular journalistic uses that would arise for photography and film in later decades. She was able to create uncanny resemblances, which she used to depict famous people or events for the public to see. She used her waxworks to convey important or sensational news to an illiterate audience, and to give the opportunity to laymen and women to see and 'feel the presence' of famous people close at hand. The technology was so

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27 ibid., 22.
28 ibid., 26.
29 ibid., 28.

sophisticated that it has still not yet been fully superseded. To this day, the figures in the modern Madame Tussaud Museums — created with practically the exact same techniques that Tussaud herself perfected — are highly regarded for the uncanny life-likeness of their celebrity exhibits. Her formula is still being used by her descendants, and continues attracting crowds that marvel at the accuracy of the representations. Her contribution to the rise of celebrity culture, which she and Barnum pioneered, is legendary.

This combination of strategies is what set her work apart: exquisite craftsmanship and attention to detail; currency and an aura of institutional authority. Institutions, like national museums, carry their own gravitas in terms of credibility. But for these small privately owned commercial enterprises, their owners had to craft that illusion carefully. Kate Berridge describes how Tussaud and Dr Curtius achieved that:

> The Palais-Royal represented these changes in a concentrated site specific way. It glittered with possibilities for self-improvement… Even Curtius' salon adopted a pseudo-educational style and arranged a series of historical artefacts and relics alongside the figures of the most influential people of the day. This lent an air of worthy instruction to idle curiosity, and gave a higher purpose to the business of having fun.[30]

In later years, Madame Tussaud advertised:

> Know all men, that madame Tussaud has come out as a great public teacher. She has converted her exhibition in Baker Street into an educational institution, and has resolved herself and her sons into a Society for the Diffusion of Useful and Entertaining Knowledge.[31]

Barnum and Madame Tussaud used the museum institution to give gravitas to their exhibits and to make a profit. They deliberately manipulated the signifiers of truth and authority to give the illusion of serious instruction.

Following in this tradition, there is a contemporary artist who questions that relationship of trust we have assigned to museological display. It is David Wilson, with his Museum of Jurassic Technology in Los Angeles. In Barnum-esque style, his exhibits seem far-fetched and confusing, yet they are meticulously well presented. Starting from the name of the museum, we are sent into a state of confusion. How can there be technology from the Jurrassic era? Their website states:

> The Museum of Jurassic Technology in Los Angeles, California is an educational institution dedicated to the advancement of knowledge and the public appreciation of the Lower Jurassic. Like a coat of two colours, the Museum serves dual functions. On the one hand the Museum provides the academic community with a specialised repository of relics and artifacts from the Lower Jurassic, with an
> emphasis on those that demonstrate unusual or curious technological qualities. On the other hand the Museum serves the general public by providing the visitor a hands-on experience of "life in the Jurassic".[32]

30 Berridge, *Madame Tussaud: a Life in Wax*: 86-87.
31 ibid., 292.
32 David Wilson, "The Museum of Jurrassic Technology,"

That all sounds really dubious and confusing. And this is just the introduction. Truly, it is worthy of Barnum.

Barnum was shameless in his use of humbug to attract audiences. According to Terence Whalen, one of Barnum's biographers, humbug was very common in the 19th century. Humbug is a difficult word to define. "In the nineteenth century, the term could be applied to a tall tale or an entertaining hoax or an outright fraud".[33] Barnum exploited the public gullibility for fun, and for financial gain. He would not even hide the dubiousness of his claims, for example, by inviting the public to judge for themselves whether or not the Fejee mermaid was a fake or for real.

> He marketed controversial exhibits such as the Fejee Mermaid by claiming that he was merely giving the public an opportunity to decide for itself, but of course the controversy had been created and controlled by Barnum himself.[34]

The wording of some of the blogs that comment on the Museum of Jurassic Technology seem to come from the Barnum era: "MJT… is a walk-through enigma."[35] "MJT… The Finest Fake Science Museum in the World."[36] Like the name of the museum, contradictions abound. As Wilson says,

> part of the assigned task is to reintegrate people to wonder. At the Museum of Jurrassic Technology, wonder becomes surprise, which becomes disbelief. But the disbelief occurs slowly. The MJT blends belief and disbelief into a continuum of reality.[37]

This is very similar to Barnum's American Museum, or the fictionalised narratives of Madame Tussaud, including her own dubious autobiographical claims.

Ralph Rugoff has said that on leaving the MJT "the visitor's mind reels with unanswered questions. Is this a real museum or a simulation of one? Science museum or an art installation?[38] I will extrapolate these questions to my own project: Is MoCO a real museum or a simulation of one? Is it a science museum or an art installation? I believe that the confusion that MoCO projects lies in the question of whether or not it is art or science. I wonder whether one can cancel the validity of the other? When I made a 'real' Flea Circus, the public didn't know it was an artwork; it was often understood as entertainment. They doubted whether the fleas were real. People came to see with their own eyes whether or not it was 'real'. I suspect that a similar kind of confusion between truth and

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http://mjt.org/themainpage/main2.html.

33 Whalen, "Introduction," xxxiv.

34 Whalen, "Introduction," xxii.

35 Meredith Scheff, "The Museum of Jurrassic Technology," http://steampunkworkshop.com/museum-jurrasic-technology.

36 "The Museum of Jurrassic Technology: The Finest Fake Museum in the World," http://www.rikomatic.com/blog/2011/03/museum-of-jurassic-technology.html

37 Carla Yanni, *Nature's Museums: Victorian Science and the Architecture of Display* (Baltimore: Johns Hopkins University Press, 1999). 166.

38 Ralph Rugoff, *Circus Americanus* (London, New York: Verso, 1995). 100.

reality happens in the public's perception of MoCO. A recently published review put it this way:

> The Museum of Copulatory Organs is not Art at all, but it is possibly the most successful of all here to open us up to nature. Essentially a collection of beautifully modelled insect and snail spermatozoa, reproductive tracts and penises – modelled from glass, metal and waxy 3D-printed resin – it is truly wondrous.[39]

And a *Sydney Morning Herald* art critic claimed that "while the aesthetic value of these works may be questionable, there's no denying their entertainment value." Early in the review he categorised the project as "a crowd pleaser".[40] I am sure that Barnum was comfortable with ambiguity, so David Wilson's point is precisely to make that ambiguity evident.

I have taken great care to make a museum collection and a museum display completely based on the science of genital morphology, and for the models in the collection to be as accurate as possible. I have used quotes from serious books and serious scientists to give credibility and authority to the content, and I have used all the signifiers of serious museological display — such as the display cases, subdued lighting, and interpretive texts. As the author and single proprietor of this small institution, I have aimed to make MoCO a *real* museum. But, I am aware of the financial difficulties of running a museum of natural history/art project. By looking to Barnum, Tussaud and Wilson as role models, I aim to find my own business model that will allow it to exist and thrive in contemporary culture. As Carla Yanni has demonstrated, architecture is essential to the essence of any museum of natural history, and for this reason MoCO at some point will need its own building. But like Madame Tussaud, who toured in England for 30 years before having a permanent base in London, I believe that touring will suffice for the first years of MoCO's life.

So is it art, or is it science? If it is a science museum, does it stop being art? Like the MJT, MoCO uses a similar principle to choose what to exhibit. This is clearly expressed by Ralph Rugoff when he quotes the old adage 'truth is stranger than fiction'. The knowledge that MJT produces is definitely in the realm of the strange.[41] MoCO's strangeness can be understood partly because it presents new knowledge to the public, and partly because insect genitalia are so arcane.

> Making use of information that lies at the edges of our cultural literacy, the museum functions in a penumbral zone, conflating science and art with a fluidity that makes both categories seem suspect… The MJT operates at an information frontier.[42]

MoCO's collection is selected from that area very close to the limits of knowledge and perception. By restraining my artistic choices to the accuracy of scientific

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39 "Review of 18th Biennale of Sydney – Part 3 Cockatoo Island, Pier 2/3, Carriageworks," Art review , http://wordsaboutmusic.wordpress.com/.

40 John McDonald, "Review of the 18th Biennale of Sydney," *Sydney Morning Herald,*, July 14, 2012.

41 Rugoff, *Circus Americanus*: 99.

42 ibid.

display and rigorous research, the presentation of the models is faithful to the scientific tradition. My aim is not to unsettle or confuse (unlike the MJT or Barnum's displays), but to surprise. I want to trigger awe and wonder, to reveal and make visible an area of biology unknown to most. In an era where we think we have seen it all, after having been exposed to decades of nature documentaries, it is refreshing to explore the edge of what is known.

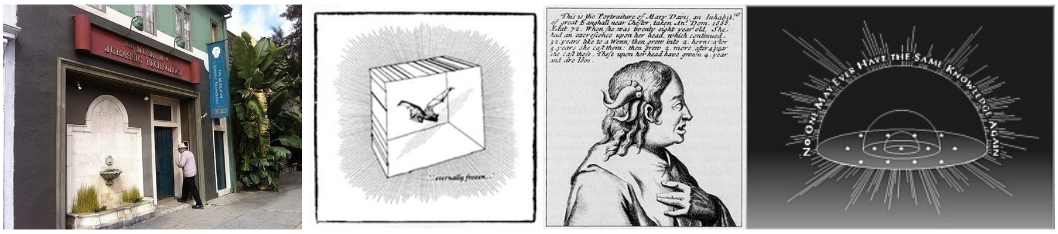

Figure 85 The Museum of Jurassic Technology in Los Angeles, California, founded in 1987 by David Wilson and wife Diana Wilson. Several images from the MJT website featuring the contents of the collection.

To conclude my comments on how museums of natural history have had a general influence on my thinking and art making, I turn now to a discussion of a Richard Ross' series of photographs entitled *Museology*. He humbly describes his approach:

> Essentially my work is about context. I want to look at the surroundings as well as at the piece presented. I am interested in the pedestal as well as with the object, the ground is as important as the figure.[43]

The effect is unsettling to the viewer. As Marcia Tucker has said of his photographs,

> the animals he depicts could be alive — some of them at least — and their natural grace contrasts sharply with the musty, decrepit, man-made interiors they have been confined in for so long. Nature is played off against civilisation here, the drama echoing more recent debates about this duality. Because for most people the photographs still claim to capture "reality", it is the photographs that give the illusion of reality to these tableaux originally intended to fool us within the context of an agreed-upon fiction. It is that fictional context of the Museum that Ross increasingly brings into view.[44]

The catalogue for *Museology* has also provided a general context for my understanding of the aesthetic, pedagogic and communicative possibilities of the museum as an art form. That is to say, fictional aesthetics of natural history museums (with all of their contradictions and difficult ethical questions concerning life and death) have informed decades of my artwork and triggered my work with preserved animals. As Paul Lawrence Farber, says the "growth of collections in the nineteenth century may have increased the appreciation of

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[43] Richard Ross, Marcia Tucker, and David Mellor, "Museology," (New York: Aperture, in association with the University Art Museum, Santa Barbara, 1989), 15.
[44] Tucker, Marcia, Introduction ibid., 7.

nature, but did little to protect it".[45] That paradoxical relationship is at the core of natural history collections. Although a full discussion of this idea lies beyond the scope of this dissertation, I now want to briefly consider some of the forces behind the popular attraction to the displays of natural history.

I propose that the aesthetics and attraction of the museum of natural history lies in the combination of what can be considered 'biophillia' and 'formaphilia'. Both of these terms help us to more fully understand the attraction, the curiosity and the pleasure that is gained by humans when they encounter the re-contextualisation of natural specimens in a human-made environment.

Biophilia is a term coined by biologist E. O. Wilson, and is a concept at the core of my art practice. According to Wilson,

> from infancy we concentrate happily on ourselves and other organisms. We learn to distinguish life from the inanimate and move toward it like moths to a porch light. Novelty and diversity are particularly esteemed; the mere mention of the word *extraterrestrial* evokes reveries about still unexplored life, displacing the old and once potent *exotic* that drew earlier generations to remote islands and jungled interiors. That much is immediately clear, but a great deal more needs to be added. I will make the case that to explore and affiliate with life is a deep and complicated process in mental development. To an extent still undervalued in philosophy and religion, our existence depends on this propensity, our spirit is woven from it, hope rises on its currents.[46]

According to the biophilia hypothesis, humans are innately or instinctively attracted to all kinds of other life forms. In short, humans 'love' animals, plants, and their morphologies.

> The biophilia hypothesis boldly asserts the existence of a biologically based, inherent human need to affiliate with life and lifelike processes.[47]

From E. O. Wilson's perspective, humans love 'biogeometries' and 'zoomorphias' because of a biological desire to associate with life-like forms and processes. Throughout all of my work, I ask why form and pattern are so attractive to humans. That question is also relevant in the display of genitalic morphologies. By choosing to work with biological life forms, I am deliberately capitalising on our biophilic relationship to other life forms in order to establish a strong attraction and connection with the public in relation to my artworks.

I want to suggest that biophilia is the bridge that allows us to connect to other forms of life. Formaphilia — which I would define as love of and attraction to form — is another aspect of the biophilia hypothesis. Borrowing Wilson's thesis, we can propose that biophilia, and formaphilia are built into each of us. When natural forms of life are re-contextualised, those innate forces of attraction that are

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45 Paul Lawrence Farber, *Finding Order in Nature : the Naturalist Tradition from Linnaeus to E. O. Wilson*, Johns Hopkins introductory studies in the history of science. (Baltimore, MD: Johns Hopkins University Press, 2000). 51.

46 Edward O. Wilson, *Biophilia* (Cambridge, Mass.: Harvard University Press, 1984). 1.

47 Edward O. Wilson and Stephen R. Kellert, eds., *The Biophilia Hypothesis* (Washington, D.C.: Island Press, 1993), 42.

perceived by our senses trigger emotional and intellectual responses. These responses are the foundation upon which we can effectively communicate knowledge about biological and natural sciences. Museums of natural history are built on that attraction and the connection they create; and MoCO is a 21st century extension of the naturalist tradition that exploits our biophilic tendencies.

By dislocating natural specimens from their habitat, and displaying them in purpose built environments called museums, we transform them. The animals become ‘specimens’ in their transition from what we call ‘nature’ to what we think of as [human] ‘culture’. Carla Yani, author of an important book on the architectural displays in museums of natural history, thinks about it in a way that is analogous to the collection of specimens for Noah’s Ark:

> There is more to this analogy [Noah’s Ark] than the gathering of animals — the ark’s purpose was preservation and conservation, a theme which has returned to the natural history museum of the twentieth century… In the western world, the natural history museum cannot escape a culture which connects museums and ships as vessels that house the whole natural world. There is not nature outside culture; the natural history museum is Noah's legacy.[48]

In her view, the architecture creates a hybrid reality, a human-made natural history. The dislocation of context that we are discussing here is evident in the photographs of Richard Ross, who focuses not only on the taxidermy but also on the vitrines and marble rooms that hold the displays. Ross captures with his lens the key features of the display of ‘natural’ specimens, placing attention on the artifice of display, rather than on the animal themselves. By objectifying animals and plants into specimens, by staging them and constructing narratives around them, we make them part of our cultural constructions.

Figure 86 Richard Ross photographs of the Museum National D'Histoire Naturelle, Paris, France, 1982, Museum National D'Histoire Naturelle, Paris, France, 1982, Rhino, Field Museum, Chicago, Illinois, USA, 1981

The act of display radically changes the nature of the objects observed. Over the years I have trained my eye and my mind to see and to analyse the cultural history of natural history. Display is part of that history.

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[48] Yanni, *Nature's Museums: Victorian Science and the Architecture of Display*: 166.

In my own museum project, I make individual objects for display. My work carefully controls the display and context in order to highlight the cultural history and biophilic tendencies of the audience. My work therefore lies in the interaction between the history of genitalic research (in the fields of taxonomy and evolutionary biology) and the history of the natural history specimen collection. The kinds of display I work with make links between the history of scientific models and illustrations (the communication of science). My work sits between the dislocation produced by our human frameworks and the natural world. It is in the intersection with the audience (as a receiver of that complex interaction of fields of science and communication) that new interpretations of the subject matter of genitalic extravagance will be constructed — with the help of the artifice of display, and by the interpretation by the audience.

Taking stock of the lessons learnt from these reflections, we can conclude that the making of a museum is about the making of knowledge. Fake or not, ambiguous or not, museology determines what is considered to be truth and what can count as 'real'. It legitimates knowledge — what the audience believes is important. By carefully following the semantics of museological display, exhibitions become not only authoritative, but become human reality. By bringing information from different scales and *umwelts*[49], and presenting them at human scale by way of human language, I am making a 'new reality' for humans to interpret. In saying this I am also asserting that making a museum is in itself performative. It requires an audience. By being rigorous in my scientific research, and by not inventing any facts, MoCO aims to be credible, even to a discerning audience of evolutionary biologists. To earn that credibility, I had to become an expert in the field. I am not creating a fiction, but presenting a little-known reality. My motto is "life is stranger than fiction." This idea was proposed by scientist, poet, and underwater film pioneer Jean Painlevé (1902-1989). According to Marina MacDougall, Painlevé "eschewed scientific dogma, claiming 'science is fiction,' and delighted in conflating fixed categories of all kinds."[50] In essence, I echo Painlevé's sentiments when he says that "reality is at the root of all great art. Without it there is no substance... Everything the artist creates originates in Nature."[51]

In essence (like the museums of the 19th and 20th centuries that I have been discussing in this chapter), MoCO aims to be both popular and serious.

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49 John Brockman, *This Will Make you Smarter* (New York: Harper Perennial, 2012). Neuroscientist David Eagleman, author of the excellent Incognito: *The Secret Lives of the Brain*, explores the concept of "the umwelt" coined by biologist Jakob von Uexküll in 1909 – the idea that different animals in the same ecosystem pick up on different elements of their environment and thus live in different micro-realities based on the subset of the world they're able to detect. Eagleman stresses the importance of recognizing our own umwelt – our unawareness of the limits of our awareness.

50 Marina McDougall, "Introduction," in *Science Is Fiction : The Films of Jean Painlevé*. (Cambridge, Mass.
London: MIT Press, 2000), XIV.

51 Jean Painlevé, Andy Masaki Bellows, and Marina McDougall, *Science is Fiction : the Films of Jean Painlevé* (Cambridge, Mass. ; London: MIT Press, 2000). 12.

Popularity means that messages need to be conveyed fluidly to a variety of audiences. For this reason, I have carefully studied Barnum's and Madame Tussaud's techniques of currency and novelty, of technical virtuosity and innovation, their attention to detail, branding and promotion and their making "the museum 'as' theatre."[52]

In order to be popular I have used established biological pathways: biophillia and formaphillia, which shape our emotional and aesthetic affinity for biological form and novelty. I also mobilise non-literary forms of communication, such as three-dimensional displays, audio-visual information, and limited written text. To be popular, I harness the power of public relations and tell the story, not only of what is inside MoCO, but who created it. To be popular, I aim to trigger curiosity, awe and wonder. And finally, I use the allure of sexual selection, that of aesthetic selection, to seduce large audiences. I show and use beauty as a language. I will explain this idea more fully in the following chapters.

[52] Goodall, *Performance and Evolution in the Age of Darwin: Out of the natural order*: 36.

Chapter Three

Making Sense of Artful Science

> So naturalists observe, a flea
> Has smaller fleas than on him prey;
> And these have smaller still to bite'em;
> And so proceed ad infinitum
>
> Jonathan Swift (1733)[53]

This chapter will study some examples of best practice in the marriage of art, science and technology in the making of scientific models. In order to answer my research question about how to best present genital morphologies to the public, I will look at some case studies that have informed my decisions for the making of the scientific models that are part of MoCO. As a visual artist and visual thinker, I believe in the power of images and objects to communicate concepts. As the old adage goes, 'an image is worth a thousand words'. But as a sculptor, I also believe in the power of three-dimensional models, not only to create and embody knowledge, but also to trigger high-order thinking[54] in others, (including the maker herself).

I want to propose that *making things* is essential in research and in the production of new knowledge. I will argue that three-dimensional models can enhance our understanding (of both art and science). They are essential in the making of culture in general, and in advancing the transference of scientific knowledge and research to a wider field. In a profound sense, I want to show that *making is a form of thinking*. Through the process of making, we come to understand, to create and to communicate simultaneously. "To see, observe and make things visible is one of the great challenges of science"[55] writes Michael Mosley, a science historian and physician. The same words can be used to describe the great challenges of art. Artists often use their perceptual skills and ability to create things in order to make things visible, tangible or available to the senses. One of the best examples that shows this integration of art, science and apprehension can

53 John Mack, *The Art of Small Things* (Cambridge, Mass.: Harvard University Press, 2007). 163.

54 In Bloom's taxonomy, skills involving analysis, evaluation and synthesis (creation of new knowledge) are considered high order thinking.

55 Michael Mosley, *The Story of Science: Science, Proof and Passion Episode 6: Who We Are* (BBC documentary, 2010).

be found in the famous anatomical waxes from La Specola in Florence, produced in the 18th century by a team of anatomists working in tandem with artists and technicians. This work provides an excellent starting point for my discussion of the role artists can play in the creation of new knowledge and the enhancement of our scientific understanding of the world.


Figure 87 Reclining female figure by Clemente Susini. Figure 88 Mascagni's lymphatic vessel man Specola Both late 18th century wax, La Specola, University of Florence.

By dissecting, casting and copying the exact textures and colours of each organ, the team observed closely and in great detail in order to be able to clearly replicate their observations in wax. After all, "models are, by definition, mimetic objects."[56] The need for the anatomical waxes was generated by the increasing necessity to use substitutes for the human body in anatomy lessons, and to complement the live dissections being performed at anatomy theatres of this period. At the same time as they learned the complexities of human anatomy, the team at La Specola innovated and then perfected the techniques for making highly accurate wax models and casts. Technically and artistically masterful, the anatomical waxes of La Specola have influenced not only the science of anatomy and medicine, but the arts as well. They influenced wax museums across Europe, including Madame Tussaud's. Their extraordinary work predates the special effects industry in today's film industry, which employs similar techniques of prosthetic make up (part of the lineage of wax modelling and casting). Challenged by the standards set at La Specola, Gunther von Haghen, the controversial anatomist and contemporary inventor of 'plastination' has taken extraordinary artistic licence for his own human anatomical models exhibited in his international touring exhibitions such as Body Worlds. We can comfortably say that the anatomical waxes from La Specola have had a profound influence upon popular culture and anatomy right up to the present day.

When I look at these waxes, I concur with Ludmilla Jordanova who says that "the physical properties of the models are far in excess of any 'need' for information."

56 Mack, *The Art of Small Things*: 72.

[57] The ineffable excess she points to is precisely the artistic component of those scientific models. These works resonate at many levels simultaneously; they are more than the sum of their parts. This is what makes these waxes so intriguing and their impact so long-lasting. They demonstrate the ways in which scientists and technicians can collaborate to produce scientifically accurate models that nevertheless are incredibly 'artful'. The making of these anatomical models is a team effort that requires not only the keen observation of the artist, but also an informed scientific understanding of the anatomy in question. This example also reminds us that we must always aim for excellence and innovation in craftsmanship. This is especially true in relation to the difficult task of mimicking life forms. Since life is generated from within the life form itself, it is technically very difficult to replicate with our human technologies and human-scale hands. Wax was the technology of choice for biological models made in 18th and 19th century. In Florence, craftsmen pushed the technology to its limits. Because casting suited the human scale of the cadavers they were depicting, their casting techniques allowed them to make accurate models on a one-to-one scale. The task for MoCO was considerably different, as my work involves the depiction of microscopic specimens. Although the wax models under discussion are an important influence on my work, my focus on invertebrate genitalia required a different approach.

Before outlining my own approach in the next chapter, it's worth noting some of the important precedents for the depiction of microscopic specimens using wax techniques. Anatomy, biology and medicine have traditionally relied on actual specimens for research and teaching. However, there are significant limitations to relying exclusively on actual specimens (or often the lack of them). The anatomical waxes at La Specola facilitated the teaching of anatomy by not having to rely on the continual supply of cadavers for anatomical dissections. They also rendered the anatomical structures more clearly than an actual cadaver could by the considered use of colour. In a way, the models were better than the actual specimens, as they could emphasise the knowledge that needed to be understood and communicated in the pedagogical framework of the operating theatre. Similarly, the 19th century science of embryology initially relied upon actual embryo specimens for the purposes of research and teaching. Obtaining embryos was a difficult and unreliable process, and brought with it the additional limitation of having to look through the microscope, one student at a time, in

[57] Ludmilla Jordanova, "Material Models as Visual Culture," in *Models: The Third Dimension of Science*, ed. Sorraya de Chadarevian and Nick Hopwood (Stanford: Stanford University Press, 2004).

order to be able to apprehend the anatomy. This was one of the main problems I had to solve in making a museum collection for MoCO. How can one solve the difficulties in obtaining and showing specimens which (often hard to obtain and to preserve) are too small for the display of many taxa? Before turning to a discussion of how I answered this question, I want to briefly deal with the ways in which this problem has been solved in the past.

As historian of modern medicine and biology Nick Hopwood confirms,

> natural preparations had an aura of authenticity, but also three major drawbacks: some objects were very scarce; most embryos had to be viewed under the microscope, an obstacle to group instruction; and even expert preparation did not display the structures of interest as clearly as a purpose-built device.[58]

According to Hopwood, the solution was found in the mid 19th century by a pair of wax modellers: the father and son team of Friedrich and Adolf Ziegler, whose studio ran from 1850 until 1918. The Zieglers invented a technique of working in wax, layer by layer, copying the sliced dissections of the embryos and then colouring the different organs in unique colours. They then stacked up the layers and removed the excess wax. The result was an accurate anatomical model of the inside and the outside of the specimen, colour coded for easy interpretation.

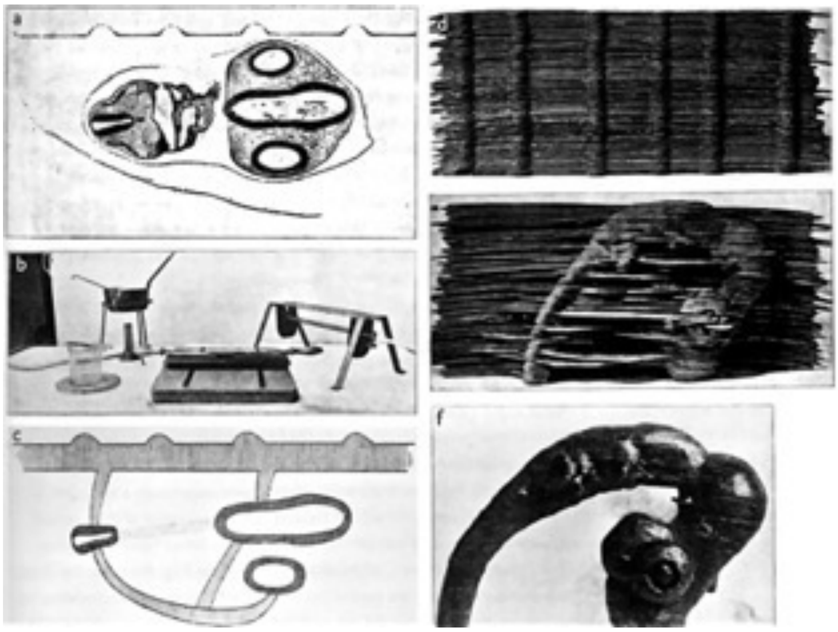

Figure 89 How to model an embryonic lizard brain by the wax-plate method of reconstruction. (a) Section on microscope slide with guideline top. (b) Instrument for rolling the plates. Each

[58] Nick Hopwood, "Plastic Publishing in Embryology," in *Models: The Third Dimension of Science*, ed. Sorraya de Chadarevian and Nick Hopwood (Standford: University Press, 2004), 182.

section was incorporated into a plate, and excess wax removed. © Diagram of cut out plate, with 'bridges'. (d) Stacked cut-out plates seen from the guide-place side. (e) Stacked plates from the object side. (f) Model produced by removing guides and bridges, and smoothing the edges.[59]

This method was revolutionary, and can be considered a precedent to the 21st century technique of 3-D printing or rapid prototyping, which similarly builds things in an additive process that 'prints' material, layer by layer. As I will show in the next chapter, this is one of the technologies I have explored and developed for the making of MoCO. The Zieglers are important as they developed innovative approaches to the technology of wax modelling, not just in terms of methodology, but also in terms of the materials they used. They developed models out of specially made hard waxes that would not melt or deform at room temperature (as was the case with most waxes up until this time).

> In the late nineteenth-century heyday of print, known for the foundation of journals, textbooks, handbooks and manuals, a major university science relied on wax modelling in its core teaching and research. [60]

Their models helped to train an entire generation of biologists and doctors around the world. Instead of making unique specimens, they made editions of objects that could be easily distributed to a number of different locations simultaneously. For this reason, they called themselves "plastic publishers" (even though they used wax). They made their technology comparable to that of paper printing, publishing multiple copies of each specimen. Since there was a great effort involved in the making of each specimen, and as they worked closely with scientists to ensure their models were accurate, it made financial and pedagogic sense to work in editions. This innovation sped up the science of embryology and created a new business model for the artistry of wax modeling.

> By comparing plastic publishing to book publishing {I show] how models that we might expect to be, on the one hand, too bulky, fragile and expensive, and on the other, too low-status, could become accessible and credible enough to play major roles in evolutionary embryology. The key was to manage relationships with scientists carefully. This allowed Ziegler to publish prospectuses that labelled each series with the name of, not just a species, but also a professor… Advertising models after Prof. X and listing the corresponding printed works made the waxes academically authoritative and relevant. [61]

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59 Nick Hopwood, *Embryos in Wax: Models from the Ziegler studio* (Cambridge: Whipple Museum of the History of Science, University of Cambridge and Institute of the History of Medicine, University of Bern., 2002). 53.

60 ibid., 4.

61 ibid., 25.

This combination of art, science and commerce also informs my own practice. The lessons learnt here have been particularly useful to MoCO, as I aim to make scientifically credible models that can be understood as part of the financially independent museum framework I am working with. All of my work is produced in close collaboration with scientists, whom I credit in my own museum displays of carefully crafted anatomical models.

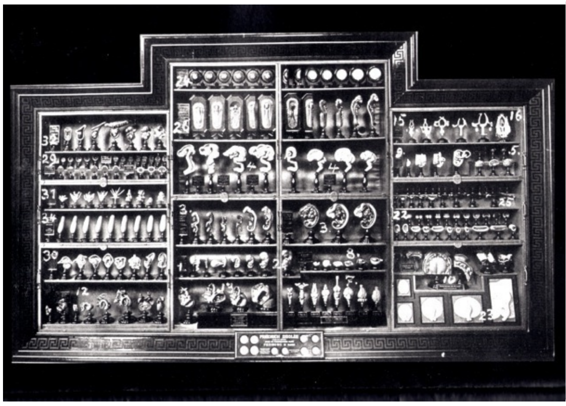
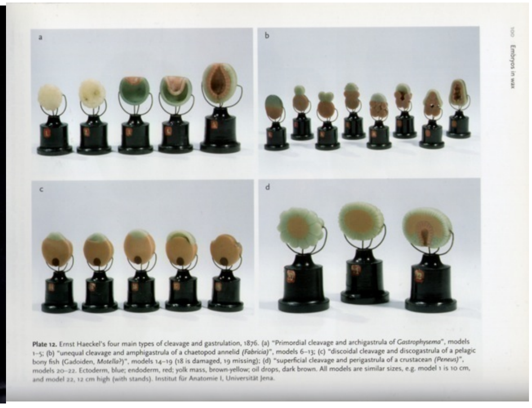

Figure 90 Evidence of their international distribution is this rare photograph of their award wining stand at the 1893 World's Columbian Exposition in Chicago. On Figure 91 wax models from the Ziegler studio of Ernst Haeckel's four main types of cleavage and gastrulation, 1876. According to Nick Hopwood, we know that they worked closely with Haeckel, and many proofs were sent back and forth until he was satisfied with the results[62].

Another aspect that is important to my research relates to how these scientific models were used. As we can see from figures 4 and 5 models were often used in conjunction with two-dimensional images. These artful images and objects supported the lecturers who were the human conveyors of this scientific information. As Nick Hopwood puts it,

> models were special — and always produced and used in tandem with various printed materials, from prospectuses and catalogues to textbooks and journal articles. We gain a richer view of both books and models when we see how modelling shaped the printed page, and letterpress joined wood-cuts and photographs in helping spectators make sense of objects that would otherwise have remained strange.[63]

I understand this strangeness Hopwood describes, as it is consistent with my experience as a sculptor. When exhibiting formalistic sculptures made out of unfamiliar materials that have been dislocated from their original context — for example in my “Colombian Material Series” from 1992-93 — I have always noted what I call ‘a gap’ in meaning when exhibiting in a culture other than my own. The audience may be able to absorb the physical shape and form of the sculptural

62 ibid., 4.
63 ibid., 5.

objects, but their interpretation is only made in reference to forms of knowledge they are already familiar with (e.g. Minimalist art, formalism, etc). They do not necessarily have access to the 'new' knowledge provided: in this case, unrecognisable materials and their meaning (understood by Colombians, but mostly opaque to others). I learnt from my practice that in order to communicate the 'inaccessible' contents imbedded in the sculptural objects, I needed to provide other forms of communication and delivery (other than the physical presence of the sculptures on their own). In the visual arts, this is usually done through artist talks, or written statements, but many people would miss both of them. If my aim is to clearly communicate knowledge imbedded in scientific models, it is very important to look at the historical precedents for guidance.

Being aware of my own experience as an artist communicating visually with objects, and reflecting on the way objects of science have been treated and used in the past reinforces my conviction that it is essential to frame the context in which such objects are exhibited. My experience also confirmed that other types of information need to be delivered simultaneously, and through different mediums. The written word, narratives, descriptions of objects, interpretation, lecturing, drawings, pictures, and video all reinforce the knowledge transmission function of the objects/models. The anatomical waxes of La Specola were not intended for aesthetic observation (the context they are mostly observed in nowadays). They were originally accompanied by guided instruction and two-dimensional illustrative plates. We can agree with Barbara Maria Strafford when she observes that the "history of science… has become fascinated with three-dimensional models as research tools. Such 'epistemic objects,' it is being argued, are mediators in the making of knowledge".[64] While Stafford is correct in reminding us that objects are important communicators, we shouldn't think of them solely in their isolated form.

[64] Barbara Maria Stafford, *Echo Objects: the Cognitive Work of Images* (Chicago: University of Chicago Press, 2007). 6.

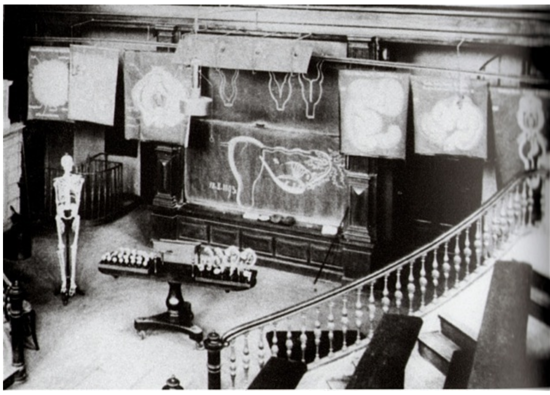

Figure 92 Visual aids for embryology arranged for a lecture in the Freiburg gynecological clinic on 18 February 1893. The Ziegler models are on the left of the table, and Berthold Hatscheck's amphioxus models on the right, two series of human embryonic anatomies. Figure 93 Ernst Haeckel lecture "The Human Problem and Linnés Master Animals" in Jena 1907.

Figure 6 shows the setting for one of the many influential lecture presentations given by German biologist Ernst Haeckel (1834-1919). An ardent Darwinist, embryologist, philosopher and artist, Haeckel strongly believed in images as communicators and as creators of knowledge. According to Olaf Breidbach, for Haeckel, "the illustration is not a depiction of existing knowledge, but is itself the acquisition of knowledge of nature. The truths of nature are seen."[65] Haeckel believed in this notion so much that he aimed to tell the entire story of his own interpretation of phylogeny in nature largely by way of illustrations in his book, *Kunstformen der Natur* (*Art forms of Nature*) published in 1904. His plates

> also illustrate his basic notion of organic stereometry... The idea of being able to discern the organisation of forms by looking at them and thereby to gain insight into their schematic order, enabling the phylogeny of living things to be reconstructed, is expounded upon by him once again in further detail.[66]

As beautiful as his plates are, in many ways he failed to achieve his goal. His theories are as idealised as his illustrations are aestheticised. He aimed to promote Darwinism through his genealogical trees of life-forms "free of contradictions"[67] as Olaf Breidbach puts it. He was an extremely talented illustrator, and yet he used illustrations as propaganda for his ideas. He saw "truths in nature" that were biased by his own ideals. Historian of science Paul Laurence Farber tells us that in Germany,

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[65] Ernst Haeckel, Breidbach, Olaf and Eibl-Eibesfeldt, *Art forms in Nature : The Prints of Ernst Haeckel* (Munich; New York: Prestel, 1998). 14.

[66] ibid., 13.

[67] ibid., 10.

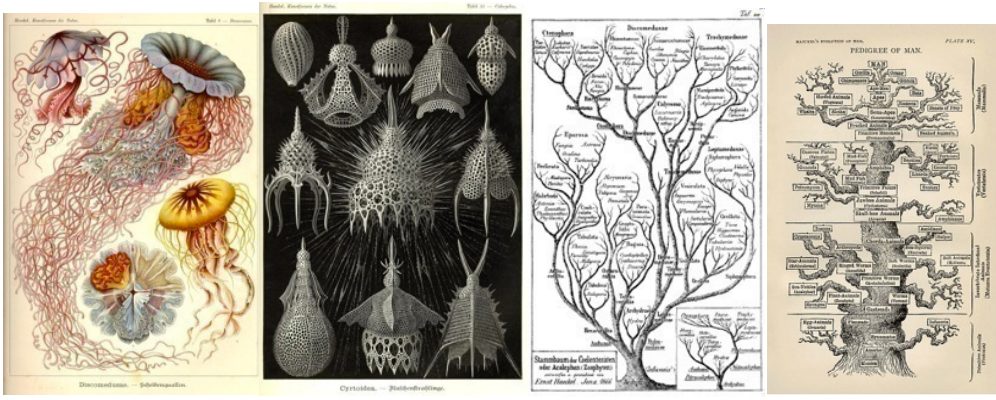

Figure 94 Ernst Haeckel illustrations of Medusae, Radolarians, Haeckels tree of life, and his *Pedigree of Man* published in *The Evolution of Man* (1879).

> where Darwin had the greatest contemporary acceptance, naturalists generally incorporated evolutionary ideas into wider synthetic visions. Ernst Haeckel emerged as the major spokesperson for evolution... Haeckel claimed that Darwin provided the synthesising vision necessary to construct a complete scientific picture of the living world. By that he meant that the Darwinian theory presented a totally mechanistic vision which did not involve any goal directed ideas. Ironically, by pursuing a total system — albeit a physical one — Haeckel often went far beyond "scientific reasoning". In his writings *General Morphology* (1868) and the more popular works *Natural History of Creation* (1868) and *The Evolution of Man* (1874) Haeckel sketched a highly speculative system that traced evolution from an early, single, spontaneously generated primitive form up through humankind.[68]

We have been focusing in this chapter on technical skill and innovation in both two- and three-dimensional scientific models. Haeckel worked in two dimensions, and was a very talented and skillful illustrator. There are many things in common between his illustrations and what I have aimed to create in MoCO. My aim is to join taxonomy and evolutionary biology, as Haeckel did. I also aim to show microscopic morphologies that are unknown to many people, as did Haeckel. I want to depict the enormous diversity of genitalic form, just as he drew upon an incredible diversity of natural forms. My work aims to understand the evolutionary theories behind genital morphologies in order to convey them to the general public, in the same way that he aimed to join Darwinian evolutionary theories and natural form.

Despite these similarities, Haeckel stands as a warning about the excesses in approach and claims that might be made in relation to MoCO. The key for me is not to idealise forms and to aestheticise them — to please the eye as it were. My

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68 Paul Lawrence Farber, *Finding Order in Nature : the Naturalist Tradition from Linnaeus to E. O. Wilson*, Johns Hopkins introductory studies in the history of science. (Baltimore, MD: Johns Hopkins University Press, 2000). 69.

work does not aim to represent everything solely by visual means. While I also include words, objects and the engagement with other senses to help understand the morphologies in question, I aim to avoid the generalized claims and speculation associated with Haeckel's approach. Haeckel aimed to tell the story of evolution in pictures, but ultimately failed.

Three-dimensional models are harder to make than two-dimensional renderings. They require a more complex cognitive effort on the part of the maker in order to accurately mimic the specimens, and to avoid the kind of stylization that proved to be Haeckel's downfall. But more importantly, it is vital not to follow one single theoretical framework in order to properly understand the inherent complexities of genital morphologies. As we will see in Chapter Five (devoted to a discussion of the evolutionary biology of genitalia), there are several current and conflicting theories about the role and formation of genital morphologies. My aim is to depict a range of sometimes conflicting interpretations in relation to each other, rather than to promote one theory over another.

An interesting example of how to present 'beautiful' natural forms without underselling the conflicting accounts of their significance can be found in the glass microbiology series made by contemporary British artist Luke Jerram. Working directly from scientific photographs generated by electro-microscopy, and in collaboration with virologist Andrew Davidson from the University of Bristol, Jerram commissioned highly skilled glassblowers Kim George, Brian Jones and Norman Veitch to make a series of large glass models of humanity's most famous and feared viruses: HIV, smallpox, Sars, avian flu, E-coli, Malaria and several other viruses. He chose viruses that are highly visible in news and contemporary culture, but which can hardly be seen (even with the aid of the microscope). His first approach was to make these objects colourless and transparent, as they are in the 'natural world'.

> I'm colour blind and this has given me a natural interest in exploring the edges of perception. Often images of viruses are taken in black and white on an electron microscope and then they are coloured artificially using Photoshop. Sometimes that will be for scientific purposes but other times it will be just to add emotional content or to make the image more attractive. The problem is that you end up with a percentage of the public believing that viruses are these brightly coloured objects. These are often portrayed in newspapers as having an air of scientific authenticity and objective truth, whereas actually that isn't the case. Viruses are so small they have no colour. They're smaller than the wavelength of light.[69]

[69] "Luke Jerram's GlassVirus Artworks," (Wellcome Collection: BBC World Service, 2009).

Making them transparent and colourless may seem like an unimportant decision, but from my perspective it is critical. As we have seen in the discussion of anatomical and embryonic waxes, colouring is a scientific methodology that helps distinguish between forms and to emphasise different aspects of a morphology. Yet in this case, the use of colour 'fictionalises' and distorts the human interpretation of viruses. The use of transparency allows for the internal structures to be seen as colourless (not white, as if you were drawing them on paper). Viruses are smaller than the wavelength of light. This provides an essential point of reference. The problem of how to indicate appropriate scale when using the microscope or electron microscope to enlarge things is very difficult to solve. Scale is a central component in our understanding of the parasitic life forms that exist within us. Making them in three-dimensional form allows for greater expression of accurate rendering of form than that allowed in the case of two-dimensional models. Colourless glass avoids the problem of introducing decorative decisions into the model, as is true of Haeckel's works in *Art Forms in Nature*.

Working in glass also pays homage to the tradition of glass model making in natural history, from 19th century virtuosi flame glass artists such as Leopold (1822-1895) and his son Rudolf Blaschka(1857-1939). This father son team are well-known for making what are widely considered to be the most extraordinary glass models of marine invertebrates and botanical specimens: the Glass Flowers from Harvard. Viruses, invertebrates and plants are all perishable and impossible to preserve and exhibit as natural specimens. The translucency and durability of glass has made it the most suitable material for the manufacture of organic models, and that technology has not yet been surpassed. Glass remains the 'gold standard' for the kind of specimens I have made for inclusion in MoCO. While I acknowledge that mimesis is a requirement for the effective construction of scientific models and the acquisition of knowledge, an exploration of the cognitive and aesthetic dimensions of mimesis in the creation of artworks and scientific models is beyond the scope of this thesis.

Figure 95 Blaschka glass models of marine invertebrates from the Harvard Zoological Collection and Figure 96 from the Cornell collections. (circa 1870-1880)

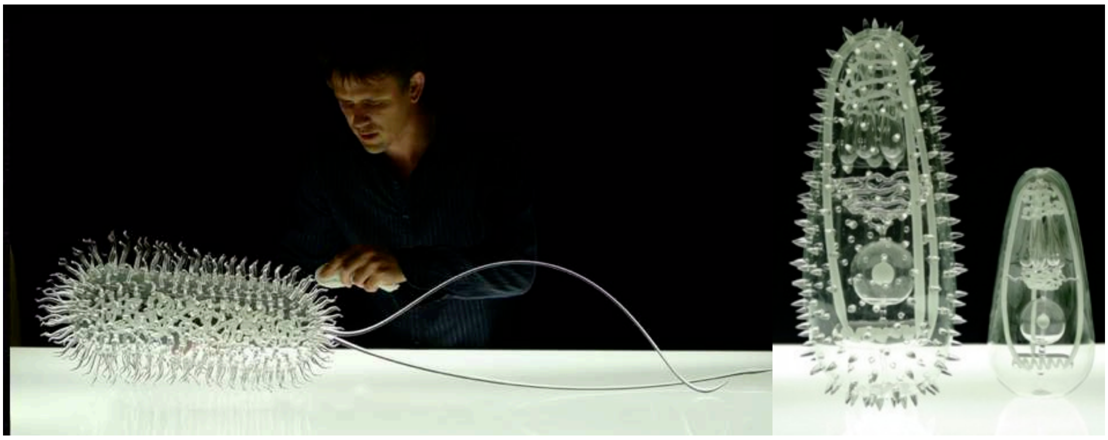

Figure 97 Luke Jerram, e-coli, HIV and malaria glass viruses.

Returning to the consideration of Jerram's large handmade glass models, I would argue that Jerram has made the virus morphologies 'exist' at the human scale. His works have made them visible and palpably understandable. The fact that there is a long tradition of teaching with three-dimensional models in science indicates that there is a need for objects that help us to apprehend the world. As Lorraine Daston puts it, "without things we would stop talking."[70]

We have all seen microscope photographs of viruses, but they don't seem to resonate in the same way that Jerram's objects do. Let's try to understand why. Firstly, he made them novel, technically masterful, beautiful, but not at all decorative. He depicts them as distinctive individual things, each with a shape we can recognise. Scientists have long known that viruses have distinctive morphologies, but this is largely unknown to the general public. Indeed, they were incredibly novel to me. It is as if he gave a face and a form to an unknown danger. He gave them a physical body that we can now more easily recognize and understand with a range of our senses. He points to one of the important

[70] Lorraine Daston, *Things that talk : object lessons from art and science* (New York Cambridge, Mass.: Zone Books; MIT Press distributor, 2004). 10.

roles played by the diversity of biological forms: diversity helps us to correctly recognise and make distinctions between forms. According to E. O. Wilson and Stephen Kellert,

> the use of nature as symbol is perhaps most critically reflected in the development of human language and the complexity and communication of ideas fostered by this symbolic methodology… Nature, as a rich taxonomy of species and forms, provides a vast metaphorical tapestry for the creation of diverse and complex differentiations.[71]

Jerram has given his viruses a presence and made them part of a taxonomy we can now recognise and negotiate. He has made them part of human language, and exposed their relevance. For this reason I argue that they are more than simple decorative objects. It is our knowledge of what they are (or what they represent) that attracts and repels us. We may like them as forms, admire them, love them, even find them beautiful. We may feel affinity for Jerram's models in a 'biophilic' and 'formaphilic' way. And yet those viruses are most fearsome. Therefore they provoke an interesting intersection of fear and empathy, admiration and respect. For this reason Jerram refers to the viruses as possessing a 'terrible beauty'.[72] By loading the morphology with all the cargo of our human emotions, as well as knowledge about those specific viruses, he creates a complex set of meanings and understandings of the viral forms. In other words, for me, the most important contribution of Jerram is to the tradition of scientific models (in addition to the field of contemporary art). The morphologies he has imaged help us distinguish taxonomies, in the same way as all biological models (like those made by the Blaschkas) were used in the past; we look at the glass viruses in relationship to our own human existence. What I have attempted to create through MoCO's genital morphologies and taxonomies is not just the faithful depiction of forms (that turn out to be quite beautiful). I attempt to connect the audience to what those forms mean to us, as humans. It is that precise intersection of the animal and the human that I am interested in. [73]

"People think microbes are bright purple beasts," says Jerram. "In fact, they are mostly transparent."[74] Popular culture has demonised viruses and microbes by

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[71] Edward O. Wilson and Stephen R. Kellert, eds., *The Biophilia Hypothesis* (Washington, D.C.: Island Press, 1993), 51.

[72] Robin McKie, "Luke Jerram's Viral Crystals: Beautiful but Deadly." http://www.guardian.co.uk/science/2010/aug/15/luke-jerram-crystal-hiv

[73] That is why it is so satisfying looking at and listening to the audience comments at the Sydney Biennale. This was the kind of interaction I was aiming for.

[74] McKie, "Luke Jerram's Viral Crystals: Beautiful but Deadly". http://www.guardian.co.uk/science/2010/aug/15/luke-jerram-crystal-hiv

enlarging them into colourful monsters cast in gigantic scale, quite often appearing in movies, computer games, and TV advertisements for the multibillion dollar hygiene industry. The scientific community has traditionally coloured their specimens, primarily for aesthetic reasons. It took an artist to present them just as they are, transparent and beautiful.

Jerram helps the viewer understand concepts that are hard to grasp — such as scale and relevance — as such simple organisms can kill and create misery for millions of humans. They look simple and complex at the same time. Their aesthetic makes them accessible as beautiful life forms, and not necessarily as dangerous monsters. Jerram gives the public a way to admire the viruses, despite their potential threatening nature. By taking the viruses away from the abstract realm of generalised fear and giving the microbes a specific form and concrete presence, he has created an empathy and a direct sense of relationship and negotiability where previously there was most likely unspecified fear. As social historian and urban theorist Mike Davis has argued in *Ecology of Fear: Los Angeles and the Imagination of Disaster*, the powerful fantasies produced by contemporary film and television have an impact on the social imagination precisely at the vulnerable border between fantasy and reality.

Jerram's simple, well-conceived artworks, are informed by both science and popular culture, and fall on the side of reality rather than fantasy. His work adds more dimensionality to our apprehension of viruses than science or popular culture can offer on their own. Jerram's work acts like a multidimensional bridge, creating connections between concepts, facts, emotions, realities. A clear concept, accurate science, and highly skilled craftsmanship are central to the success of his project. Because of both art and science's interest in the visual, science and art are inherently linked. Art theorist Barbara Maria Strafford has convincingly shown "how images integrate information and make us aware of that fact".[75] Following cognitive scientist and neurophilosopher Andy Clark, Stafford has proposed "that complex and unruly problems are 'representationally hungry'".[76] That is to say, we have a need, a hunger, for representations. The tools that allow us to make those representations have the capacity to organise and integrate knowledge. Once we can assign some sort of visual pattern to these objects, we can comprehend a concept; and not before. Visualisation is for this reason very important for science. Visualization is deeply affected by the technologies that are available. To clarify this point, I will provide two examples:

[75] Stafford, *Echo Objects: the Cognitive Work of Images*: 3.
[76] ibid., 43.

the first is in the realm of mathematics, and the second is in the area of optics (microscopy in particular):

> For two thousand years mathematicians knew about only two kinds of geometry — the plane and the sphere. But in the early nineteenth century they became aware of another space in which lines cavorted in aberrant formations. Offending reason and common sense, this new space came to be known as the hyperbolic plane. Although the properties of this space were known for 200 years, it was only in 1997 that mathematician Daina Taimina worked out how to make physical models of it. The method she used was crochet.[77]

Figure 98 On top, mathematically precise models of a hyperbolic panes by Dr. Diana Taimina. (1997)

Figure 99 Hyperbolic Crochet Coral Reef and Anemone Garden by the Institute for Figuring IFF (2005-2011)

Hyperbolic geometry is widespread in nature such as in corals, anemones, flatworms, kelp, even flowers. But nobody saw it as such, or understood it as such until the technology of crochet allowed for the expression of these hyperbolic formulas by human hands. Nowhere is it more precise than in the example of what Lorraine Daston describes as things knitting together "matter and

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[77] Margaret Wertheim, "The Beautiful Math of Coral," http://www.ted.com/talks/margaret_wertheim_crochets_the_coral_reef.html.

meaning".[78] The act of making these morphologies by hand, in three dimensions, with a conscious awareness of the algorithmic variations of the hyperbolic planes, is what allows the crochet models to 'make sense'. This 'making sense' is also the result of the changing of contexts that I referred to when looking at natural history specimens in the previous chapter. It is also the result of the mimetic act of replicating a life form in a new material and a new context. It is the transition between *what a life form is* to *what it is to us*, that gets revealed in the making.

My penultimate example of how our hunger for representations is technologically influenced is the oldest and perhaps most influential of all the instances I have referred to so far. Most of the case studies I have looked at involve microscopy: Jerram's viruses, Haeckel's radiolarians, the embryology models, even the anatomical models. Artists have been mediators between new technologies and the worlds they can reveal to us. However, none of them is more influential than Robert Hooke (1635-1703).

Hooke was a polymath, scientist, artist, and natural philosopher. He has been named England's Leonardo by art historian Allan Chapman.[79] Hooke, who was at the time the curator for experiments at the Royal Society, was commissioned to make a book to showcase the novel technology of microscopy. *Micrographia: or some physiological descriptions of minute bodies made by magnifying glasses, with observations and inquiries thereupon w*as an instant hit when it was published in 1665, and became the first popular science bestseller. It is one of the best examples of artful science. The book, with its spectacular fold out engravings, was not merely a technical book about microscopy. The publication glorified the most minute, perfect, and complex of 'god's creations', and at the same time showcased a state of the art technology (the microscope), explaining how it worked. Hooke's popular success made his own work accessible to all, not just the scientific community. His success was made possible by the novelty of the organisms he was describing, and the exquisite detail of his illustrations. The grand scale of the engravings, coupled with the choice of specimens he described, helped make his work accessible to a lay audience: a louse, a flea, and the fly's eyes became accessible to the general public and the scientific community alike for the first time. Everyone was familiar with those particular creatures, as they have been in a parasitic relationship with humans for millennia. What better choice than to take those subjects that are familiar and a nuisance to all in everyday life? Hooke's microscope and his engravings allowed humans to

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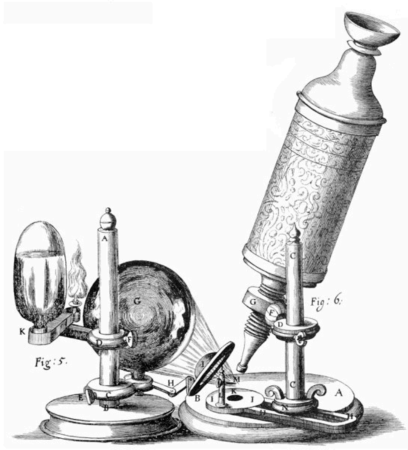
78 Daston, *Things that talk : object lessons from art and science*: 10.

79 Allan Chapman, *England's Leonardo: Robert Hooke and the Seventeenth-Century Scientific Revolution* (Bristol and Philladelphia: Institute of Physics, 2005).

see these creatures for the first time in a completely new way and in the most intricate detail. That was the strategy of the artist in him: finding ways to make the work connect and resonate in the viewer. Like Luke Jerram's choice of 'famous' viruses, Hooke knew what mattered to the people of his day and time. That was his stroke of genius. Like Jerram, making his work on microscopy accessible and relevant to society had a great impact on both science and on society at the same time.



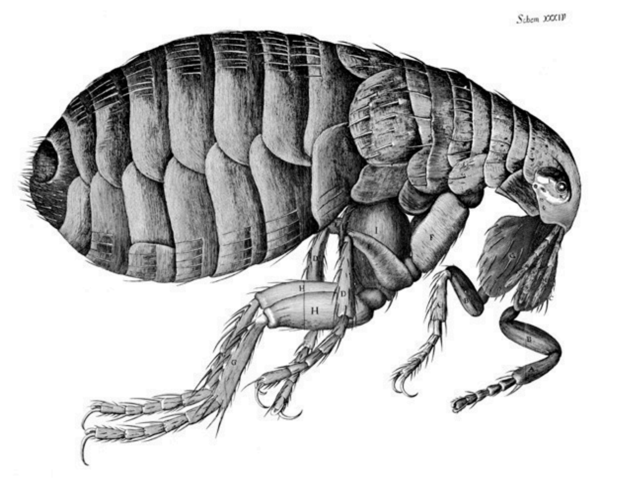


Figure 100 Hooke's microscope and Figure 101 flea plate from *Micrographia*

In this regard, art historian John Mack argues that

> *Micrographia* retains the power to impress, not least through the quality and impact of its illustrations. The philosopher of aesthetics and art critic Arthur Danto has devoted a lively essay to a consideration of the sources of 'the uncanny power and strange beauty' of Hooke's illustrated creatures. (Danto 1994, p376-87) He is drawn to the contrast between fleas as pestilent, yet as 'imposing in the intricacy and the proportion of their astonishing bodies'. He finds in Hooke's illustrations a mingling of the aesthetic with the cognitive. The microscope had summoned in an Age of the Marvellous, like the discovery of new continents, it opened up and enhanced understanding of the possibilities and beauty of nature; and like the artefacts and products brought back by returning explorers, these illustrations made visible whole new worlds.[80]

This idea of the discovery of new worlds and the mingling of the aesthetic with the cognitive by means of new systems of vision (utilized by artists interested in deeper understandings of the natural world) also finds expression in the field of mathematics. In the late 1860s and early 1870s the concept of embodied

80 Mack, *The Art of Small Things*: 43-44.

mathematics was first expressed by Herbert Mehrtens when looking at the studies of algebraic surfaces of the third order by Felix Klein. He comments that it is

> the geometrical form that guides the mathematical interest and the characterisations given in typographical formalism. The models (and diagrams) were constructed to 'grasp' the form and to show the typical forms of a class of surfaces. If form or *Gestalt* is the epistemic thing around which the research circles, then the model is one of the representations of this thing, and not fundamentally different from the algebraic formula or the diagram. It is one of the many simultaneous and consecutive representations of the object. In this sense the model is part of doing mathematics, embodied mathematics. Research is the creative work of representing epistemic things. In this act of representation I suggest the model is real mathematics, embodied mathematics.[81]

According to Herbert Mehrtens, mathematicians like Thomas Kuen (who made one of the models that Man Ray photographed) considered his models as a valid form of scientific research.

> The history of science, for example, has become fascinated with three-dimensional models as research tools. Such "epistemic objects," it is being argued, are mediators in the making of knowledge. [82]

Ludmila Jordanova argues for something very similar in her essay "Material Models as Visual Culture". She suggests that we might want

> to consider the extent to which the distinction between conceptual and material models reflects academic practice in the humanities and social sciences. Professional scholars place great, if generally unconscious emphasis on two-dimensional items. Words, pieces of paper, computer screens, and, to a lesser extent, images are our bread and butter. I would suggest that virtually every person who has received a humanistic education feels more comfortable working in two dimensions than in three… So working with three dimensions, which is a commonplace in most sciences, could be seen as the province of some specialists, while most other academics operate with two… Thus while serious attempts are being made here to get a way from the dominance of words and texts, perhaps because so much is being covered the precise problem of understanding 3-D thinking in general and models in particular is swamped. The issue here has been marginalised further by the dominance of literary critical methods in humanities and social-science disciplines, which has reinforced their propensity for 2-D thinking.[83]

Even though the 3-D model has been an instrumental tool in the history of science and in the making of knowledge, its role has been neglected by historians

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81 Herbert Mehrtens, "Mathematical Models," in *Models: The Third Dimension of Science*, ed. Sorraya de Chadarevian and Nick Hopwood (Standford: University Press, 2004), 289.
82 Stafford, *Echo Objects: the Cognitive Work of Images*: 6.
83 Jordanova, "Material Models as Visual Culture," 443.

of science, until the publication of the groundbreaking book *Models: The Third Dimension of Science* edited by Soraya de Chadarevian and Nick Hopwood. The authors make the parallel of imagining a history of art without the inclusion of sculpture. Despite this observation, much of our teaching and learning of science continues to be done in two dimensions, in spite of how much effort two-dimensional communication requires. Learning how to read and write requires of years of schooling. Watching movies is a learnt skill. Even drawing, and interpreting drawing is an acquired technique, also taught at school.

We know, as expressed by innumerable artists, scientists, illustrators and educators that we draw in order to understand, and to help others understand. (Leonardo's sketches are a perfect example of that process.) There is a practicality to drawing, which has made two-dimensional illustrations quite ubiquitous in the tradition of scientific research. There are reasons for this: "There is nothing you can dominate as easily as a flat surface" writes Bruno Latour.[84] This expresses something of the practical side to drawings. They are quick, cheap and easy to make; they can be stored flat, collected and catalogued in libraries, where historians can find them easily. They can be inexpensively reproduced thanks to the printing press, and placed in the context of illustrated books. Drawings of models have also been common, and so three-dimensionality is not completely separate from two-dimensional media. In fact they often go together.

Objects are harder to collect than drawings or text, harder to store, more difficult to classify and harder to preserve. They may be "too expensive and immobile for routine use" write Chaderevian and Hopwood[85]. They might be too fragile or cumbersome to move around and as unique objects, and they are expensive to make and to reproduce. But despite this, they are unsurpassable as objects of display for public exhibition and education, and the traditions of early museums and museums are built upon them. As objects of inquiry, they display relationships that are hard to represent on paper. By making visible those relationships, they become ideal educational models to be used in pedagogy and in the popularisation of science. Their role has been essential because teaching was "the centrally important means of ratifying and conveying knowledge, and addressing wider audiences crucial to establishing scientific authority."[86] Scientific models were first used as research tools, and secondly as teaching aids,

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[84] Bruno Latour and Steve Woolgar, eds., *Laboratory Life: The Social Construction of Scientific Facts*. (Beverly Hills, Calif: Sage, 1979), 45.

[85] Sorraya de Chadarevian and Nick Hopwood, eds., *Models: the Third Dimension of Science* (Standford: University Press, 2004), 2.

[86] ibid., 3.

as they embodied and displayed knowledge that is relevant to scientific research and for the teaching of science.

Based on all the case studies and the lessons learnt, I want to remind the reader of the importance of the multidisciplinary approach to all of the research conducted as part of my PhD. I have studied the history of science and art, together with the history of 3-D models. Shortly, we will look at the history of taxonomy and evolutionary biology in relation to animal genitalia, and we will proceed with a discussion of the technological and aesthetic aspects of my practice-led research. At this point in the thesis I can summarise my work by saying that I make three-dimensional models based on the morphology of animal genitalia as embodiments of the knowledge I have produced. I also utilise other forms of media such as text and image. I use the framework of museological display to house the models, objects, sculptures, images, text and video, in order to provide a context. I also use this framework to guide the narratives constructed as the body moves around the space and interacts with the 3-D exhibits. The point I am making is that my work engages with the science of taxonomy and evolutionary biology through the use of multilayered and physical pathways, such as those used in 3-D thinking and 3-D model making. This chapter has given an account of how art and science have combined to make models and representational forms that assist a variety of different audiences in the apprehension of complex biological forms. The following chapter will explore the various ways I have invented to present my findings in two and three-dimensional formats.

Chapter Four

Specimen by Specimen a Museum Collection is Made

According to the Oxford English Dictionary, 'to grasp', means 'to comprehend fully'. The physical act of holding an object can be thought of as being synonymous with intellectual comprehension. In order to make 3-D objects that hold scientific knowledge, I had to embark on a long process of hands-on experimentation and trial and error (technologically as well as aesthetically). This chapter will describe the processes of the making, thinking, and communicating of the objects that comprise the collection of specimens included in MoCO. The making of these works was developed over a period of four years, and involved experimentation with different mediums and technologies, as well as the development of relationships and collaborations with technicians in different fields. When appropriate, I reached outside the university when I couldn't find what I needed within our institution. By experimenting with old and new technologies, I have been able to assemble a startling variety of sculptural objects and images.

As diverse as the genitalic morphologies are, I set myself the task of finding the most appropriate technology for each group of specimens (rather than to have a blanket approach for their representation). In making a museum collection from scratch and with audience interaction in mind, I resolved to use tactics developed from my research into the practices of P. T. Barnum, Madame Tussaud and David Wilson, whose principles clearly indicated that a museum presenter should aim for uniqueness, wonder and habitual novelty in both subject and mode of presentation.

This tactic encouraged me to continue with my experimentation as I sought new display techniques throughout the development of MoCO. Each object on display must have a story to tell and distinctive 'information' to impart, partly derived from the way each artifact has become loaded with meaning through the process of making. This aspect of my research involves technological investigation, record-keeping, and reflective analysis — all followed by further experiments in innovation, as well as multiple aesthetic decisions and realisations, which I will now describe along with images of the objects produced.

On 3-D modeling 3-D printing and 2-D rendering

> …so it goes without saying, for it is the shape of the solid object, not that of the mere drawing of the object, that we want to understand.[87]

[87] D'Arcy Wentworth Thompson, *On Growth and Form*, Abridged ed. (Cambridge Cambridgeshire: University Press, 1961). 448.

D'arcy Thompson

> 'Model' is what can be called an incomplete concept in implying the existence of something else, by virtue of which the model makes sense. This 'something else' might already be in existence or yet to come. It might be larger or smaller, more or less complete, sophisticated or accessible. Models then, however verisimilitudinous, beautiful or satisfying, always refer onwards. As a result there are interpretative gaps for viewers to fill in, the 'beholder's share' in Gombrich's words. In the case of the models used in scientific, medical, and technological practice, precisely how this interpretation is accomplished becomes absolutely vital."[88]

Jordanova, Ludmilla

In order to make scientific models of selected animal genitalia to the highest of standards, I explored one of the newest contemporary techniques — that of 3-D computer modeling and 3-D printing. 3-D graphics are now ubiquitous in our moving image and gaming culture. However, making physical objects out of that data is just starting to emerge as one of the new trends in manufacturing. Not many artists have ventured down this path, though it is clear that very soon we will see more examples of artists using this sort of technology. Before we continue, some definitions might help the reader in case they are not familiar with the terms.

> In 3D computer graphics, 3D modelling is the process of developing a mathematical representation of any three-dimensional surface of object (either inanimate or living) via specialised software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The model can also be physically created using 3D printing devices. Models may be created automatically or manually. The manual modelling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting.[89]

> Additive manufacturing or 3D printing is a process of making three dimensional solid objects from a digital model. 3D printing is achieved using additive processes, where an object is created by laying down successive layers of material. 3D printing is considered distinct from traditional machining techniques (subtractive processes) which mostly rely on the removal of material by drilling, cutting, etc.[90]

The technology of 3-D modeling is changing rapidly and becoming more user-friendly. At the moment it is still a highly technical skill, and relatively labour-intensive. The same thing is happening with 3-D printing, which is revolutionising the way we manufacture things. Traditionally, we make things by removing material, as we do when we carve a piece of wood or stone to make a sculpture. 3-D printing uses layers of material that build up, layer by layer, in an additive process that doesn't waste any material. The technique is not dissimilar to the way that Friedrick Ziegler built his wax models in the 19th century, stacking

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[88] Ludmilla Jordanova, "Material Models as Visual Culture," in *Models: The Third Dimension of Science*, ed. Sorraya de Chadarevian and Nick Hopwood (Stanford: Stanford University Press, 2004), 447.

[89] "3-D Model," Wikipedia, http://en.wikipedia.org/wiki/3-D_model

[90] "Additive Manufacturing," Wikipedia, http://en.wikipedia.org/wiki/Additive_manufacturing

up layer upon layer of wax, each one corresponding to a microscopic slide. Ziegler's technique was called the wax-plate method of reconstruction,[91] and can be considered one of the precursors to 3-D printing. Ziegler, in a visionary way, called himself a 'plastic publisher', and that is exactly one of the ways that 3-D printers are being used today i.e. by 'printing' objects instead of text.

A precursor to 3-D imaging can be found in the work of Scottish mathematician D'arcy Thompson. In the last chapter of his early 20th century masterpiece, *On Growth and Form*, Thompson imagined a three-dimensional co-ordinate system as an extension of his theory of transformation, which relied on two-dimensional coordinates. The system he envisioned basically describes how 3-D computer modeling now works.

> In this brief account of co-ordinate transformations and of their morphological utility I have dealt with plane co-ordinates only, and have made no mention of the less elementary subject of coordinates in three-dimensional space. In theory there is no difficulty whatsoever in such an extension of our method.[92]

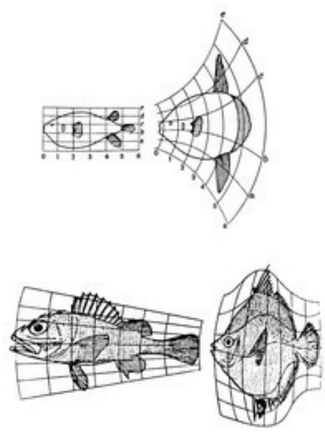
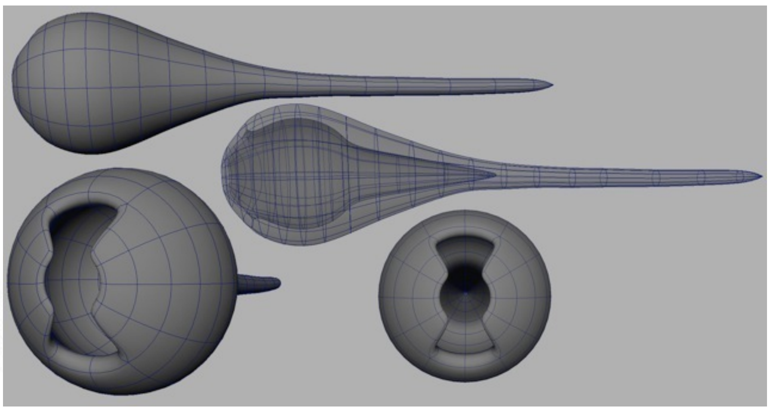

Figure 102 D'Arcy Thompson's mathematical model for describing changes in form. Figure 103 screen shot of a snail's copulatory dart as work in progress showing the vector lines, 2009.

The possibilities for 3-D printing are so various that there is a great deal of experimentation going on with artists, architects and designers printing in unexpected materials such as metal, ceramics, chocolate, even making a glass vessel printing directly on the sands of the Sahara Desert. (See the video of the Solar Sintering Project by Markus Kayser, a MA design student at the Royal College for the Arts.)[93]

In Australia I have developed a working relationship with a Melbourne based company called Formero, (now owned by the company 3D Systems) and overseas, with 3-D printer company Shapeways. I will proceed to narrate the

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91 Nick Hopwood, *Embryos in Wax: Models from the Ziegler studio* (Cambridge: Whipple Museum of the History of Science, University of Cambridge and Institute of the History of Medicine, University of Bern., 2002). 53.

92 Thompson, *On Growth and Form*: 323.

93 Markus Kayser, "Solar Sinter Project," https://vimeo.com/25401444.

process of experimentation and the collaborations that I have made, incorporating my experiments with 3-D model-making in the process of making my museum.

First specimens

The main difficulty I had faced as an independent artist trying to research animal genitalia and to make a museum collection was obtaining or having access to genitalic specimens. Having conducted the literature research and having found a limited amount of visual images, I needed to get access to the primary sources. I had approached the Australian Museum in 2004, but was unable to gain access to their collections or scientists at the time. That changed once I became a PhD candidate. In 2008 I approached the microscopist at the Australian Museum, Sue Lindsay, to find out whether or not she had seen or had any genitalic specimens worthy of including in my project. To my surprise, there were several genital specimens already prepared in the Museum microscopy collection. Indeed, Sue had been involved both in preparing them and in producing images for several different taxonomists within the Australian Museum, which specialises in taxonomy.

During the period of 1992-1996 the late taxonomist Glen Hunt and Sue Lindsay collaborated to study the taxonomy of the Harvestman (*Opiliones*) from Tasmania. The common name of these spiders is 'daddy long legs' (but they actually have medium size legs); they are typically found in leaf litter, moss or decaying moss, and they all very much look alike. By looking at the genitalia of the male Harvestman, which is relatively easy to access and dissect, Mr Hunt was able to describe and name several different species. He wrote three papers about these specimens.[94] Only one of these essays ventures to suggest that sexual selection explains the extravagant size of the stylus in some Harvestman[95] (but without much depth).

Hunt was, after all, a taxonomist, not an evolutionary biologist. Taxonomists describe, name and group species, genus and families. They don't normally question the function or reason for certain morphology, so his suggestion of the impact of sexual selection on penile morphology was unusual. The penile specimens that he prepared for his research were still in the museum collection, along with his files and original SEM scans, but they were not enough for what I wanted. I explained to Sue my intention to make sculptural 3-D models of the specimens, using the technology of 3-D printing. In order for me to be able to use the whole specimens, we scanned them from all sides using the electronic microscope. We rotated the specimen in front of the camera, at 30 degrees for each rotation. The process ended up being too time consuming, so we then

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94 Glen Hunt, "A Preliminary Phylogenetic Analysis of Australian Triaenonychidae (Arachnida: Opiliones)," *revue Suisse de Zoologie* hours série (1996): 243-52.

95 Glenn S. and Emilio A. Maury. Hunt, "Hypertrophy of Male Genitalia in South American and Australian Triaenonychidae (Arachnida: Opiliones: Laniatores)," *Memoirs of the Queensland Museum* 1993.

simplified our process to take only four scans per specimen: front, side, back and one detail of the top.

Figure 104 Close up SEM Scans of the Glyptobunus sigunatus, rotating every 30 degrees. The shapes were later manually drawn in 3-D software.

I want to clarify here that at that point I didn't know anything about 3-D printing; I had only heard about it and I wanted to try it. But it soon became evident that the technology addresses several of my most urgent needs. Because I sensed the need to convey the astonishment associated with genitalic morphology as palpably as possible, I didn't want to simply show SEM scans as artworks. Also, the technology of Electron microscopy has been around for 80 years, so it's not new or particularly attention-grabbing (from a 'Barnum-esque', museological point of view). I needed to work in 3-D, to make the images from the SEM 'real' and tangible at a human scale. There were also other more political and personal reasons influencing my decision making. As a woman artist, I didn't want to use my hands to model penises. I wanted to remove any suggestion of zoophilia from the process. I also wanted to avoid using actual specimens, to avoid the references to castration and its Freudian associations. Using actual specimens was not original either, (the Phallological museum in Iceland holds a collection of pickled marine penis specimens). I also wanted to keep the models as small as possible. As a post-feminist, I didn't want to aggrandise the phallus. Many cultures have already done that. But most importantly, I wanted to experiment with a new technology of our time, keeping in mind the lessons learnt from Barnum and from the Blaschka glass models.

From the Australian Museum microscopy collection I selected a dozen of the Harvestman penis specimens, choosing those with more distinctive anatomies. I sat next to Sue Lindsay and together we scanned them. Next, with the scans in hand, I proceeded to explore the industry of 3-D modeling and of rapid prototyping in Sydney. Since 3-D modeling is a highly technical skill and involves years of training, I needed to find technical assistance to make the models. I started with the phone book. I approached different rapid prototyping companies and visited them. I showed them my scans, and asked for referrals to companies that could make the 3-D computer models for me. At the same time I looked at the technical possibilities of different 3-D printing technologies. After shopping around in the industry, I was referred to Andrew Simpson from Vert Design, a small industrial design firm in Sydney with whom I started an ongoing collaboration to make the 3-D models. They were interested in the technical challenge of the images I wanted to make in 3-D, as well as the poetics of the subject matter. Being interested in collaborations, Andrew also generously gave me artist rates. We experimented with different software for a period of about year. Mitchell Brown, an industrial designer from Vert who was involved in the project, describes our process:

> The very first models were attempted in Solidworks, which is a parametric based modeling program. Meaning that every point in space needs to be precisely defined in order to create geometry. Due to the extreme complex nature of the geometry, we found that a mesh based modeling program (namely 3DS Max and MAYA which Matt [Booth) uses) would be the best to re-create the forms. These programs allowed for free form modeling and distortion, much like how a sculptor manipulates a ball of clay, which would allow us to replicate features such as un-symmetric bodies and random surface imperfections that are found in organic shapes.[96]

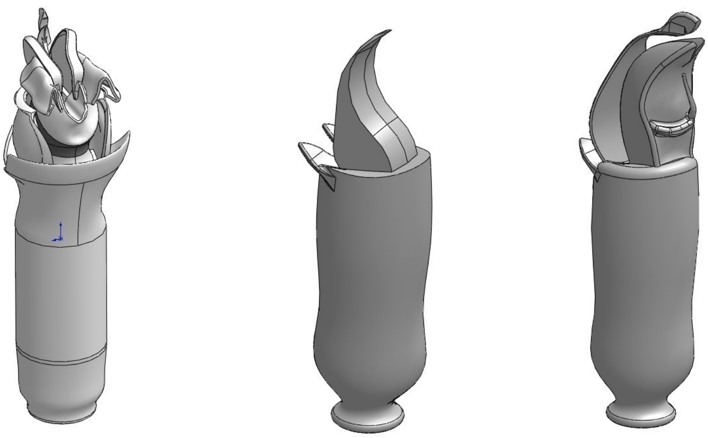

Figure 105 The Solidworks software didn't suit the organic shapes we aimed to mimic.

The first 3-D models made using traditional CAD software were disappointing, as the technology didn't suit the organic shapes; nor could they capture the delicate detail I required. I engaged a young animator, Matt Booth, a recent graduate from animation school, who was trained in Maya software. We experimented for six months and achieved encouraging results. This was largely because of his skills of observation and his ability to manually copy the shapes he saw to the software (a process which is very similar to that of a visual artist making a drawing, but here achieved in 3-D software). Then there was a lot of back and forth between different software to make the data printable. Once we had some models, I explored the industry of rapid prototyping for the more suitable technology for the 3-D prints.

96 Mitchell Brown, email, 26 July 2012.

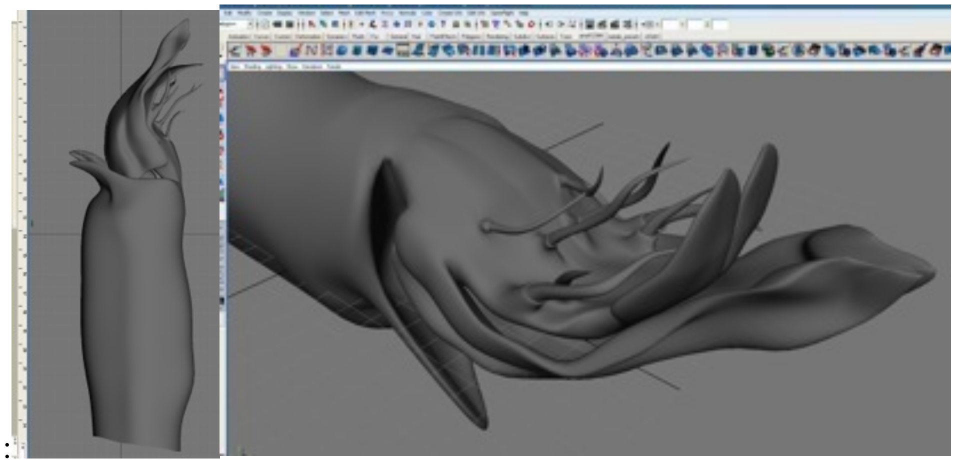

Figure 106 Screen shots of the Pyeganella stricta. The software was better suited for the making of organic shapes and delicate detail. This was achieved using either 3DSMAX or MAYA software, which are normally used for animation, not for making solid objects.

I contacted many commercial companies for rapid prototyping in Australia in order to print our computer models, but none of their equipment could achieve the high resolution and delicate detail that I required. After trial and error, and talking to the technicians in the industry, we found a rapid prototyping company, Formero, based in Melbourne, with a technology called Objet printing, capable of printing at the high resolution and the detail that we wanted.   The Objet printer uses a resin that is cured with UV light. The material, in Vero White, has the translucency of wax, and is creamy in colour. Since the normal use for 3-D printing is for rapid prototyping, the materials used are not necessarily of archival quality, as required by the art industry.

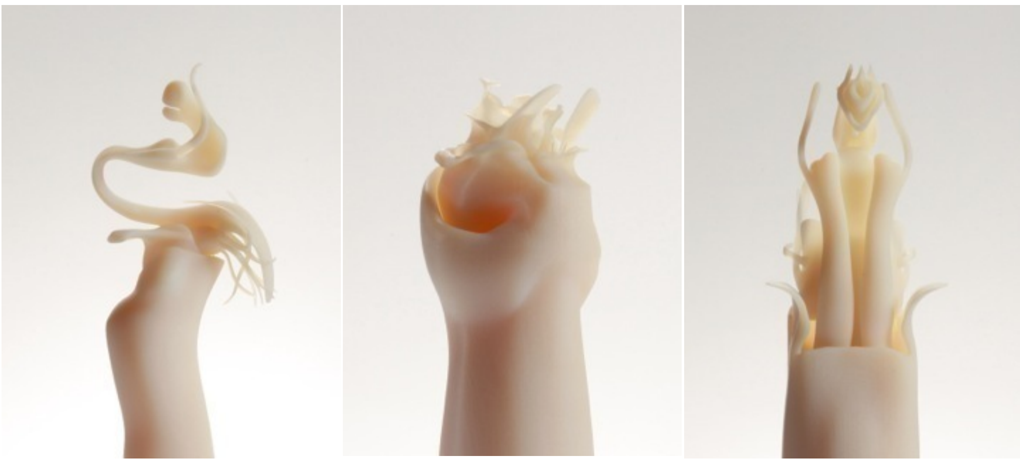

Figure 107 Exquisite detail as digital sculptures using Objet Printing in high resolution on Vero White UV curing resin.

Figure 108 Maria Fernanda Cardoso, *Tasmanian Harvestman* penis specimens. Developed between 2008 and 2009. They are mounted in metal bases and protected from dust with custom-made glass 'condoms', a signifier for male genitalia.

Everyone involved in the process of the making of these models is very proud of the results, as it was a significant technological accomplishment. No one involved had made anything like it — neither the industrial designers involved (Andrew Simpson and Mitchell Brown), the animator (Matt Booth), the microscopist (Sue Lindsay), or the company that printed the objects (Formero).[97] We all derived pleasure from the technical mastery we achieved in materialising and embodying knowledge that had been sitting in the basement of the Australian Museum, and would have probably languished unacknowledged for decades had we not embarked upon our museological experiment.

There is real significance, too, in our 'discovery' and refinement of a museum-grade material and process that delivers the precision of the best historical models studied. Ludmilla Jordanova talks about the pleasure we can derive from our interaction with models:

> Models give diverse pleasures, and those pleasures contain many clues to their nature. People use models to think with, hence one pleasure is the intellectual mastery that models permit. Models in art are part of production processes during which problems are solved; this is thinking, as it were, with the hands. Making models, specially small ones, poses technical difficulties, hence the more elaborate and detailed, the more their makers and viewers can take pleasure in their achievement, in the obstacles overcome, in the very scale itself.[98]

In order to demonstrate our technical mastery, I decided to show the models side by side with the SEM Scans, so the viewer can see the source images that inspired the models, and compare the results. Another reason was that I wanted to emphasise the mimetic accuracy of the representations. I want to be able to satisfy the rigorous standards of scientific models so that they will be taken seriously by the scientific community. I also want to avoid the potential assumptions that I have invented the shapes out of my own imagination, using

97 Formero is now owned by 3D Systems
98 Jordanova, "Material Models as Visual Culture," 448.

artistic license to invent imaginary forms. For the exhibition of MoCO at the Biennale, I borrowed some of the original Harvestman specimens collected by Glen Hunt to give the public a point of reference for scale and truth. By following a rigorous process of trial and error, slowly building our skills and knowledge, we aimed to present perfect, scaled-up physical representations of something less than a millimetre in size. We stretched our senses and skills, achieving models of exemplary standard suitable for display not only in art galleries but also in science museums and laboratories.

At this point I have answered my second research question: how can I best communicate my findings? 3-D prints are a highly effective way to do so. But things didn't end there. As the technology is digital, the outputs can be manipulated in many different ways. The 3-D computer model (essentially the data file) can be used to display the objects on the computer screen, which can be moved around to see all sides. Other outputs can be manifested as 3-D animations, or as computer renders (2-D 'photographic' output of the data files). Instead of drawing with my hands, the computer drawing can be printed on paper. Instead of sculpting with my hands, my sculptural objects can be printed. The options are endless in terms of how data can be manipulated to express scale, medium, materials, and backgrounds. To explore scale and medium, I decided to experiment with 2-D computer renders, which I exhibited at ARC One Gallery in Melbourne. I produced a series of human size prints of the Harvestman as computer renders (ink printed in greys, over a 320 gram white cotton rag paper).

Figure 109 *Its not size that matters it is shape*, installation view at ARC ONE Gallery Melbourne, 2011

For this test-case exhibition I also exhibited the SEM scans of the Harvestman penises, showing three variations of the same specimen (including the SEM's which were the closest to reality I had) in order to see how they worked together and individually. To make the SEM scans more three-dimensional, I chose to display them in tin boxes, which could be held by hand, opened, and closed, or hung on the wall open or closed. They became 'image-objects', even though the prints were two-dimensional. The prints could be held by hand — literally grasped, understood. In my view, the physical act of holding an object triggers intellectual comprehension, in the sense that Jordanova has suggested.

The only aspect I thought was not addressed in full in this test-case exhibition was the issue of scale. I thought that by showing the SEM scans I had given the audience the signifiers to properly apprehend the microscopic and the small. Yet, in my observations of the audience's reaction, it was not evident that they understood what they were looking at. I concluded that the exhibition lacked the display of real Harvestman specimens. From that experience I learnt that I still need the use of real specimens, as well as their representations. For the Sydney Biennale I borrowed specimens of Harvestman from the Australian Museum, and displayed them in the same case with the 3-D models and the SEM scans. I also included *Phallomedusa* shells and a few other dried insect specimens. They were very discrete, and seemed to interact in a dialogue with the images and objects produced, closing a gap in the visual information provided by the overall exhibition.

Figure 110 *It's not size that matters, it is shape,* 2010 Installation view. Stamped tin box with pigment print on 300 g cotton rag 31 x 24 x 4 cm

Overall, the exhibition was well received, and people thought the objects reminded them of flowers, which, I pointed out to them, are themselves reproductive organs. Generally, the audience had an idea that they were looking at genitalia because of the title, "It's not size that matters, it is shape", because of the phallic shape of the specimens and the glass domes that covered them. But for the viewers who didn't read the press release or the wall signage, it was not clear what they were looking at. Commercial collectors were reluctant to buy, and the gallery directors Fran Clark and Sue Hampel were uncertain whether it was because the subject matter of 'penises' made people uncomfortable, or whether this was because of a generalised market slump. Probably it was because of both. What I learnt from the Sydney Biennale exhibition is that the term 'insect penises' is much more palatable to media and audience, triggering curiosity, while the term 'penis' alone triggers immediate anthropomorphism and inhibition.

On microscopic specimens and how to make them exist at human scale

The aesthetics of the electron microscope are very particular, as it is photographing electrons (not photons) as they reflect on a prepared surface. For the specimens to be scanned, they are normally dried first and then coated in a light layer of gold or coal, so the electrons can bounce off the surface. The result is a photograph of white light on black backgrounds, rather than of shades of black on white backgrounds as with regular B&W photography. Yet, in SEM microscopy the scanning procedure is standardised and mechanical, without much control of the exposure, contrast or framing, and without deliberate attention being paid to aesthetic options. Working with a professional scientific microscopist forced me to work on the images digitally in order to make them into artworks, and not simply photographic references.

To be able to use the images I had to buy the copyright from the Australian Museum. I then worked on them with a Photoshop expert in order to maximise the aesthetic values ('cleaning' the images as it is known in the industry). I left some imperfections like dust specks (which could have been easily removed) in order to show the 'realness' of the actual specimens. I worked on the images as a group, so there was consistency of backdrops, symmetry, positioning and proportions. Such tools of the trade are part of visual arts training, but I don't think biology students are taught them. This is one area where the overall visual communication in microscopy could be improved, by making more effective and considered images.

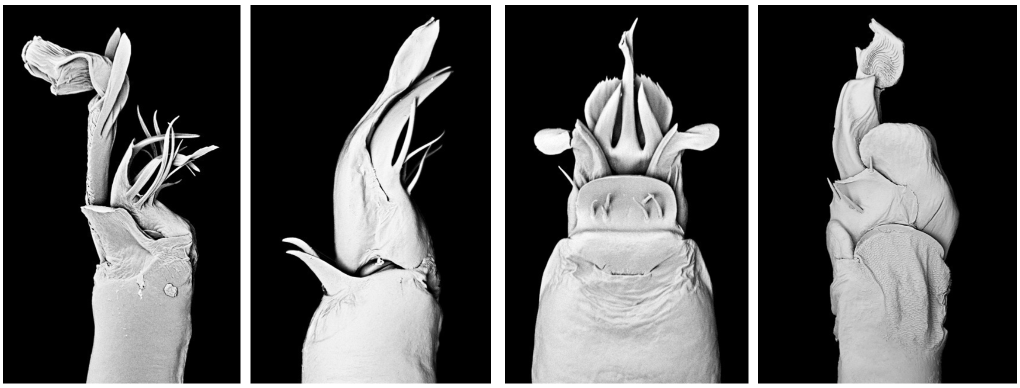

Figure 111 Electron microscopic scans details of the tip of several Harvestman penises. Each different species has a unique penile morphology.

Multiple aesthetic decisions also were taken at the printing stage. I worked closely with Nick Greenwich, the technician at the 2-D Lab at Sydney College of the Arts to guide me as to which type of printing and paper to choose. I ended up using a 12 ink-jet printer and cotton rag paper, which gave me the best blacks without reflections. I used the same technology for the large renders, using a state of the art DaVinci ink-jet printer.

Before choosing ink-jet printing for the SEM images I explored the 19th century technique of photogravure, which is an etching technique that produces beautiful deep blacks. I did this in the context of a residency at USF GRAPHICSTUDIO in 2008 at the University of Southern Florida. The ink-jet prints matched the 19th century technology (which is quite labour-intensive, requiring inking and printing each print by hand).

An important discovery about SEM microscopy, considered in the context of artistic research and production, was the fact that it is a convention for representing the very small (for objects even smaller than anything you could see under a light microscope). SEM micrographs are also a convention that signify science, or the scientific approach. I incorporated the 'cleaned' and printed SEM images in the context of the exhibition to give a sense of scale and truthfulness in a scientific context. Another artistic decision I took was to compose the images in a very straightforward way: front, side and back, describing the process of looking at a three-dimensional object and attempting to describe it accurately, with the limitations of 2-D form.

Based on all of these perspectives, it is possible to reconstruct a mental image of the three-dimensional specimen. I have learned from looking at the photographs of Karl Blossfeldt that in order to make images the subject of intense observation, they had to be imaged in the most simple and clear way (often with 'objectivity'). The background of my works was darkened completely to allow the specimen to stand out free from distractions. Because of the nature of microscopy, there is an inherent novelty to the anatomies or forms that can be described or presented, often for the first time ever. Their strangeness presents a compelling visual proposition that the mind aims to understand; the mind attempts to recognise a pattern that is not yet fully identifiable in the image. This creates a cognitive tension, an effort that activates further observation. The 'not knowing' of the images created is at the essence of MoCO. The world of microscopic invertebrate genital morphologies is mostly new to us humans. In a world where we think that we have seen it all, it is extraordinary to find new wonders that challenge our previous knowledge and understanding of nature. That sense of confusion and discovery is rare not just among the uneducated viewer, but also for the professional scientist.

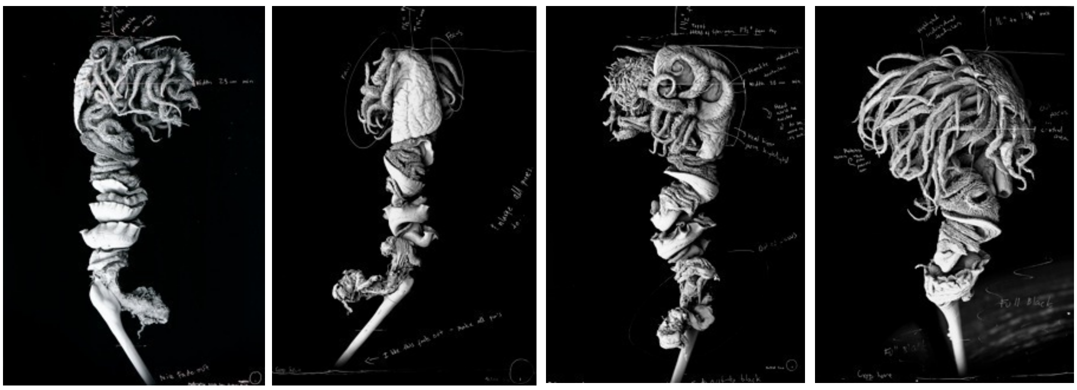

Figure 112 Artist proofs of the *Phallomedusa Solida* Penis with editing notes. 2008-10 Pigment prints on paper

There was another set of specimens at the Australian Museum microscopy unit that caught my attention: the phalluses of the *Phallomedusa solida*, a common snail indigenous to the Sydney Harbour's mangroves and salt marshes. Here is a description from an email by Australian taxonomist Rosemary Golding, who described a new genus and a new species of snail based on the discovery of this genitalic anatomy.

> When I first dissected specimens of 'Salinator solida' (this is the A. fragilis[99] that Bouvier had mis-identified), I was expecting to find a normal penis structure like other pulmonate snails. But as soon as I dissected open the body wall the penis popped out and it looked completely different – I was completely amazed and at first I thought it might even be a parasite! I drew illustrations of the penis, but it seemed strange that no-one had ever described the anatomy of this snail before, because it is extremely abundant in mangrove forests around eastern Australia. I looked in the literature, and when I found this description of the anatomy of 'A. fragilis', I knew immediately that Bouvier was describing the same penis, although he seemed equally confused. Because there were no illustrations in Bouvier's article, and because he had used an incorrect species identification, his work was completely ignored for over 100 years. The reproductive anatomy of these specimens of 'Salinator solida' was so strange that I designated a new genus Phallomedusa and family Phallomedusidae for this species. The name was derived from the Greek god Medusa and the latin word phallus, because the penis has a cluster of 'tentacles' which look like the snakes around Medusa's head.[100]

I was privileged to have had access to Golding's specimens and have been able to scan them many times until we achieved the best possible images. I was originally intending to use sculptural objects inspired by the micrographs I had previously taken, but because of the complexity of the *Phallomedusa solida* genitalia, making a 3-D model was impossible (because of the texture of the specimen, which is one of the limits of 3-D printing). So I concluded that a SEM image could be used instead, and to give it as much three dimensionality as possible in a 2-D form. This was achieved by taking three shots — front, side and back — and exhibiting them as a group with as much detailed focus as possible.

My job as a visually trained artist is to create the strongest most powerful image of the specimen that conveys the sense of surprise and confusion that those two taxonomists (Bouvier and Golding) witnessed on the dissecting table 100 years apart. I wanted to convey that morphology with gestalt, with immediacy. I felt that the world needed to know what the *Phallomedusa solida* penis looks like as accurately as possible. One of the main problems in microscopy and macro photography is to do with the limited depth of field. This is also true of the SEM microscope. In theory there are ways to solve that problem: by taking images at different depths of field, and then 'stacking' them together and choosing only the in-focus areas of each layer so the end result is fully in focus. In the past, that was done manually. Nowadays we have software to do it automatically. With the microscopist Sue Lindsay, I re-shot the specimen at different depths of field for a total of ten photos. Then we used the software Auto-Montage Pro to stack them

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99 Eugène Louis Bouvier, "Sur L'organisation des Amphiboles," *Bulletin Societe Philomathique* 1892.

100 Rosemary Golding, Email, November 10 2008.

automatically, but failed to get good results. There was distortion in each image, so they never aligned exactly. I then commissioned two Photoshop experts to do the stacks manually, but both failed as well, in spite of many hours of work. Finally we did a third shoot of the *Phallomedusa* specimen with the SEM and shot with the most depth of field we could. It was technically impossible to create a fully focused image, so we had to accept that and improve it a little bit in post production, using sharpening tools in Photoshop. This entire process was incredibly labour intensive. Normally microscopists don't have the luxury to spend so much time perfecting an image for maximum impact. I have heard from biologists that if someone could technically improve that aspect of microscopy, it would be a great contribution to science. Though this is not my field of expertise, I hope someone will improve microscopy, in a similar way as inventor and cinematographer Jim Frazier[101] did for macro cinematography. What Frazier achieved was technically impossible, according to the experts in the field. However, he approached the problem of low depth of field by manually experimenting, moving lenses around and fixing them in place with plasticine, rather than working from a theoretical point of view. His hands-on approach triumphed, just as Anton von Leeuwenhock was able to make the first and best microscope lenses of his time by grinding them by hand.

Another way to solve this particular difficulty is by using a more recent technology: Micro-Computed Tomography, generally known as micro-XCT. The Micro-XCT uses X-rays to visualise the surface and internal structures of a specimen in three dimensions, and could potentially output printable computer models directly from the scans. This technology sounds really attractive and it could deliver the most accurate description of genitalic structures in three dimensions yet. However, the technology is still new and it requires many person-hours to learn how to use it. We did some experimenting with this new technology at the Australian Centre for Microscopy and MicroAnalysis at Sydney University, with the assistance of Associate Professor Allan Jones. I borrowed a few snake penis specimens from the Australian Museum, which were critically point dried. Professor Jones did the scanning, and then created a computer render of the results. Unfortunately, the soft tissue was not ideal for the X ray technology as the rays went right through them. But what we saw on the screen was that the penises had really hard spines, which the X-rays didn't penetrate. Unfortunately the files became too big if we captured all the data, and the polygon count greatly exceeded what a 3-D printer could accept. We ran these tests two years ago, and I am certain that if we tried again with more suitable specimens, and with the technical know how developed for our 3-D prints we would now generate better results.

[101] His infinite focus lenses were first used in *Cane Toads: an unnatural history* by Mark Lewis, with Jim Frazier as cinematographer.

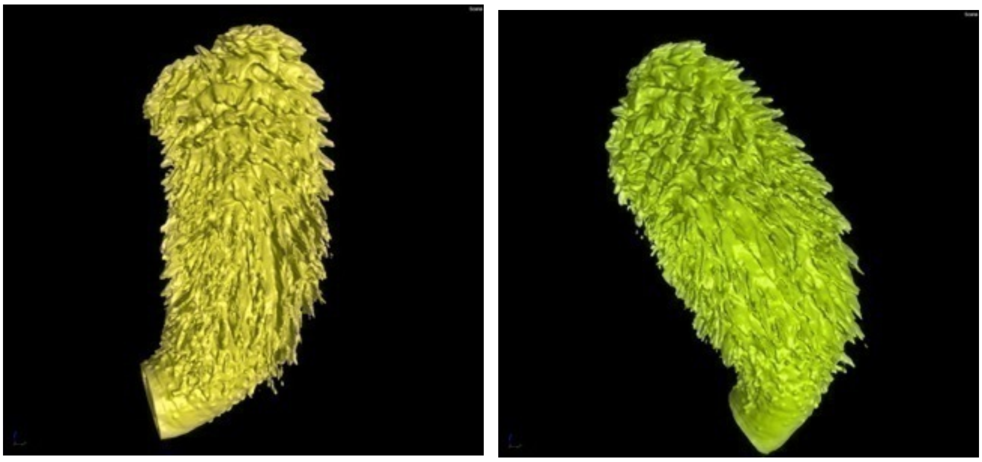

Figure 113 At a low resolution the computer file has not enough data to describe the specimen accurately, therefore I approximated the morphology between the penile spines and the penile skin. At a higher resolution the polygon count becomes too large for 3-D printing. Image courtesy of Allan Jones.

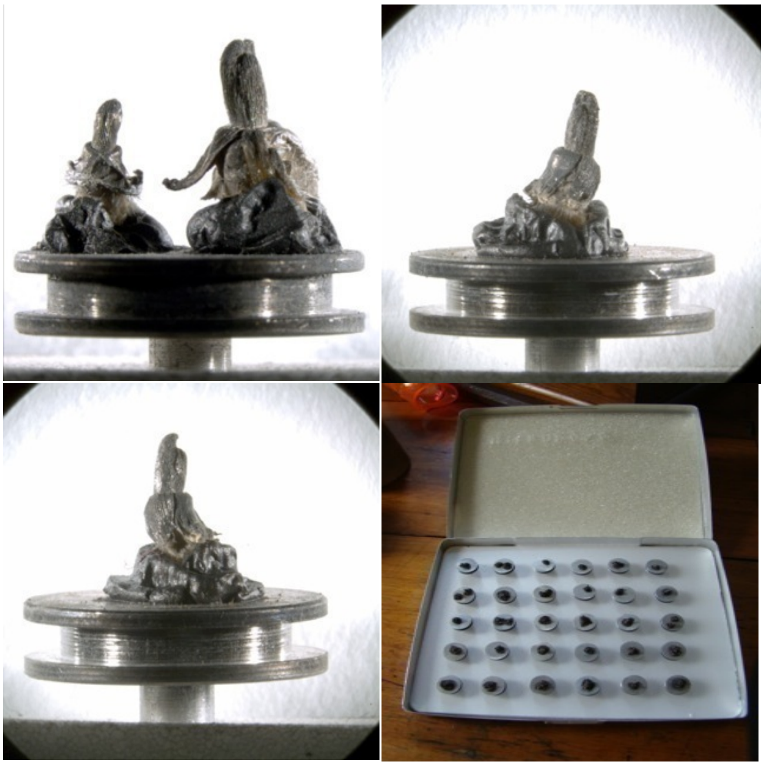

Figure 114 Light microscopy photographs of micro bat penises, from the collection of the Australian Museum, and life size replicas inside an aluminum box, made by the artist using silver clay, and using the same stubs as the real specimens.

One of the most intriguing aspects of my research is discovering the worlds of the small. As Eberhard wrote to me in one email:

> One moment in the video (*The Wonderful World of Professor Cardoso*) struck a chord with me. When you were with the museum person observing the snail penis with the SEM the dialogue concerned all the hairs, and how the hairs themselves had complex forms. I have had the same experience repeatedly with the SEM, of discovering new orders of complexity

> at smaller and smaller dimensions. As a biologist, I sometimes wonder at the power of natural selection to make organisms be so perfect at such tiny dimensions, and also at the amounts of genetic information needed to code for so many details.[102]

There are many realities that coexist with humans, but that our senses cannot perceive. That is the principle of *Umwelt* that philosophers talk about, in which each animal has a realm of the senses in which they operate. These worlds coexist with other animals but are not necessarily perceived by the others. My thesis is dealing with microscopic realities and re-interpreting them in the human scale and fields of perception. Cross-species communication, and cross-scale communication are a great challenge to us, humans. Richard Dawkins says that technologies like telescopy and microscopy have allowed us to perceive other worlds. Scale determines not only what we can perceive, but also what is possible. John Tyler Bonner states in his small book, *Why Size Matters: From Bacteria to Blue Whales*:

> Changes in size are not a consequence of changes in shape, but the reverse: changes in size often require changes in shape. To put it another way, size is a supreme regulator of all matters biological… No living entity can evolve or develop without taking size into consideration. Much more than that, size is a prime mover in evolution. There is abundant evidence for the natural selection of size, for both increases and decreases. Those size changes have the remarkable effect that they guide an encourage novelties in the structure of all organisms. Size is not just a by-product of evolution, but a major player.[103]

Studying small things while I was training fleas, I discovered that gravity at a small scale is not so important. That's why fleas (and other small invertebrates) are so strong in proportion to their size. I learnt from both D'arcy Thompson[104] and from John Tyler Bonner, that the rules of physics change depending on scale, and the study of form has to do with the study of size. So when we look at the microscopic, we have to interpret what we see with different frameworks. How we might convey this visually is a central aspect of my research. How we depict the small without losing the sense of scale is one of the great difficulties we face when of working within our own *Umwelt*. It is an important aspect of my work that will lead to further exploration beyond the scope of this current thesis.

Enlarging and shrinking are tools we use with current technologies, and this is why I chose to work with silver clay and bronze clay. Photography and microscopy have often overused enlarging as a technique to 'show more'. I wanted to explore what happens if I shrink things and make things small so people are forced to look closely if they want to see more clearly.

This brought me to my last material exploration of that academic year — the use of shrink plastic to make drawings. I traced some of Eberhard drawings and shrank them in order to then display them. They looked interesting and the text is

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102 William Eberhard, Email, 26 May 2012.

103 John Tyler Bonner, *Why Size Matters: from Bacteria to Blue Whales* (Princeton: Princeton University Press, 2006). 2.

104 Thompson, *On Growth and Form*.

hardly readable. I have exhibited them next to the objects they refer to, as another reference to not only scale, but to the source of the images. I titled them, After Eberhard Series, with Eberhards permission to rework the illustrations from his 1985 book.

While I explored all of the above technologies using real specimens from the Australian Museum collection as a primary source, I wanted to experiment with other technologies for the making of sculptural models. I thought it would be interesting to use metal for the making of micro sculptural specimens sturdy enough to tour (in terms of conservation problems that natural specimens often have). There is a new technology developed for the jewelry market, which is called precious metal clay. Bronze clay came onto the market only a few years ago, and I was keen to use such a traditional medium in such a new way. The Prometheus Bronze Clay company describes their product as

> a claylike material, which turns into pure solid bronze when fired in the kiln. It is a mixture of micron sized bronze powder, water, and organic binder… When the clay is fired in a kiln, the organic binder evaporates and burns away, and you are left with pure, solid bronze.[105]

I was familiar with the traditional way of making lost wax metal casts: to make a wax model, make a mould around it, then pour the molten metal, losing the wax model as it melts away, then removing the metal object from the mould. I was attracted to this process not only because it removed the mould step from the process, but because of a byproduct of the technology: when the water and the binder evaporate, the piece shrinks. Depending on the specifics of each product, it can be between 10% and 30%. What that meant to me was that I could add more detail in a piece than working on a 1:1 scale such as the lost wax technique.

Scaling up is an overly used strategy in art making. Shrinking things down is not that common. And making miniature things is really difficult because of the limitations of our human scale and tools. In practical terms, it meant that my fingerprints and marks would be slightly smaller and less recognizable. Making bronzes is such an ancient technique that to me it was important to be able to innovate with it while keeping the qualities that have made it such an enduring technology. There were some drawbacks in working with this technology: the pieces are unique, and can't be used as models for an edition, as the detail prevents the use of moulds to copy them. That was disappointing, as I am very interested in working on editions so multiple copies can be exhibited simultaneously. Also, working the clay was not as easy as it sounds. The working time of the clay is very limited as it dries quickly, and I had to increase the humidity of the room I worked as much as possible. Joining parts sometimes work, but not always, and so multiple firings were necessary for many of the pieces. It was perhaps because of my lack of expertise that some of the models were fragile. Finally, working with my hands and fingers is not as accurate and

105 "Prometheus Bronze Clay™ Instructions," (ODAK Arts, Hobby and Crafts Ltd., 2009).

precise as working with the computer, so there is a lot more of the 'artist's interpretation' in these models than in the computer generated ones.

Figure 115 Eberhard, (1985) Penes of different species of the damselfly genus Argia.[106] Figure 116 Damselfly genitalia, after Eberhard (1985), 2010. Bronze Clay, metal.

Since I lacked access to more diversity of genitalic specimens, for this series, I worked from line drawings. Reinterpreting their already abstracted knowledge into three-dimensional form was very hard as the information is simply not there. I have always found two-dimensionality insufficient in data and quite abstract to understand. As young humans, we have to learn to interpret flat images as conveying concepts and other realities, at the same time that we aim to represent those images better. These are all learned skills and conventions. Precious Metal Clay offers new technological possibilities to make metal micro-sculptures with a simple set up, and the technique is very simple to learn. Working in metal has in the past being a specialist job, and this technology is directed to the hobbyist allowing anyone to try it. Even though it sounded easy, mastering the technique required of a lot of trial an error; but the concept of accessible techniques is quite exciting to makers like myself, who don't want to specialise in one technique or another. I endorse all these new technologies that facilitate the making of objects in our lives. Similarly, in the same way that 3-D printing will eventually delegate making skills to others, I welcome this new technology of metal clay.

I also made another set of bronze micro-sculptures, this time after illustrations of mite spermatophores. In making those I learnt something about scientific illustration. They draw or 'describe' the specimen from front and side, so you get an idea of the volume of the specimen, of it's three-dimensionality. This created an interesting pattern in the drawings. With the spermatophores and many other of Eberhard drawings, I was also attracted to the repetition of similar morphologies. This comes from a taxonomic tradition, where you can tell species apart by subtle variations in morphologies by way of comparative anatomy taxonomic techniques. The idea of repetition or iteration — not of the same, but of subtle variations — visually communicates the idea of biodiversity. That

106 William G. Eberhard, *Sexual Selection and Animal Genitalia* (Cambridge, Mass.: Harvard University Press, 1985). 26.

‘comparative morphology aesthetics' is a tool I incorporated into the exhibition of the MoCo collection. The visual language of groups communicate differently to the use of single elements. Slowly, I am building a palette of visual resources for conveying information.

Figure 117 Mite spermatophores in bronze clay, after scientific illustrations.

Doing my visual research, I found some of the drawings fascinating — Spermatophores of pseudoscorpions particularly so. The illustration had stylised the specimens, making them orderly and erect, showing only variation in size and shape. I combined this with the visual information of some photographs of spermatophores (which were transparent), and I concluded that the best medium to display these specimens would be flame glass. The Blaschkas have already demonstrated the precision that flamed glass could achieve. They are fragile during handling and transport, but otherwise comprise an ideal archival material to make museum display models.

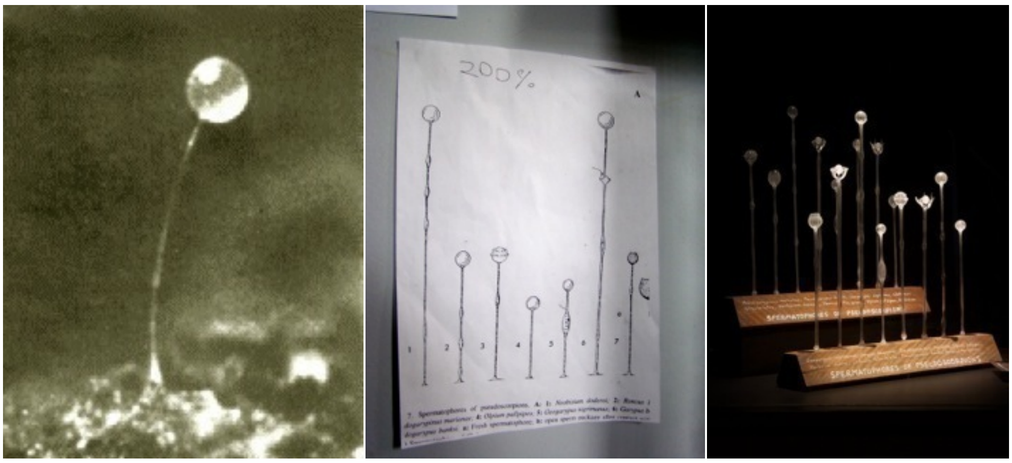

Figure 118 On the left, stalked spermatophore of a collembolan mite. In the middle, taxonomic drawings of mite spermatophores. On the right, spermatophores of pseudoscorpions in glass, 2009-2010 in collaboration with flame glass artist Mark Elliot.

Another drawing that caught my attention was of the mite spermatophores. They were so ordered, all with straight, perfectly-aligned stems, and subtle variations in the shape of the capsules. I was aware of the glass models of the Blaschkas since my days as a student at Yale University — I had made a special trip to Harvard University to see the Glass Flowers of Harvard. They were the ultimate example of virtuosity in scientific models using glass. I wanted to learn how to do lamp work so I could turn this illustration into glass models. After talking to my colleagues at the Glass Department at SCA I got in touch with Mark Elliot, a flame artist with 30 years of experience in that technique. I commissioned him to make these models, and we worked together trying to get the most accurate 3-D description of the drawings based on minimal information. The drawing itself — a low-res image of a real spermatophore found on Google images — indicated transparency, and informed my choice of glass for this model. Even though the medium is hand made, I made three identical sets, as it is my intention for the museum collection to travel to various locations simultaneously.

One aspect that became increasingly important was the use of words along with the display of the objects. What caught my attention about the drawings was not just the graphism but the words that I couldn't recognise (such as spermatophore). By making spermatophore replicas, I aimed to access their meaning. Incorporating the words into the object displays, I wanted to trigger the viewer's curiosity, placing unusual shapes and unusual words into their consciousness. In this way, I am integrating my research questions into the mode of presentation, inducing a similar question in the viewers by a process of visual communication that includes both image/objects and text.

Figure 119 Salamander spermatophores in glass, after (Eberhard 1985). In the front, shrunken drawing of the salamander spermatophores, after (Eberhard 1985).

While the practice-led research has already found several answers 'for how to best display my findings', it has also been used as a tool to ask and answer my primary research question, 'why are genitalia so complex and diverse?' Doing the literary research also included the understanding of images and words that were new to me. Those words became the entry point to the scientific literature, and by mimicking the shapes of genitalia in three-dimensional form, I gained an embodied understanding of their function. Words and images started to work together to clarify and make visible knowledge only known to a small handful of scientists. For the first time, ever since Eberhard'S 1985 compilation of scientific literature, I am grouping together knowledge acquired by different groups of scientists over a period of decades, allowing for a comparative and comprehensive study of the subject matter of genitalic morphology from the 'big picture' point of view.

In the next chapter I will explain the answers to my question 'Why is there is so much complexity and diversity in animal genitalia?' I will do so through the images and objects that I created for the MoCO collection. As my process of knowledge acquisition and knowledge generation is an integrated one, I will present the science as it has been integrated to the art objects I have made. But before I continue on to the next chapter, I will brief the viewer on the other aspect not answered yet about my first research question: 'How to best present my findings?' Since I first proposed that a Museum model was the best way to create the context for the objects and knowledge I was producing, I will proceed to explain the decision making in the museological design for the display of the MoCO collection as a site specific installation at Cockatoo Island, in the context of the 18th Biennale of Sydney 2012.

On Museum and Exhibition Design and Display

Along with my supervisor Ross Gibson I dreamt of making MoCO a reality, applying all that I have learnt about Museums from my literary research, as well as applying the lessons learnt from the Cardoso Flea Circus. Two things happened that allowed that dream to become a reality. In 2011, I was invited to exhibit at Building 123 in Cockatoo Island, in the middle of the Sydney Harbour, by Biennale of Sydney's co-curators Katherine de Zieger and Gerald MacMaster. I accepted the invitation, and proceeded to apply for funding from sources other than the Biennale, as the budget they offered was quite limited. I was successful raising enough money through an Arts NSW grant for presentation and production to cover the material costs of the production, as well as in-kind contributions of skill and labour from several collaborators. With the existing works already produced, I had a reasonable budget to produce the exhibition for the Biennale.

What interested me about exhibiting on Cockatoo Island in the context of the Biennale of Sydney is that it is a free and popular event, that attracts about 500,000 visitors,[107] not only locals, but also people from interstate, and international visitors. Old and young lined up at Circular Quay to take a free ferry to Cockatoo Island, a historical site in the centre of Sydney Harbour. With its rich history, the island buildings have a lot of character, and the art is displayed throughout the island in different buildings, this year hosting 55 artists projects. The entire event is quite festive, and that spirit, the large crowds, and the fact that I could have an entire building for my project attracted me to accept the invitation, as it was in a similar spirit that Barnum or Madame Tussaud exhibited their respective museums. They were events not designed for the elites, but for

[107] "17th Biennale of Sydney Report," Biennale of Sydney, http://www.bos17.com/page/media_releases.html.

the masses who want to have fun while participating in a cultural event. The Biennale of Sydney at Cockatoo Island fitted the edutainment profile identified in those early museums. The exhibition, which ran for three months, is longer than most museum or gallery exhibitions. That allows for the word of mouth build up, and by using the Biennale's promotional efforts and PR professionals (again mimicking Barnum in his emphasis on promotion to get the press to promote the project to the general public. We did a great job in attracting media attention, including two TV documentaries, a few stories and mentions in the *Sydney Morning Herald*, the main paper in Sydney, a story in the Sydney *Telegraph*, multiple radio interviews, and other public appearances. (Please find in the Appendix to the thesis copies and links to the press received.)

The Cockatoo Island site attracted the large audiences I was aiming for, yet it posed numerous difficulties. There is no security for the exhibition spaces, and the work is vulnerable to theft, vandalism and environmental damage. There is no insurance covering the artworks unless they are properly locked and secured from the public. As heritage buildings, the artists are not allowed to modify them in any way — no nails, drilling, painting or glue could be used. There is basically no lighting, the buildings are not weather proof, and wind, dust, humidity and temperature variation is to be expected. During the three months of the exhibition, the spaces were unguarded most of the time, as the Biennale relies on volunteers as gallery sitters. With those limitations in mind, I commissioned Gary Warner, artist, museologist and multimedia expert to help me with the exhibition design, lighting design, and with the installation and object display.

Figure 120 I dreamed of dressing up this building Barnum Style,[108]but I was not allowed to alter the exterior in any way.

The brief for the museological display was:

- To provide protection from people and environment for the exhibition of about 300 small objects, specimens and prints, video and

[108] Philip B. Kunhardt, Kunhardt, Peter W., *P.T. Barnum: America's Greatest Showman*, 1st ed. (New York: Knopf, 1995). 36.

multimedia, for an expected audience of 500,000 people over three months in an unguarded space.

- To light the objects to focus audience attention on them.
- To display one video projection and several small slide shows as small digital displays.
- To install the works without touching the building in any way.
- That the exhibition display would be suitable for touring and to host a growing museum collection.
- To collaborate in decision-making for all display and object support.

All these limitations made us conclude that we needed to build museum display cases, to protect, light and display the objects, and that the displays should be of a museum scale — not of a domestic scale, but at the same time, small and light to be able to be transported and toured in the future. Gary presented various designs for my consideration. We steered away from Victorian style display cases, and opted for the most simple and modern design — large simple boxes on legs without any ornamentation. Two of them, measuring 180 x 180 x 900 cm had clear 100 mm perspex on both sides, and two of them, measuring 1800 x 2700 x 900 cm, had a fin in the middle, creating two distinct sides, one painted white, one black.

We used Tasmanian Oak for the legs, and a light-weight composite board for the top of the cases, called Ecoboard. They were painted black inside and out, except for the back of the long cases, which were painted white. For the lighting design we used small LED lights, with small holes to concentrate the beams of light to illuminate the objects with minimal lighting spill. For the white side of the cases we used stripped LED lights, giving an even light for the display of printed works, creating a surprise effect and contrast with the other side, interesting in terms of the exhibition design. All the cases are capable of holding multimedia yet we only used one for that purpose.

The way the cases were placed within the building allowed for people to circulate around them and for display objects to be viewed from both sides of the cases. The cases were built in relationship to the spacing between the old wooden columns, and to the existing elements within the space. In that way, they there were site specific to the space, without directly touching the existing architecture. The building known as 123, was previously used for shipbuilding, and has a large wall covered in wooden shelving. It was allowed to be lit by natural light through the only window that remained uncovered, as we darkened all other windows in the space so our miniature lighting would attract the public attention to the small objects in the display cases. As the audience entered the building, their eyes had to adjust to the dark, giving them enough time to admire the old shelving wall, before encountering the MoCO exhibit. Towards the end of the space audience encountered a large scale video projection of stick insect mating, visible from all sides of the space while people circulated around the cases.

Figure 121 View at the entrance of the exhibition space. Old shelving on left, video projection at the back, and cases on the center of the space.

Figure 122 Audience interaction viewing vitrines and video. Over three months the work attracted an average of 3,000 daily visitors.

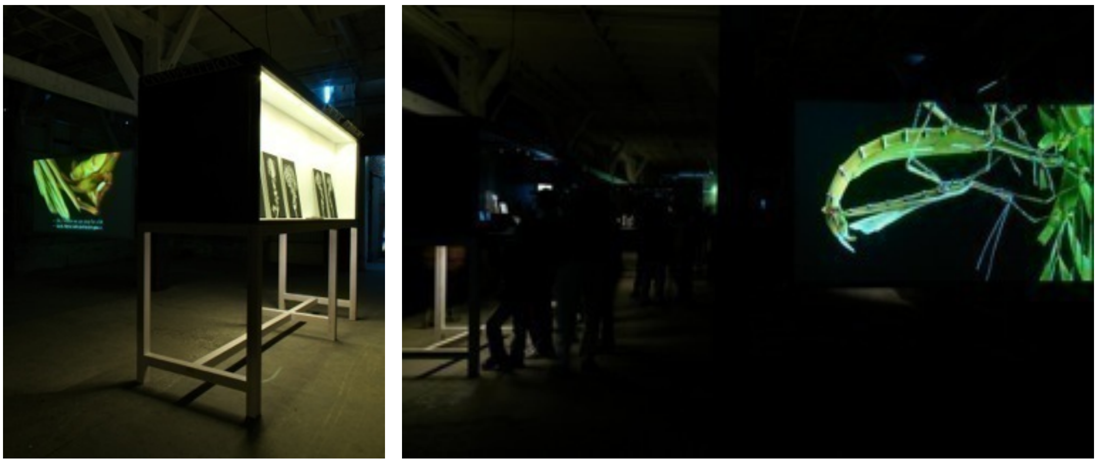

Figure 123 Stick insect video, rear projection screen visible from everywhere in the space.

Figure 124 Each vitrine would focus the attention of 12 or more people simultaneously. Quite an achievement for small object display.

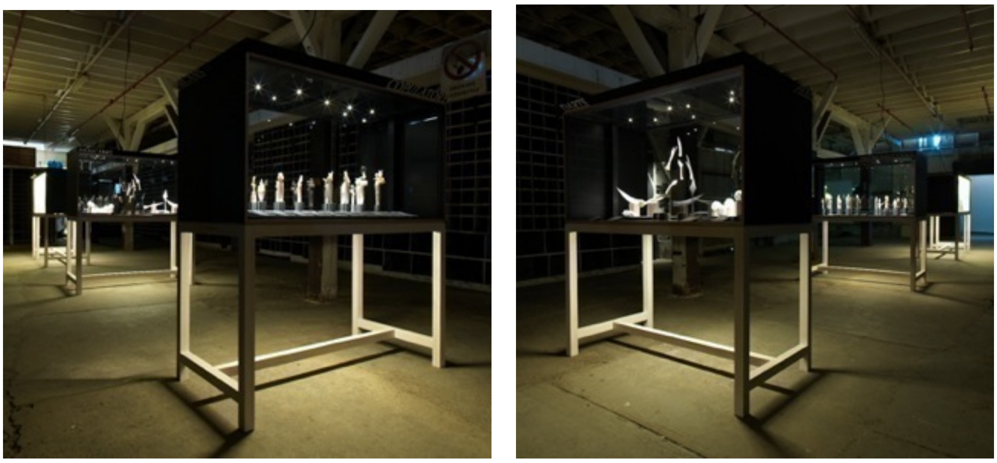

Figure 125 Two transparent vitrines on both sides, exhibiting Love Darts, Pollen and Harvestman.

Figure 126 White back, flat light, for contrast for print displays. Front of cases was painted black inside and out, and LED light was pointed at small objects alone, through 4-8 mm holes cut out in circles or rectangles depending on the object to be lit.

Figure 127 Dark side of case with multiple of digital screens and objects. On the other side, pigment prints of the *Phallomedusa solida*. Not very visible in the documentation are the words in laser cut lettering on the top of the display cases.

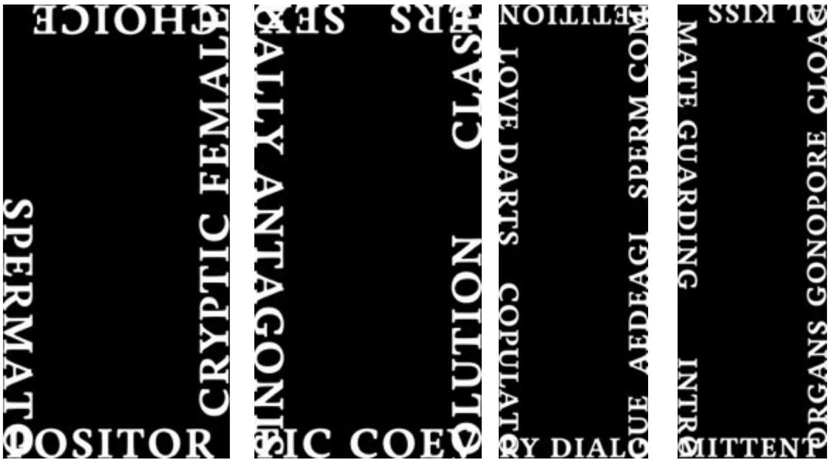

Figure 128 Mock up for laser cut words to be displayed on top of museum cases. As words were made as 3-D objects, using laser technology to cut wood and hand painted in painted white. Words were also treated as sculptural physical objects.

Another of my conclusions relating to how to best present my findings was to incorporate words and objects in such a way as to make them 'speak'. I used mainly words or terms that referred to what science had to say about animal genitalia (this will be the subject of the next chapter). I also used the occasional quote or titles of the works to tell the audience about my findings. The aesthetic choices were firstly inspired by the white on black aesthetic of the electron microscope images. For most of them (other than the laser cut terms sitting on top of the cases and around the space) I used hand writing, as I did in my studio to make visual reminders to myself regarding what was important to remember. Since my goal was not simply to provide an aesthetic experience of a multiplicity of forms, but to lead the viewer into the world of knowledge around animal genitalia, words were one way to fulfill the educational mandate of having a museum. In museological terms, this is often thought of as 'interpretation', while for me it is more about making 'objects speak'. It was an intuitive decision on my part, but it seemed to work well when watching the audience interact with the displays. They looked, they read, they interpreted the images they were provided;

they 'grasped' if not all, then at least some of the knowledge embedded in the exhibition.

The hand written text also reminded the viewer that this was a one-person museum, a 'person' with an urgency to communicate. Because the computer models were so 'perfect' it was a nice counterpoint to have the artist 'hand' expressed in the texts. The audience perceived the presence or the researcher/artist/curator and museum owner through those hand written words. They also gleaned this in the economy of the object support techniques, which were all hand made. I am referring here to the sheets of metal, metal shelves and wooden bases, all hand made and sanded by hand, somehow precariously, the opposite of industrial perfection. Through these handmade indicators, an immediacy between 'my presence' and the audience was created —again, I was following the steps of Barnum, Madam Tussaud, and David Wilson. Another way I included my personality in the exhibition was to leave my voice and that of my family as the sound component to the video projection of *Stick insect most intimate moments*. It made evident those parallel worlds: that of the observers, the filmmakers; the reality of the insects mating; and the audience observing them. Like the natural history display photos of Richard Ross, which showed the 'reality' of the architecture of display, I showed the reality of the human observers of insect sex, as well as the sexual act itself, exhibited in full colour, as it has never been seen before by human eyes. By making my human presence felt through all these techniques, I aimed to enhance what the audience is really looking at: the human-animal interface around the subject matter of animal genitalia.

Through all of this experimentation and artistic decisions, the project was made 'real', in a physical way, with a tangible collection of specimens, with a professional museological display, and with an educational mandate. To further support that educational mandate, I offered guided tours of MoCO every two weeks during the three months of the exhibition. This allowed me to explore the performative aspects of the transference of this information to the general public. In the future it is my goal to develop a 'performance/lecture' titled *Sex Education for the 21st century* to accompany the exhibition of MoCO. An illustrated lecture will be a format to fit all of that in. There is a great tradition of lectures and experiments being part of the diffusion and advancement of science, and this is another thing that I have learned about how to best present my findings to the public.

In the next chapter, I will present what I have learnt by reflecting on my primary research questions: why is there so much complexity and diversity in reproductive morphologies and how can I best present my (aesthetic) findings to a broad audience?

Chapter Five

Objects That Talk: The Science of Sexual Reproduction

> Exhibitions provide public spaces in which curators and designers orchestrate stimulating walks. Along the way, the key inspirational ingredient they imply are the 'enriched things' that museums and galleries store, and that in turn keep them alive. Exhibits are 'nodes,' as Lorraine Daston has them, where matter and meaning come together in the most pronounced of fashions. And in bringing materiality and meaningfulness together, museum objects embody a form of concrete rather than abstract knowledge —a knowledge without which we might, speculates Daston, even stop talking, becoming as mute as things are alleged to be.[109]

Objects, words, and museum display all became part of the vocabulary I had to learn in order to accurately communicate the biology behind a good deal of the 'indecipherable' images and specialist technical terms I encountered in the early stages of my research. This chapter will explain how this understanding of biology became embodied in my art practice, in what Lorraine Daston calls "objects that talk".

As part of my practice-led research process, words that caught my attention (often words and terms I couldn't comprehend but which nonetheless intrigued me) were quickly written on my studio walls. Single words became the points of entry to entire scientific concepts and theories. For instance, the phrase 'sperm competition'[110] compelled me to buy a science textbook by Leigh Simmons: *Sperm Competition and Its Evolutionary Consequences in the Insects.* It was one of the first science text books I bought as part of this research. As much as I tried reading it, I could not comprehend it. An edited anthology, it contained technical papers written by diverse authors. Their lingo and methodology were completely unintelligible to me, a lay reader.

The term 'sperm competition' kept reoccurring in the scientific literature[111] I was researching regarding animal genitalia. This was but one of a variety of specialist scientific terms being referred to: taxonomy, sexual selection, evolution, sperm, spermathecae, spermatophore, female choice, cryptic female choice, sexually antagonistic coevolution, aedeagus, intromittent organs, among other scientific

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[109] Ken Arnold, "Show Business: Exhibitions and the Making of Knowledge," in *Acts of Seeing: Artist, Scientists and the History of the Visual. A volume dedicated to Martin Kemp*, ed. Assimina Kaniari and Marina Wallace (London: Artakt & Zidane Press, 2006), 26.

[110] Leigh W. Simmons, *Sperm Competition and its Evolutionary Consequences in the Insects*, Monographs in behavior and ecology. (Princeton, N.J.: Princeton University Press, 2001).

[111] Robert L. Smith, *Sperm Competition and the Evolution of Animal Mating Systems* (Orlando: Academic Press, 1984).

A. P. Møller and Tim. R. Birkhead, eds., *Sperm Competition and Sexual Selection* (San Diego: Academic Press, 1998).

Tim Birkhead, *Promiscuity: An Evolutionary History of Sperm Competition* (Cambridge, Massachusetts: Harvard University Press, 2000).

terms. I want to clarify again that I have not been trained as a biologist, nor is it my aim to make scientific claims. As an artist with a research question concerning animal genitalia, I simply needed to understand the 'big picture' in terms of why animal genitalia are so complex. In order to do so, I had to learn the language that the biologists who have studied animal genitalia used. I also needed to learn about the history of taxonomy and evolutionary biology, the two fields that have mostly studied animal genitalia.

This led me to the cutting edge of evolutionary research, which I didn't expect at the beginning of my candidature. All I knew was that taxonomists used genitalia to identify different species, and that their work was a primarily descriptive 'no-questions-asked' approach. I learnt that genitalia were evolving under accelerated evolutionary pressures. In William Eberhard's words, "genitalia evolve rapidly and divergently."[112] That is the reason for so much diversity in genitalic form, as their shape is evolving faster than any other anatomical feature.

What I at first expected to be researched by way of a study of form (morphology) and of taxonomy, was in fact being studied under the premises of 'post-copulatory selection' — a concept first proposed by Eberhard as the most appropriate term to refer to the various hypotheses that aim to explain the complexity and diversity of animal genitalia.[113]

Figure 129 Words and quotes on the walls of my studio. Hand written text became part of the aesthetic decisions in the museological display of MoCO.

Very briefly, I will explain the key scientific concepts that are relevant to my research questions. I followed them like a detective, and slowly the doors of understanding started to open for me. I will present those concepts, roughly in a sequence similar to the order in which my own comprehension developed, as the terms tell the story of what is known about genital morphology. At the same time, I will show the reader images of how the different concepts were presented in the

[112] William G. Eberhard, "Rapid Divergent Evolution of Genitalia," in *The Evolution of Primary Sexual Characters in Animals*, ed. Janet Leonard and Alex Cordoba-Aguilar (New York: Oxford University Press, 2010), 40.
[113] ibid., 40-78.

MoCO exhibition through objects, images and words. This chapter should allow the reader to understand the hidden forces of sexual selection that affect the morphology of animal genitalia. Here I present my findings and a few definitions for the lay readers.

Evolution in a nutshell

> Darwin asked his reader to consider how slight changes, introduced at different points in the process and in different parts of the body, over the course of many thousands to a few million years, can produce different forms that are adapted to different circumstances and that possess unique capabilities.[114]

> There is a grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.[115]

I want to emphasise here how evolution has been defined around the question of *form* since Darwin to the present. This will be relevant later on, as this research is about genital morphology.

> Evolution is like the land of the Red Queen: The pressures on an organism mean it must run — that is, evolve as fast as it can merely to maintain itself. This, many believe, is ultimately why sex exists.[116]

Darwin's theory of sexual selection was first proposed to explain why sexual dimorphism and flamboyant display-ornaments exist (such as huge antlers, bird, insect and frog songs, and outlandishly colourful feathers in birds). Ornamental displays didn't fit into the logic of natural selection, as being loud or highly visible makes its wearer more conspicuous and vulnerable to predators, potentially diminishing the individual's chance of survival. Twelve years after publishing his theory of evolution in *The Origin of Species by Means of Natural Selection*[117] (by which most people came to know the 'survival of the fittest' theory), Darwin published *The Descent of Man, and Selection in Relation to Sex,*[118] in which he proposed the theory of sexual selection in order to explain those features he couldn't explain under the framework of natural selection.

There were two main components to this theory: mate choice, where the female chooses the male based on her aesthetic preferences; and male-to-male

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114 Sean B. Carroll, *Endless Forms Most Beautiful : the New Science of Evo Devo and the Making of the Animal Kingdom* (London: Phoenix, 2007). 5.

115 Charles Darwin, *The Origin of Species by Means of Natural Selection : or the Preservation of Favored Races in the Struggle for Life* (Cambridge, Massachusets: Harvard University Press, 1859; repr., 1964). 490.

116 Adrian Forsyth, *A Natural History of Sex : the Ecology and Evolution of Sexual Behavior*, pbk ed. (Buffalo: Firefly Books, 2001). 159.

117 Darwin, *The Origin of Species by Means of Natural Selection : or the Preservation of Favored Races in the Struggle for Life*.

118 Charles Darwin, *The Descent of Man, and Selection in Relation to Sex* (London: William Clowes and Sons, Limited, 1871; repr., 1885).

competition. Males not only develop ornamentation, song and courtship rituals to lure the females, but they also develop other visible features to compete with other males for access to a female, such as deer antlers or large muscles and size. Those aesthetic features have evolved not so much for practical reasons, but mostly to impress females and to intimidate other males. Females in general tend to be less conspicuous, by being silent or wearing 'cryptic coloration' as is the case in birds, where sexual dimorphism (the difference in shape, size, and coloration between males and females of the same species) is quite marked. In *The Descent of Man, and Selection in Relation to Sex* Darwin muses:

> so it appears that female birds in a state of nature, have by a long selection of the most attractive males, added to their beauty or other attractive qualities. No doubt this implies powers of discrimination and taste on the part of the female which will at first appear extremely improbable; but by the facts to be adduced hereafter, I hope to be able to show that the females actually have these powers. When, however, it is said that the lower animals have a sense of beauty, it must not be supposed that such sense is comparable with that of a cultivated man, with his multiform and complex associated ideas.[119]

This theory made Darwin a reluctant feminist and an animalist, as he dared to assign powers of reasoning or intelligence and aesthetic judgment to females as well as to lower animals. This is where aesthetics meets with feminism, animal studies and evolutionary theory. Now let's proceed to our subject matter.

Genitalia

For this dissertation I have followed the definition used by Eberhard in his 1985 book on *Sexual Selection and Animal Genitalia:*

> Male animals employ a remarkable assortment of structures in sperm transfer. I use the term male genitalia in a broad sense to include all intromittent structures on the male body as well as the packages of sperm (spermatophores)… In many species males have additional structures (claspers) for holding the female during copulation... I will include as genitalia all male structures that are inserted in the female or that hold her near her gonopore during sperm transfer. I exclude other reproductive organs such as testes, accessory glands and so on that are not normally in direct contact with females… In keeping with the definition above, I will consider as genitalia those parts of the female reproductive tract that make direct contact with male genitalia or male products (sperm, spermatophores) during or immediately following copulation. Specifically excluded are those structures higher up, such as ovaries and others not in direct contact, such as accessory glands, shell glands and such.[120]

What is important about this definition is that it broadly describes the variety of ways that nature has invented to deliver sperm. These structures are much broader and flamboyant than hypodermic style penises. That is to say, not every male of every species has a penis. For example, most male birds have a cloaca instead of

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[119] ibid., 211.

[120] William G. Eberhard, *Sexual Selection and Animal Genitalia* (Cambridge, Mass.: Harvard University Press, 1985). 1-2.

a penis. Flying birds use what has been described as a ‘cloacal kiss’ for sperm transfer; fish spawn on the female eggs externally, and have no need for a penis. Ancient organisms such as scorpions or salamanders lay a spermatophore on the ground and through a courtship ritual the male of the species persuades the female to take the spermatophore or sperm packet, which explodes inside her. The male octopus has a whole arm devoted to gamete transfer, and male spiders have pedipalps to perform the same function. The diverse structures used for sperm transfer are nevertheless all morphologically distinct, and are used by entomologists for species identification. From my perspective as an artist, this provides a wide range of forms to explore in relation to the aesthetics of reproductive morphology.

Sperm Competition

In the words of the scientist who first proposed the term, ‘sperm competition’ is “the competition within a single female between the sperm from two or more males for the fertilisation of the ova.”[121]

At this point I would like the reader to recall the damselfly penises I made in bronze, inspired by the drawings of William Eberhard.

Figure 130 Detail of bronze clay micro-sculptures of damsel fly genitalia. Figure 131 Damsel fly penis *(Ischinura elegans),* photo credit Power and Syred from PSMicrographs.

They held the key to my understanding of the term ‘sperm competition’. Male-to-male competition is common in the natural kingdom (as nature documentaries have done much to popularise), with images of males fighting each other in order to win the female or to control a territory. The loser in those violent fights, we assume, had no chance to pass on their genes. But the concept of sperm competing between each other defied the idea that the females only mated with the winning male. How sperm compete with each other was something that didn’t immediately spark an image in my mind, as it happens after copula, and

121 Geoffrey Parker, "Sperm Competition and its Evolutionary Consequences in the Insects," *Biological Reviews* 45(1970).

inside the female. It was nevertheless important for me to include this idea in my practice.

I only began to comprehend the concept when I finally realised why damselfly penises have hooks and scoops. I came to this realisation in the process of making my own models, these ‘objects that talk’. The Eberhard illustrations that inspired these little bronzes made reference to ground-breaking research by Jonathan Waage (1979) of Brown University, who discovered a shovel-like structure on the end of the male damselfly’s *aedeagus* (penis). Waage demonstrated that this structure was used to dislodge sperm from previous matings. To further support this theory, scanning electron microscopy (SEM) images of damselfly scooped penises visually supported his theory in later studies. I used one of them to make the artwork *Gently rocking up and down as he scrapes away,* 2012 (Figure 55), and the Eberhard drawings that formed the basis of the bronzes at the lower end of the photo.

> Before passing his sperm, the male inserts his peculiarly shaped copulatory organ and cleans out the female’s genital tract with a hook-shaped tool that empties her of sperm from previous matings. Copulation lasts for a minute or so, and for most of this time the male can be seen gently rocking up and down as he scrapes away, removing the sperm from the female. Only in the last few seconds is his own sperm transferred.[122]

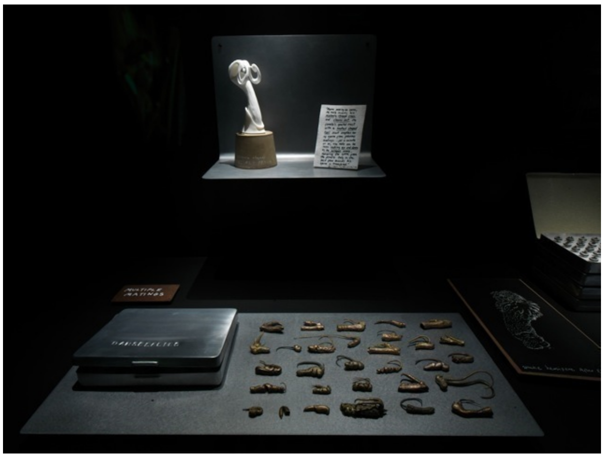

Figure 132 *Gently rocking up and down as he scrapes away* 2012, 3-D model in nylon with the quote from Catton and Grey, handwritten in shrink plastic, on an aluminium shelf. Below, *After Eberhard: Damselfly penises* in bronze clay and tin metal box, on aluminium base. Installation view MoCO, 2012

Before 1970, when British scientist Geoff Parker wrote a paper describing the mechanism of what he called “sperm competition”,' biologists assumed that females were monogamous — or that they only mated once, while males seek to mate as many times as they possibly could. The concept suited patriarchal morals, and became an assumption that was held by many. However, sperm competition suggests that females are promiscuous, and that not only does the dominant male gain access to the female, but that other suitors also find a way to mate with the same female. It also indicates that sperm somehow compete inside the female,

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[122] Chris Catton, James Grey, *Sex in Nature* (New York: Facts on File, 1985). 169.

and that the process of mate choice continues post-copula. As the editors of a major study of the history of the idea of sperm competition have put it, this "revolution in evolutionary thinking made it clear that rather than competing for females, as Darwin suggested, males competed for fertilisations."[123]

This is where the explanation of genitalic extravagance begins to cohere, as the conflict between males competing for fertilisation (inside the female tract) affects genital morphology for both males and females. External courtship and mating are what we can easily see and observe, but if we look at the genital morphology, it can 'speak' of what happens after mating. Scientists are beginning to look more closely at genital morphology in order to understand more about post-copulatory processes. As noted above, hooks and scoops are developed to remove the sperm of other males. What is even more interesting is that many female insects and invertebrates possess an organ to store sperm: the spermatheca, which may give females the ability to choose which sperm they like and which they do not. (But I am getting ahead of myself. More on this topic soon.) In the words of Marlene Zuk,

> scientists used to assume that copulation was the end of the story… That assumption is far from true … The action inside a female after copulation is as important from the stand point of evolution as what goes on during even the most energetic coupling.[124]

Genital morphology has been used to demonstrate behaviours that we couldn't or didn't want to see. This is why visual research and the art practice I am engaged in is important. We are learning about sexual behaviour through the study of morphology. And through the analysis of evolutionary processes, *we can demonstrate how sexual behaviour affects anatomical form*. This is a classic implication of the process of sexual selection. What we didn't know until a few decades ago is that the process of sexual selection continues behind the scenes — post-copula. The forces of sexual selection and sperm competition are the ones shaping genitalic morphology.

Sperm Plugs

Not only have males invented scooping devices to prevent females from fertilising their eggs with the sperm of another male; in many species they have also developed strategies similar in function to what we know as a chastity belt — the sperm plug. Perhaps the most dramatic example of a sperm plug is that of the drone bee, whose entire genitals explode inside the queen bee, breaking off from his body and remaining inside her. But male-male competition doesn't end there. The drones have not only evolved to sacrifice themselves for the sake of securing fertilisation of the female. As Dr. Olivia Hudson explains,

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123 Tim R. Birkhead, David J. Hosken, and Scott Pitnick, eds., *Sperm Biology: An Evolutionary Perspective* (USA: Academic Press, Elsevier Ltd., 2009), xi-xii.

124 Marlene Zuk, *Sexual Selections: What We Can And Can't Learn About Sex From Animals* (Berkely and Los Angeles University of California Press, 2002). 76.

males, obviously, will also gain if they can thwart previous lovers by removing the plug and mating with the female in their turn. You might imagine, then, that male honey-bees would have evolved some way of removing the chastity belt. You'd be right. If you look closely, you'll see that each male honey-bee sports, on the tip of his phallus, a hairy structure than can dislodge the severed genitalia of his predecessor.[125]

Figure 133 Scooping and plugging are penile functions other than delivering sperm. Male drone bee with expanded genitalia. Images courtesy of Glenn Apiaries.

There are many other animals that use sperm plugs according with Dr. Hudson, whose list includes

> bats, rats, worms, snakes, spiders, butterflies, fruit flies, guinea pigs, squirrels, chimpanzees… In many species of rodents, for example, males have enormous glands to secrete rubbery corks that they place deep in their partners reproductive tracts as they finish copulating. The house mouse makes a plug so tough that a scalpel virtually bounces off it; once the plug has formed inside a female, attempts to remove it can tear the ligaments of her womb.[126]

As a result of research such as Hudson's, we are starting to gather evidence of penile functions other than delivering sperm. As Eberhard says, the mere transfer of gametes (sperm cells) is not enough to explain genitalic extravagance. When looking at complex genitalia, we could use the same quote that Darwin used when referring to mate choice in sexual selection: "It is incredible that all this display should be purposeless."[127] Other functions of genitalia, not only mechanical connection between male and female, affect their morphology.

Female Promiscuity

Sperm plugs and sperm scooping devices are evidence of female promiscuity and a challenge to many of the unconsciously 'moralistic' assumptions that have governed zoological research at least since Darwin's time. As zoologist Tim

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125 Olivia Judson, *Dr. Tatiana's Sex Advice to All Creation* (New York: Metropolitan books, Henry Holt and Company, 2002). 18.

126 ibid., 19.

127 Darwin, *The Descent of Man, and Selection in Relation to Sex*: 399.

Birkhead explains in his book *Promiscuity: An Evolutionary History of Sperm Competition*:

> The very recent recognition that females of most species are promiscuous and routinely copulate with several different males, together with the realisation that in an evolutionary sense all organisms are basically selfish, has revolutionised our view of reproduction.[128]

But how could reproductive biologists not have noticed all the evidence of promiscuity before? A single flawed experiment by geneticist A. J. Bateman gave credibility to that idea of female chastity. In 1948, in a paper published in the magazine *Heredity*, he described his findings on the reproductive behaviour of the fruit fly *Drosophila melanogaster*.[129] He claimed, in popular words, that because eggs were expensive to make, and sperm was cheap, females were better off being choosy and males better off being indiscriminate. In recent years, this idea has been widely contested, especially after the development of DNA marking techniques in the 1980s, which can identify the paternity of any creature. What we now know is that females in many species are choosy by being promiscuous.

Cryptic Female Choice (CFC)

Under the classical theory of sexual selection by female choice, it was assumed that once a female has chosen a mate — the most handsome, the tallest and strongest, and the one with the best resources — that was the end of the story. This implied that the female genitalia was a passive vessel for the sperm and that all her control had already been exercised prior to copulation. But the discovery that most females are not only promiscuous, but that they can store sperm to choose from later, turned them into active participants in a behind the scenes process dubbed “cryptic female choice” by Randy Thornhill in 1982.[130]

In 1985 William Eberhard proposed a challenge to long held assumptions about female passivity, suggesting that genital courtship was part of the process of sexual selection. These processes, as we can see in the images below, influence the morphology of both male and female genitalia. The competition among males is not for mating exclusively, but also for fertilisation, as the females choose who will fertilise their eggs post-copula. This is also known as sperm choice, and it is exercised not only by females but also by hermaphroditic species. For example, the bulb like shapes on each of these four female tracts are spermathecae, or sperm storage organs.

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128 Birkhead, *Promiscuity: An Evolutionary History of Sperm Competition*: ix.
129 Angus John Bateman, "Intra-Sexual Selection in Drosophila," *Heredity* 2, no. 3 (1948).
130 Randy Thornhill, "Cryptic Female Choice and its implications in the scorpionfly *Harpobittacus nigriceps*," *American Naturalist* 122(1982).

Figure 134 Female reproductive tracks of a fruit fly *Drosophila bifurca* on the left, and of three different species of spiders on the right. Installation view MoCO 2012.

Figure 135 Coiled pedipalps of a Hunstman spider. They are able to reach the spermathecae inside the female tract, which is long and coiled as well. The tip of his palp sometimes breaks inside the spermathecae, and it has been proposed that it serves to block other males from fertilising the female. Light microscopy by MF Cardoso

Sperm morphology and coevolution

According to evolutionary biologist Tim Birkhead, "spermatozoa are the most diverse cell type known, exhibiting dramatic evolutionary divergence in form in nearly all taxa"[131]. Sperm morphology and size affects genital morphology. (We will see this in an example below). What is also little understood, but which also has an impact upon female morphology, are the proteins in seminal fluids that accompany them.

> Eberhard and his colleague Carlos Cordero call these seminal products 'chemical genitalia,' because they can be seen as extensions of the more conventional physical reproductive organs. We are only beginning to understand their complexity. Tracey Chapman from the University of East Anglia in the United Kingdom, in an article titled "The Soup in My Fly," referred to the bewildering diversity of seminal proteins as "an

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131 Birkhead, Hosken, and Pitnick, *Sperm Biology: An Evolutionary Perspective*, 269.

embarrassment of riches," surely the first time this phrase has been used in the context of sperm. At least 133 different substances have been identified, with doubtless more to follow.[132]

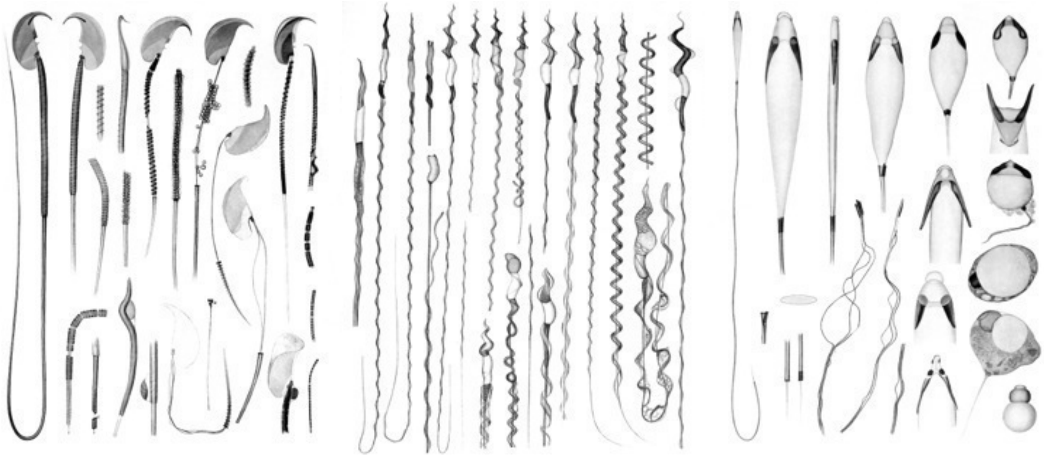


Figure 136 Gustav Retzius (1842-1919) illustrations of several species of sperm, from a collection of hundreds, in what can be called comparative spermatology[133]

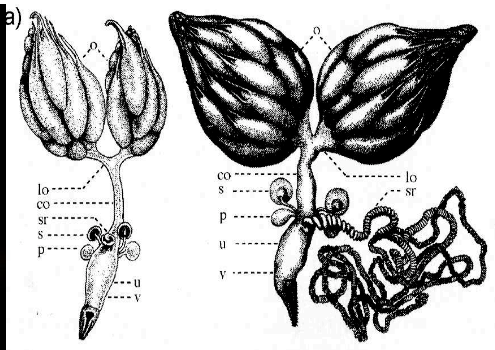
The influence of seminal fluids in female genital morphology is elegantly exemplified in the anatomy of the fruit fly *Drosophila bifurca*. This is another example of how Bateman was wrong to generalise about sperm being cheap. The giant sperm produced by *Drosophila bifurca* which, according to Hudson, measures up to 6.5 cm, can take three weeks to be replaced. The female tract is reciprocally convoluted, making her spermathecae hard to reach. Size does in fact matter in the coevolution of genital morphologies: not the size of the male organ but of its sperm. "Indeed as a general rule, where females are promiscuous, males don't just make more sperm, they make bigger sperm."[134] The female plays hard to get through her internal morphology, as well as behaviourally. The result of this conflict of interests between the sexes has been referred to as sexual conflict.[135]

132 Marlene Zuk, *Sex on Six Legs: Lessons on Life, Love, and Language from the Insect World* (Boston: Houghton Mifflin Harcourt, 2011). 113-14.

133 Gustav Retzius, "Die Spermien der Amphibiens," *Biologishche Untersuchungen* Neue Folge 13 (1906).

134 Judson, *Dr. Tatiana's Sex Advice to All Creation*: 27.

135 Patricia Adair Gowaty and Stephen P. Hubbell, "Killing Time: A Mechanism of Sexual Conflict and Sexual Selection from " in *The Evolution of the Primary Sexual Characters*, ed. Janet Leonard and Alex Cordoba-Aguilar (New York: Oxford University Press, 2010).



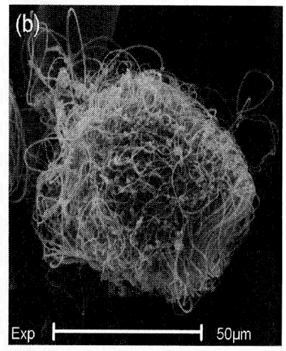


Figure 137 Female tract of the fruit fly *Drosophila bifurca* 2012. Nylon, rubber, glass and metal. Installation view at MoCO 2012. Figure 138 There is a widespread pattern of coevolution between sperm and female reproductive anatomy, illustrated here for sperm length and female receptacle (SR) length among *Drosophila* species. (A) Female reproductive tracts of D. Pseudoobscura (left), which as a short receptacle SR (0.41mm) and short sperm (0.36 mm), and D. Bifurca, with the longest known SR (81.67 mm) and sperm (58.29 mm). Figure 139 The male has the longest sperm ever recorded. Her reproductive tract has coevolved with his sperm by getting longer and longer.[136] She is playing hard to get, morphologically.

Birkhead suggests that the interrelationship between sperm and the female reproductive tract plays a complex and somewhat paradoxical part in the formation of reproductive morphologies. As he suggests,

> it is thus initially paradoxical to recognise that the female reproductive tract may also present an environment that is somewhat unfavourable to, and thus selective on, sperm. Conditions precluding some sperm reaching eggs may include I) active sperm ejection by females, ii) physical barriers (e.g., cervix, long ducts), iii) chemical barriers (e.g.), low pH and viscous mucus, and iv) leukocytic/phagocytotic responses within the female.[137]

Reproduction is not a cooperative affair. These selfish and antagonistic processes are driving the evolution of genital morphology.

Sexual Conflict

Scientists have realized that a key assumption we have to drop in order to understand genitalic morphology is that sexual reproduction is a cooperative affair.

> Remember: while a female may gain from mating with several males, each of her lovers will do better if she mates with no one but him. Whenever this conflict of interest occurs, it ignites an evolutionary battle that is fought on two different fronts. On the first front, each of a female lovers tries to thwart the lovers of her past and future while avoiding being thwarted himself. The prickly penis is one device …high sperm counts should sound familiar; but as always there are always other possibilities. For example, a male may use chemicals to disable his predecessor's sperm. Or he may make his own sperm hard to remove.[138]

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136 Birkhead, Hosken, and Pitnick, *Sperm Biology: An Evolutionary Perspective*, 268.
137 ibid., 248.
138 Judson, *Dr. Tatiana's Sex Advice to All Creation*: 133.

Males compete with other males to win the female. Males also attempt to control females, either by persuasion or by force; and if he can't, his sperm will continue to compete internally. Whenever repeated mating is beneficial to the female, she will gain by resisting male efforts at control. Thus, as males evolve to control, females evolve to resist.[139] Sexual selection operates at an individual level, "even at the other's expense."[140]

The example of penis fencing in flatworms is a classic case of sexual conflict. The encounter is a vicious and, to our eyes at least, violent coupling. The flatworms rear up and aim to stab each other with their two penises, ripping the skin of the other and injecting sperm under the dermis. In this hermaphroditic struggle, the 'loser' takes on the female role of bearing the offspring. Leslie J Newman describes the encounter:

Figure 140 Hermaphroditic marine flatworms rearing up to engage in penis fencing.

> …then, with deliberate motions each tries to stab its penis into the body of the partner — any part of the body. With short, stabbing motions each worm thrusts its penis stylet through the soft epidermis of its partner and injects a white bundle of sperm. They may do this repeatedly, until each bears multiple stab wounds and white blisters of foreign sperm. Then, they lower their bodies, retract their penis stylets and glide apart.[141]

Intradermal hypodermic insemination causes tissue damage, diminishing the fitness of the recipient, who will assume the female role of 'child bearing'. Evolving a vagina has its advantages. And the conflict doesn't end after the copulatory battle:

> Lukas Schärer at the University of Basel in Switzerland and his colleagues watched 16 species of promiscuous hermaphroditic flatworm (Macrostomum), which have a variety of sperm shapes (pictured), mating under a microscope. After sex, some species suck out the ejaculate, possibly as a way of selecting which sperm are ultimately accepted. The researchers found that those species that exhibit this sucking behaviour have ornate sperm with features such as a pair of long bristles emerging at the mid-point and a tail resembling a paint brush. These appendages can become lodged in the female orifice

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139 ibid., 19.

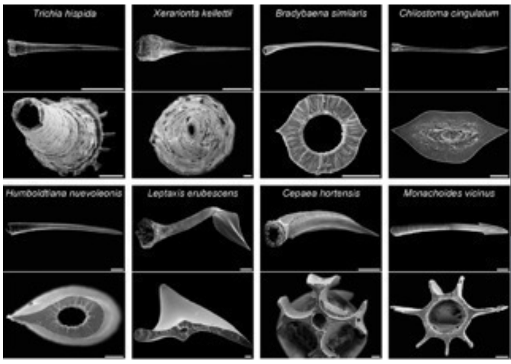
140 Birkhead, Hosken, and Pitnick, *Sperm Biology: An Evolutionary Perspective*, XII.

141 Leslie J. Newman, L. R. G. Cannon, and Andrew Flowers, *Marine flatworms : the world of polyclads* (Melbourne: CSIRO Publishing, 2003). 33-34.

after copulation, preventing the sperm from being sucked out. Species that don't remove sperm have evolved simpler sperm that tend to be smaller and lack hairs or bristles.[142]

Figure 141 Flatworm sperm have bristles that prevent being sucked out by a choosy mother to be.

This is a telling example of how *behaviour affects form*. The scientific method of comparing behavioural empirical observation with morphological research provides a more comprehensive picture of the dynamics of fertilisation, and of the resulting morphological diversity. After several hours, each partner injects a copulatory dart into the other, which seems to hurt but nevertheless results in a renewed bout of tentacle caressing.[143] In this example, sperm bristles have coevolved to compensate for the sucking action of the recipient worm in an evolutionary antagonistic race. The creation and exhibition of my own work has been useful in the clarification of some of these issues. The morphologies that I have concentrated on shed new light on how we might understand or apprehend some of these difficult concepts, which we are only just coming to terms with. Many of the models and renderings that I have created 'speak' in new ways to the natural histories I deal with. My Love Dart series is an especially good instance of this, as is the series on *Callosobruschus maculatus*, which I'll deal with now.



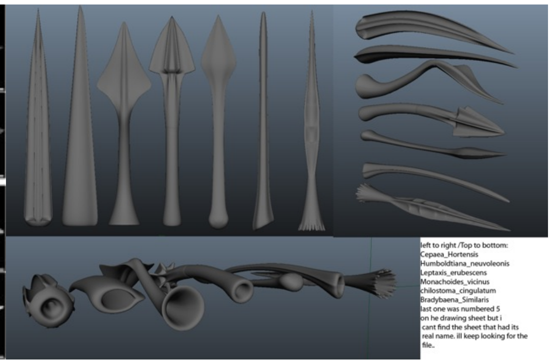


Figure 142 Electro microscope scans of Love Darts from Arqvist book *Sexual Conflict*. Figure 143 Computer renders of seven love darts, work in progress.

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142 "The Many Styles of Sperm," *Nature* 469, no. 269 (2011).

143 Catton, *Sex in Nature*: 98.

Figure 144 *Callosobruschus maculatus* penis in Love Hurts 2011-2012 Digital slide show, 3-D object, beans, metal.

A classic example of Sexually Antagonistic Coevolution (SAC) is that of the *Callosobruschus maculatus*, or bean weevil. These females have been observed to resist copulation by vigorously kicking the male in order to defend themselves. Under the microscope, the tip of the male's penis shows hard sclerotised spines, and in her reproductive tract, scars are visible after mating. Eberhard puts it this way:

> Male genitalia are thought to be devices that manipulate the female in ways that favour the male's reproduction but reduce the females' reproduction. Females coevolve to counteract these negative male effects, resulting in an arms race between the sexes. In this view, the sexual selection of males that results from female rejections is a side effect of natural selection of females.[144]

In the case of these bean weevils, the lifespan of unmated females is longer than non-virgins. Yet, females are evolving thicker walls to minimise the damage done by these penile spines.[145] The artworks I have made draw our attention to the form and function of these structures by way of two- and three-dimensional objects that speak volumes in regards to this arms race between the sexes.

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[144] Eberhard, "Rapid Divergent Evolution of Genitalia," 49-50.
The expected sequence of evolution can be outlined as follows: The male does something to the female with his genitalia or non-genital contact structures that increases his chances of paternity, but at the same time reduces the number of offspring produced by the female. For instance, the male might use spines or a rough surface on his genitalia to scrape a hole in the lining of the female's reproductive tract, thus increasing the ability of his seminal products that induce the female to oviposit by giving them increased access to her body cavity and to her nervous system… The female evolves defenses against the damaging effects of male genitalic manipulation. For instance, she might evolve a thicker lining of her reproductive tract in the area that is abraded by the male, reducing the strength of his negative effects on her reproduction. The male evolves a way to overcome the new female defense, etc.

[145] "Weevil Penis," Science Photo Library, http://www.sciencephoto.com/.

Penile spines are quite common across diverse taxa. (I have handled specimens of snakes whose hemipenis have spines so hard that x-rays couldn't penetrate them.) It is possible that the spines are a mechanism that serves a purely mechanical function of holding on, and that injuring the female is an unfortunate side effect of the need to hold on long enough to deliver the sperm. Empirical observation of the *Phallomedusa solida* 'hairs' under the electron microscope showed that each hair is a trident in shape. Once a trident penetrates flesh, it is extremely hard to remove.[146] Spikes, spines, and darts abound in the natural world, and their little-known existence sparked a whole series of works for MoCO. These works attempt to show the shape and form of these structures at a scale that is comprehensible to humans. The apprehension of these forms as three-dimensional objects helps in our understanding of the enormous diversity of copulatory structures that are employed in sexual competition. For instance, scientists have demonstrated that

> the function of the spines on the endophallus in longhorn beetles is to fix the male genitalia inside that of the females in order to warrant proper sperm transfer, rather than to penetrate the female genital tract. We have also presented the first plausible explanation for the function of the basal endophallus swelling.[147]

American evolutionary biologist Patricia Adair Gowaty's research into sexual conflict has helped me in thinking through the implications of this 'arms race' in terms of my own creative practice. My interest in sexual conflict led me to the discovery of an extraordinary range of aggressive-looking structures and morphologies that were essential for me to include in MoCO. Sexual aggression towards females may be a concept that is hard for us to reconcile in terms of our own human social and cultural mores, but it somehow seems to be widespread in nature. As Gowaty observes, our human frameworks sometimes make it difficult for us to 'see' sexual conflict and aggression in nature:

> Thus we think it possible that Darwin put aside consideration of the traits that interest us here [claspers], because these male 'contrivances' for holding, seizing, and grasping females sometimes hurt and killed these same females.[148]

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146 Anecdotally, Rosemary Golding, the taxonomist that described the snail, says that the penis snaps very easily when handling the specimens. Is that a form of blocking the reproductive tract of the 'she' snail?

147 L. Hubweber, & Schmitt, M., "Differences in genitalia structure and function between subfamilies of longhorn beetles (coleoptera: Cerambycidae)," *Genetica* 138, no. 1 (2010): 7.

148 Gowaty and Hubbell, "Killing Time: A Mechanism of Sexual Conflict and Sexual Selection from " 80.

Figure 145 Installation view of MoCO at Cockatoo Island 2012. A quote near the objects reads: *"After several hours, each partner injects a copulatory dart into the other, which seems to hurt but nevertheless results in a renewed bout of tentacle caressing."*[149]

For this reason, it was essential that I included as many of these morphologies as I could in MoCO. Consider, for instance, *Helix aspersa*, the ubiquitous garden snail.

> Mating individuals sling arrows of outrageous fortune at each other: each has a love dart that is sharp and pointed and that, if fired, pierces the lover's skin. As it does so, it delivers a gob of mucus. The mucus contains a substance that alters the female part of the partner's body, widening the passage to the sperm-storage chamber and closing the entrance to the sperm-digestion chamber, thereby increasing the chance that arriving sperm will be kept for future use rather than sent to the sperm-digestion chamber and destroyed.[150]

The existence of 'love darts' in snails has been known since ancient times (Aristotle is said to have observed them), and yet they are not widely known in the popular scientific imagination. One of the aims of my research is to make these forms palpable, and place them in a context that helps us to understand more of what their mechanical and aesthetic function might be in the natural world.

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149 Catton, *Sex in Nature*: 98.

150 Judson, *Dr. Tatiana's Sex Advice to All Creation*: 134.

Figure 146 Intromittent organs of Harvestman (opiliones) Computer generated renders 2008-2010.

Female Sense Organs

While the focus of the previous section of this chapter has been on the apparently violent and warlike nature of some sexual couplings, winning a fertilisation can also be a pleasurable affair. According to William Eberhard, under the influence of post-copulatory sexual selection, male genitalia has, in some cases, evolved to be used as an instrument of persuasion.

> Male genitalia are thought to be courtship devices. Sexual selection by female choice occurs after copulation has begun, with females favouring some male genital designs over others, via biases in post-copulatory processes such as sperm transport, oviposition, re-mating, etc. Male designs can be favoured because they result in more effective stimulation of the female, or because they fit better with her genital morphology.[151]

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[151] Eberhard, "Rapid Divergent Evolution of Genitalia," 49.
The expected sequence of evolution can be outlined as follows: Females are inevitably stimulated by male genitalia during copulation in species with internal insemination (and also by non-genital male structures that contact them during sexual interactions). Natural selection on females favours female use of such stimuli to trigger certain reproductive processes, such as sperm transport, ovulation, oviposition, resistance to further copulation, secretion of products to help maintain sperm alive in storage sites, etc., that are otherwise kept inactivated until mating occurs. Triggering these same female processes is, incidentally, favourably to the reproduction of the current male. If, as is probably usually the case, females do not give 100% complete responses in all of these post-copulatory processes to every copulation (e.g. they do not ovulate or oviposit all available eggs, do not always dump all of the sperm of previous males, etc.), and if they are not strictly monogamous, then sexual selection on males will favour the ability to increase the effectiveness of their stimulation of the female during copulation (including stimuli from their genitalia or non-genitalic contact devices)in eliciting more complete female responses. Selection on females will favour discrimination that allows them to bias paternity in favour of the males best able to deliver these stimuli, in order to obtain the benefit whose genitalia and non-genital contact structures that are especially effective stimulators. This can result in a runaway process, which will tend to produce sustained, rapid divergent evolution of the corresponding male structures. Females could conceivably benefit from superior sons with respect to both good survivorship genes or good signaling genes, but theoretical expectations suggest a stronger correlation with signaling genes (Eberhard 1985,1996). Direct empirical tests for a correlation between indicators of male "condition" with measures of genital size have been negative (Schult..etc)... Because there are so many different ways a female may be stimulated, and because many types of stimuli are likely to have effects on triggering a variety of reproductive processes

This is important for me to underscore here, as much of my work is concerned with the role that aesthetics, form, beauty and attraction have in the evolution of reproductive morphologies. So while there seems to be a dynamic that may involve what we might think of in human terms as 'pain', 'pleasure' is also part of sexual conflict. Eberhard has proposed that this is an aspect we should also consider, hypothesising that

> females should have sense organs in the area that is contacted by species-specific portions of male genital structures. He continues: The CFC sense organ prediction has almost never been tested. Two techniques are available: morphological or histological studies to reveal sense organs; and experimental behavioural studies in which potential female receptors are covered or otherwise inactivated, and then possible changes in female responses to the male are checked.[152]

This is probably the hardest thing to test and to prove, and yet some empirical observation of insect matings are helpful to refer to in this regard. I aim to continue filming insects and invertebrate matings of this kind so that I can offer to the scientific community behavioural visual evidence. After looking at one of the videos created for MoCO, *Stick Insects Most Intimate Moments,* Eberhard wrote to me:

> You are doing for genitalia what others in the past did for peacock tails and bird songs (how even more impressive it would be if we could communicate effectively about tactile sensations — the tickling vibrating sensation that a female stick insect must feel with a male quivering on her back, the feel of the gentle periodic rubbing with his genital claspers. This is a wonderful area of biology in which to combine science and art. I only wish that more people (biologists included!) had the patience you obviously have to really carefully observe and appreciate what you are seeing.[153]

Understanding the perceptions and sensations among animals, and in particular in invertebrates, is one of the great challenges for us as humans. Evolutionary biologists have developed a thorough understanding of chemical communication among insects, and I can see a lot of potential to demonstrate genitalic communication by the use display technologies that can help capture evidence for further research into the complexity of reproductive morphology.

During my research I have asked myself 'why is there is so much diversity and complexity of animal genitalia?' As I hope I have amply shown, we have learnt that genitalic diversity is the result of evolutionary processes (like all the diversity of life). We have learnt that genitalia express those evolutionary changes faster than any other body part and that they are under tremendous evolutionary pressure.

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through the highly inter-connected nervous system of the female, divergence in male designs in different populations is likely.

152 ibid., 65.

153 William Eberhard, Email 26 January 2012.

In summary, through my scientific research and through the work in my studio filming specimens, constructing models, and fashioning a museological context for the exhibits, I have been able develop and communicate a deeper understanding of genitalic complexity. I have been able to enhance the understanding of how genitalic complexity is the result of the previously unknown forces of post-copulatory sexual selection, which comprises three main factors: sperm competition, cryptic female choice and sexually antagonistic co-evolution. By looking at genitalia, we are looking at evolution in action. This accelerated evolution is triggered by the conflicting nature of sexual reproduction.

Sex, as we have learnt from Eberhard and others, is a complex and difficult affair. It is not a simple matter of delivering gametes (sex cells) from one individual to the other. As my art practice highlights, the more complicated those interactions become, the more complex genitalia evolves.

Conclusion

In my doctoral research — by providing a context for a broad visual collection of genital morphology — it has not only become possible to make some comparative anatomical analyses of genitalia in different taxa, but it has also been possible to make some reflections about human beings and their cognitive and communicative possibilities. My contribution has been to bring together a large amount of the specialised data that taxonomists and evolutionary biologists have gathered in reference to genital morphology, and to use all my skills as an artist, a maker, a visual thinker, and as an amateur naturalist.

We are already limited by our senses, which we expand through technology; but we are even more limited by our own *umwelt*,[154] which is perhaps a better way to think about our relationship to the natural world than anthropocentrism (but with perhaps the same result). It is very hard to see and 'know' difference. With regard to the topic of sexual reproduction, culturally inculcated prudishness and morality haven't helped. But precisely all of those limitations have made the work and research presented in this thesis novel.

In this dissertation I have looked at the evolutionary forces that affect morphological change concerning the diversity and complexity of animal genitalia. In order to answer my research questions: What contribution can visual arts research and practice make to a general public's understanding of complex scientific phenomena, and what strategies are most effective for representing these phenomena in a way that honours that complexity and engages the viewer comprehensively and with well-informed affects, beyond the simple provision of verbal information? I have interpreted genitalic shapes as *diagrams of sexual forces*, I have succeeded in making them 'talk' about the mysterious and complex 'behind the scenes' processes involved in reproduction.

What we have learnt from the study of genitalia is that *the forces of sexual selection dramatically and rapidly affect form*, much faster than natural selection or random mutation. It is this change that is much exaggerated and visibly expressed in genitalia. We have simultaneously developed a more comprehensive understanding of how morphological change is a result primarily of the struggle to reproduce, and secondarily of the struggle to survive. Genitalic diversity is at the apex of all the forces of evolutionary change. Without the struggle and conflicting forces of sexual reproduction, life on earth would be much simpler. The artworks I have created as part of this investigation palpably demonstrate this evolutionary fact.

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[154] David Eagleman, "The Umwelt," in *This will make you smarter*, ed. John Brockman (New York: Harper Perennial, 2012), 144-45.
Neuroscientist David Eagleman, refers to the concept of "the umwelt" coined by biologist Jakob von Uexküll in 1909 as– the idea that different animals in the same ecosystem pick up on different elements of their environment and thus live in different micro-realities based on the subset of the world they're able to detect. Eagleman stresses the importance of recognizing our own umwelt – our unawareness of the limits of our awareness

This research into genital morphologies has been long overdue. For centuries, we have neglected to look at and to study these morphologies. Indeed, it could be argued that such studies have often been actively censored:

> As a result of the sustained exploitation by taxonomists of genital morphology to discriminate closely related species, we surely know more about the evolution of species-level divergence in the morphology of genitalia than any other set of structures in the animal kingdom. For more than 100 years this huge mass of data on genitalia accumulated in nearly complete isolation from the study of sexual selection. The isolation was explicit in the original description of sexual selection by Darwin (1871), in which he specifically excluded genitalia form his discussion of sexual selection: "There are, however other sexual differences quite unconnected with the primary reproductive organs, and it is with these that we are specially concerned".[155]

Through the research of this doctorate, I have developed an enhanced understanding of how sexual reproduction is essential to the delivery of new 'skills' that can be served by *new forms*:

> … sex is selected when it becomes important for an individual to leave behind a set of offspring with a wider range of specialised skills, a richer variety of vocational orientations, than she could possibly make on her own.[156]

Sexual reproduction not only reproduces form. Genital morphologies themselves change rapidly, confirming the extraordinary variation and complexity contained in Darwin's observation of "endless forms most beautiful, and most wonderful".[157]

As I have shown throughout this thesis, the celebration of pattern and form in all of the contexts that I have studied is an essential part of life and culture. Formaphilia is the concept that identifies this general tendency (of humans and other life-forms) to focus upon and admire morphological biodiversity. While Darwin couldn't prove it in his lifetime, his intuition was correct: variation starts with genitalia. In his words, "I believe that the conditions of life, from their action on the reproductive system, are so far of the highest importance as causing variability."[158]

Throughout my research, I have focussed on making the variability of these morphologies visible, comprehensible, by use of my hands, by digital technologies, and by other three dimensional techniques. This approach to the

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155 William G. Eberhard, *Rapid Divergent Evolution of Genitalia Chapter 4, The Evolution of Primary Sexual Characters in Animals*, The Evolution of Primary Sexual Characters in Animals (New York: Oxford University Press, 2010). 40.

156 Fred Hapgood, *Why Males Exist: An inquiry into the evolution of sex* (New York: William Morrow and Company, Inc, 1979). 34.

157 Charles Darwin, *The origin of species by means of natural selection : or the preservation of favored races in the struggle for life* (Cambridge, Massachusets: Harvard University Press, 1859; repr., 1964). 490.

158 Ibid., 43.

construction of the models in MoCO has been led by the principle that we can 'make sense' of natural history specimens in a broad scientific and cultural framework. I want to suggest that the mimetic act of replicating a life form in new materials and in new contexts gives us new understandings and intuitions about these forms. As I have suggested earlier, it is precisely this transition from *what a life form is* to *what it means to us*, that lies at the heart of my doctoral study.

As I have shown throughout the thesis, my work engages with the science of taxonomy and evolutionary biology through the use of multi-sensorial thinking and 3-D model making. The 3-D objects, images, and carefully framed contexts provided by MoCO suggest new ways to think with things, and are an essential part of the production of knowledge and comprehension of the complex scientific ideas at the heart of my study.

The 3-D rapid prototyping and 2-D digital prints have provided a highly effective way for me to communicate my findings to a variety of different audiences — specialist and general public alike. In other words, the creation and exhibition of my own work has been useful in clarifying some of the specificity surrounding these basic 'conditions of life' and the incredible morphological 'variability' intuited by naturalists such as Darwin and Eberhard. The morphologies that I have concentrated on shed new light on how we understand or apprehend some of the most important findings of evolutionary biology, which we are only just starting to come to terms with.

My work 'speaks' in new ways to the natural histories I deal with. It can help reveal the central role that aesthetics, form, beauty and attraction have in the evolution of reproductive morphologies. It is my hope that this creative/investigative practice provides a fresh insight into the array of information available to the general public and to the scientific community (perhaps for the first time) in the original configurations that I have been able to offer in the course of my research.

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Appendix

Images of the Installation of MoCO at Cockatoo Island

As exhibited in the 18th Biennale of Sydney, June 26th-Sept 16th 2012

CD attached

The Wonderful World of Professor Cardoso

30 min documentary by Emma Watts Produced by ABCTV Artscape 2012
First aired on ABC Channel on April 24th 2012. Now available online at:
http://www.abc.net.au/arts/artists/maria-fernanda-cardoso-the-museum-of-copulatory-organs/default.htm

DVD attached

Museum of Copulatory Organs (MoCO)

Catalogue of Works

1
Intromittent Organ of the Thelbunus mirabilus (Tasmanian harvestman)
Sculpture in resin, glass and metal
40 x 10 x 6 cm
2
Intromittent Organ of the Cluniella distincta (Tasmanian harvestman)
Sculpture in resin, glass and metal
60 x 6 x 6 cm
3
Intromittent Organ of the Phanerobunus asperrimus (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
4
Intromittent Organ of the Notomincia divera (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
5
Intromittent Organ of the Triaenobunus sp (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
6
Intromittent Organs of the Allabunus distincta (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
7
Intromittent Organ of the Pyenganella Stricta (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
8
Intromittent Organ of the Thelbunus sp (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
9
Intromittent Organ of the Mestonia acris (Tasmanian harvestman)
Sculpture in resin, glass and metal
28 x 6 x 6cm
1**0**
Intromittent Organ of the Thelbunus mirabilis (Tasmanian harvestman)
Sculpture resin, glass and metal
28 x 6 x 6cm
11
Intromittent Organ of the Allonuncia grandis (Tasmanian harvestman)

Sculpture resin, glass and metal
28 x 6 x 6cm

12
Intromittent Organ of the Allonuncia Grandis (Tasmanian harvestman)
Pigment print on cotton rag
195 x 87 cm
13
Intromittent Organ of the Allonuncia grandis (Tasmanian harvestman)
Pigment print on cotton rag
195 x 87 cm
14
Intromittent Organ of the Notomincia Divera 2(Tasmanian harvestman))
Pigment print on cotton rag
195 x 87 cm
15
Intromittent Organ of the Pyenganella Stricta (Tasmanian harvestman)
Pigment print on cotton rag
195 x 87 cm
16
Intromittent Organ of the Phanerobunus asperrimus (Tasmanian harvestman)
Pigment print on cotton rag
196 x 87 cm
17
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Thelbunus sp penis (Harvestman)
Archival pigment print on 300gr cotton rag Mounted on tin box
18
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Triaenobunus sp. (Harvestman)
Archival pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
19
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Thelbunus mirabilus penis (Harvestman)
Archival Pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
20
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Pyenganella Stricta Penis (Harvestman)
Archival Pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
21
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Phanerobunus asperrimus penis (Harvestman)
Archival Pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm

22
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Allonuncia Grandis (front) Penis (Harvestman)
Archival pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
23
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Notomincia Divera Penis (side) (Harvestman)
Archival pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
24
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Intromittent organ of the Allabunus distincta (Harvestman)
Archival pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
25
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Intromittent organ of the Mestonia Acris Harvestman
Archival pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
26
IT'S NOT SIZE THAT MATTERS, IT IS SHAPE: Electro microscopic scan of the Intromittent organ of the Triaenobunus sp Harvestman
Archival pigment print on 300gr cotton rag mounted on tin box
4 x 31 x 24 cm
27
Insect Erection
Preserved dry beetle with everted genitalia, magnifying glass, rubber, metal
35 x 20 x 25 cm
28 - 31
Phallomedusa solida Penis
Pigment prints on cotton rag
61 x 35 cm ea.
32 - 33
Phallomedusa solida Penis
Pigment print on cotton rag
22 x 22 cm ea.
34 - 35
Phallomedusa Specimens Display
Snail shells, aluminum, pigment
36 - 38
Spermatophores of Pseudo scorpions
Set of 12 flamed glass sculptures with wooded base
39-51
Spermatophores of Mites
Bronze and rubber on aluminum shelf
52

Salamander Spermatophores
Flamed glass and wood
53-54
Snake Hemipenises
Wax and metal
55 - 60
After Eberhard: Snake Hemipenes
Drawing on board
Variable dimensions
61
After Eberhard: Snake Hemipenes
Drawing pigment on board
Variable dimensions
62
Micro bat Genitalia
30 silver sculptures (1 x 1x 1 cm each) in aluminum box
2 x 16 x 14 cm when closed, 12 cm high when opened
63
Micro bat genitalia
Silver sculpture on an aluminum base, glass and rubber
7 x 3 x 3 cm
64 - 73
Spiders' epigynum
Nylon, metal, pigment.
Variable dimensions.
74 – 78
Spider pedipalp
Print archival ink on cotton rag
18 x 12 cm ea.
79
Fruit Bat Flasher
Work in progress
80 - 115 Sperm Morphology Display
Nylon, pigment and Glass
Variable dimensions
116
The Longest Sperm on Earth: The Fruit Fly' Claim to Fame
Metal, cotton, glass, preserved fly, pigment
Variable dimensions
117
Female Tract of the Fruit Fly
Nylon, metal and rubber
22 x 22 x 22 cm
118
Female Tract of the Fruit fly
Pigment on plastic
28 x 22

119
Female Tract of Spiders
Nylon, metal
Variable dimensions
120
Female tract of spiders drawing
Pigment on plastic
11 x 8 cm
121 - 127
After Eberhard: Animal Genitalia and Sexual Selection
Pigment on Board and pigment on plastic
Variable dimensions.
128 – 139
Untitled
Pigment on plastic
28 x 22 cm
140 - 144
Love Darts
Nylon, wood, pigment, metal, snail shells
Variable dimensions
145 - 154
Love Darts
Resin, rubber, metal
Variable dimensions
155 - 169
Pollen
Nylon, wood, metal
Variable dimensions
170
Damselfly Genitalia
37 small bronzes on metal, aluminum box
Variable dimensions
171
Damselfly Genitalia
Nylon, rubber, plastic, metal on aluminum shelf
Variable dimensions
172
Bean Weevil Callosobruschus maculatus
Resin, rubber, metal, beans, preserved dry specimens
Variable dimensions
173
Bean Weevil Callosobruschus maculatus Slide Show
Digital images, iPad
174
Bee Explosive Genitals
Digital images, iPod
175 - 176

Flatworm Penis Fencing
Porcelain, pigment, metal
Variable dimensions
177
Argentinean Duck Penis Display
Modified toys, plastic, metal
Variable dimensions
178
Argentinean Duck
Digital print on plastic
11 x 8 cm
179
Garden Snails Mating
Shells, wax, love darts, metal
Variable dimensions
180
Pack of Dogs
Modified plastic toys, metal
Variable dimensions
181
Phalloblaster
Pigment print on plastic
28 x 22 cm
182
Phalloblaster
Drawing on plastic
28 x 22 cm
183 - 184
Mating Fleas
Plastic, metal
Variable dimensions
185
Flea Copulation Quote
1994
Pigment on vinyl and wood in two components
125 x 161 x 3.5cm and 100 x 61 x 2.5
186 – 190
Flea Genitalia Slide show
Digital images, iPod
312-334
Metal Signage Drawings
Pigment on metal
Various dimensions
313
Museum of Copulatory Organs MoCO Logo
Pigment print on wood
110 x 110 x 2 cm

314
After Thompson Beetle Genitalia
Pigment on wood
110 x 220 x 2 cm
315
Museum of Copulatory Organs signage
Pigment on galvanized metal
Variable dimensions
315-450
Studio Table Display
Miscellaneous objects, drawings, sculptures, glass tubes, prints, metal boxes, penis gourds, tools, artists’ materials on table and shelves
Variable dimensions