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Micros Cosmos
An Immersive Experience Inside The Microcosm

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Table of contents

Abstract/Resume...4
Introduction 5
CHAPTER 1
Setting the foundations for an immersive, artistic representation of the microscopic environment
Research of the necessary elements......7
1. State of the art..8
2. Microscope – Stereoscope...13
2.1. The first microscopes …...13
2.2. Types of microscopy …..14
2.3. Stereoscopic Observation 17
3. Behaviour Of Light - Utilising light and other techniques used for the study of worlds that differ human size
3.1. General Light Behaviour...19
3.2. Lighting techniques in Macroscopic observation and Microscopic observation...........................24
3.3. Utilisation of the artistic qualities that derive from the microscopic and macroscopic representation...29
4. The Elements that constitute the microscopic environment
4.1. Fractals – Patterns in microcosmos...30
4.2. Fractals structure in particles...33
4.3. The Inhabitants – Study of form, of structural and behavioural patterns, of movement - The Tardigrade - The Mite - The Eyeworm.............. 36

CHAPTER 2
Description of the creative process of implementing the virtual world...39
A. Modeling the microcosm
1. The Micro organisms...39
1.1. Modeling and texturing software- Description of the process …...40
1.2. Rigging, Skinning, Animation software - Description of the process...49

2. The environment

2.1. Creating the fractal microcosmos -Software and techniques used for the creation of the environmental elements....................54

2.2 Particles and ambient environment....................59

B. Real Time conduct of sightseeing in the microcosm

1. Game engine – Importing models and animations – Experimentations....................60

2. Virtual implementing – VR hardware....................68

3. Educational Application of the Virtual Experience....................68

Conclusions....................69

List Of References – Bibliography....................70

Abstract
The patterns and the colours of the microcosm provide a dynamic terrain that any visual artist could spend a lifetime examine. Being a visual artist and painter I have been interested in the patterns that where hidden in the minute. The goal of the present essay is to provide a deep view in the means and the optical tools that allow us to visualize the microcosm and the macrocosm. We will examine the patterns and the different visual styles that this observation is being realised with. The mindset, in which this master's essay is being realised, is this of a digital creator. The main pillars of this research are how the visual styles of the macro and micro observation can be used in the implementation of a virtual application and how the forms and lifeforms could reveal to us a truly - visually and educationally - fulfilling experience. It is always my hope that the utilisation of this derived conclusions and ideas can be utilised even in the minimum for any future attempt of virtually visualising the microcosm.

Résumé
Les motifs et les couleurs du microcosme offrent un terrain dynamique que tout artiste visuel pourrait passer une vie d'examen. Êtant artiste visuel et peintre, j'étais intéressé sur les motifs cachés dans la miniature. L'objectif de ce mémoire est de fournir une vue en profondeur dans les moyens et les outils optiques qui nous permettent de visualiser le microcosme et le macrocosme. Nous allons examiner les motifs et les différents styles visuels qui aident à accomplir cette observation. L'état d'esprit, dans lequel le présent mémoire est libéré, est celui d'un créateur numérique. Les principaux piliers de cette recherche sont la façon dont les styles visuels de l'observation macro et micro peuvent être utilisés dans la mise en œuvre d'une application virtuelle et comment les formes et les formes de vie pourraient nous révéler une expérience vraiment -visuellement et du point de vue éducatif- épanouissante. Il est toujours mon espoir que l'utilisation de ce découlant des conclusions et des idées peut être utilisée même dans le minimum pour toute tentative future de pratiquement visualiser le microcosme.

Introduction

The goal of the development of a VR application that allows the user to experience the Microcosm from the inside

A microcosm or "mikros kosmos" in Greek is, quite literally a little world. The Greek term was modified to "microcosmus" in Medieval Latin and employed by early scholars of the time to refer to humans as miniatures of the natural universe. As John Trevisa wrote when translating Bartholomaeus Anglicus' Encyclopedia in the 14th century: a microcosm is called the small world, because people find likeness of their own experiences in it. Furthermore, it is believed that the term is applied specifically to human beings as they are considered a smaller scale model of the universe in all its variety and contradiction.

Merriam-Webster dictionary [online] defines the microcosm as the following: "1: a little world; especially: the human race or human nature seen as an epitome of the world or the universe. 2: a community or other unity that is an epitome of a larger unity".[1]

The latest offerings in microscopic observation have now made visible to us small, representative systems that are having analogies to the larger system (our visible system), in constitution, configuration, and development. Amazing images of strange, uncanny creatures and wondrous new worlds can be now seen by everybody through a microscope or a stereoscope up to their finest details. These everyday discoveries of the same principles rule the microscopic domains as the larger systems help to verify the definition of the word 'microcosm' as tiny, small worlds, often invisible to the naked eye, that exist in parallel to our own perception and understanding.

The notion of parallel worlds has always intrigued the creative nature of human beings. This intriguing notion has long been expressed, with various means, through different forms of art, such as literature, painting, sculpting, performance arts, theater, cinema photography and even music. Nowadays there is a new and powerful tool to experiment and create: digital media. Virtual reality and digital media can offer an immediate perception of immersion to the user, by placing them at center-stage and giving the power of immediate interaction. This can be seen as a bold and intriguing new way in the creation and perception of art.

Virtual Reality technologies are rapidly advancing and digital creators are making even more immersible environments for the users. With the means available to us now, we can almost place ourselves inside a fictional environment and experience it to the full. This microcosm can therefore give access to landscapes and creatures that exceed even the most vivid imagination.

The goal of this project is firstly to study all the elements the microcosm consists of. It is hoped that this could aid to the creation of an environment in which the user can take a stroll and feel a small part of these amazing, but very real worlds. This project will also study the tools and mediators that provide us with a visual understanding, as these could be the artistic references for the modeling of a digital environment. Finally, these analises will culminate in an attempt to construct a virtual experience inside the microcosm as faithful as possible to the findings of this research.

The scenario is the following:

The action takes place inside an uncanny, strange and bizarre world in which the user will have no familiar sights. Strange creatures with the size of large animals like elephants or ever bigger will move around the user. For quite a while the user will have the time to explore this strange land in the same way he would the countryside, or the beach.

1 http://www.merriam-webster.com/, (collected 16-10-2015)

The goal is for the user to wander inside this different place, inside a drop of water, where we encounter the Tardigrade, an amazing microscopic creature, where the user can spend time observing it. This virtual experience can provide us with an interaction, not through the sterile lens of a microscope, but with the feeling of the actual analogies of the space and the elephant-sized animals moving around us in a larger than human scale. Never before could we have moved side by side with the inhabitants of the microcosm, and actually experience the change of our size and scale. Now, thanks to the digital and virtual reality tools, we finally can.
This use of the Virtual Reality technology can help provide a better understanding of other parallel worlds, thus opening new horizons in the fields of Science, Art and Education. At the same time, this can be an opportunity to experience change of scale and invoke emotions to the user, keeping always in mind that the measure of everything is the human perception. As the ancient philosopher Protagoras wrote: the measure of everything is the human.[2]

2 http://plato.stanford.edu/entries/sophists/#Pro, (collected 19-10-2015)

CHAPTER 1

Setting the foundations for an immersive, artistic representation of the microscopic environment

Presentation of the necessary elements

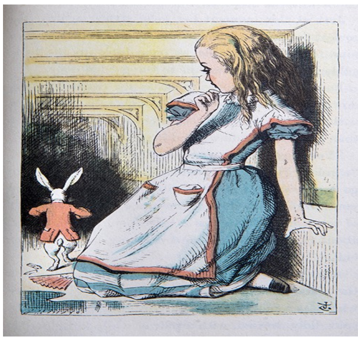
1. State Of the Art

The idea of other parallel and uncanny worlds has been the source of inspiration for many artists. In this part we will take a look at some of them which have elements that can be very useful on this study of a virtual, artistic take on the microcosm. These works of art deal with notions of change of scale and the exploration of the elements that our human statusquo often prohibits us from seeing and have been a source of inspiration for this project too.

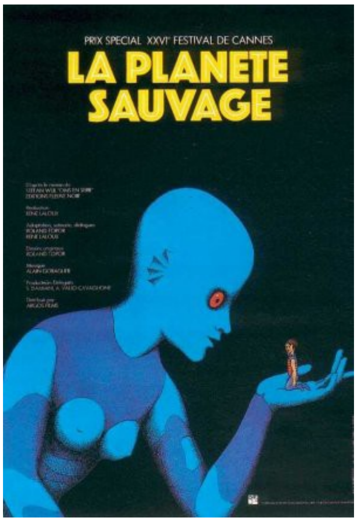
Fitz-James O'Brien's "The Diamond Lens" was probably the first piece of fiction to involve the microcosm. "The Diamond Lens" tells the story of a scientist who invents a powerful microscope and discovers a beautiful female in a microscopic world inside a drop of water.

In ***Alice's Adventures in Wonderland,*** a 1865 novel written by Lewis Carroll, a girl named Alice falls through a rabbit hole into a fantasy world populated by strange creatures. In Chapter One – Down the Rabbit Hole Alice is feeling bored when she notices a talking, clothed White Rabbit with a pocket watch run past. She follows it down a rabbit hole, but suddenly falls onto a hall with many locked doors of all sizes. By drinking a potion she changes scale in order to get through the doors and continue.[3] In Chapter Two – The Pool of Tears we see Alice growing to such a size that her head ends up hitting the ceiling. In these chapters we observe the notion of dwelling in a bizarre word but also the change of scale followed by the change of view on things.

The book has inspired numerous film and television adaptations including Tim Burton's 2010 film Alice in Wonderland, which has a vast use of 3d animations and technologies for the visualization of the imaginary landscapes.



This edition of "Alice's Adventures in Wonderland" by Lewis Carroll was released in 1966, and features illustrations by John Tenniel that were colored by Fritz Kredel. (Photo by Tyler Stabile/Ohio University Libraries)



- *Poster for Fantastic Planet*

An amazing animation film that is one of great inspiration is ***La Planète sauvage,*** a 1973 cutout stop motion science fiction animation film directed by René Laloux. This animated tale follows the relationship between the lillipoutian Oms and the large blue Draags, who rule the planet of Ygam. Fantastic Planet is recognizable for its surreal, psychedelic imagery, created by French writer and artist Roland Topor, who was the production designer and co-writer of the film. The landscape and lifeforms of Ygam are bizarre, as are various portrayals of the Draag society and its functions, such as their meditation (which allows them to communicate with each other and different species without using words and can even lead to transformations of their shape and colour) and their technology (such as the devices they use to

3 http://www.the-office.com/bedtime-story/alice-background.htm, (collected 19-12-2015)

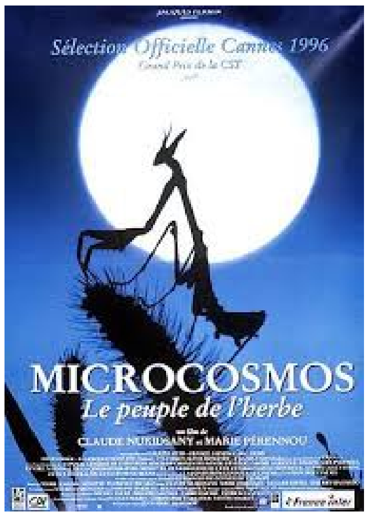
slaughter Oms).[4] A parallel can be made with the methods that we, humans use to exterminate lesser forms of life such as insects and bacteria. The strange atmosphere of the film is enhanced by its soundtrack, that is composed by Alain Goraguer.[5]

The relationship between Draags and Oms can be seen as allegorical of the relationship between various groups of humans, as well as between humans and animals. A view on the different perception of scale and the power that derives from it is obvious in this classic animation film.

Still pictures taken from the animation film La Planète sauvage (1973)

Microcosmos (original title Microcosmos: Le peuple de l' herbe - Microcosmos: The grass people by Claude Nuridsany and Marie Pérennou) is a 1996 documentary film offering a close look inside the everyday living of microscopic creatures. It uses close-ups, slow motion, and time-lapse photography creating an immersive, yet highly artistic atmosphere. It shows, among others, bees collecting nectar, spiders wrapping their catch, caterpillars forming endless lines, and an underwater spider creating an air bubble to live in.

To quote Roger Egbert on his review on the movie «The movie is a work of art and whimsy as much as one of science [...] If a camera could somehow be transported to another planet, in order to photograph alien life forms, would the result be any more astonishing than these invasions into the private lives of snails and bees, mantises and beetles, spiders and flies? [...] Every one of these amazing creatures represents a successful Darwinian solution to the problem of how to reproduce and make a living.



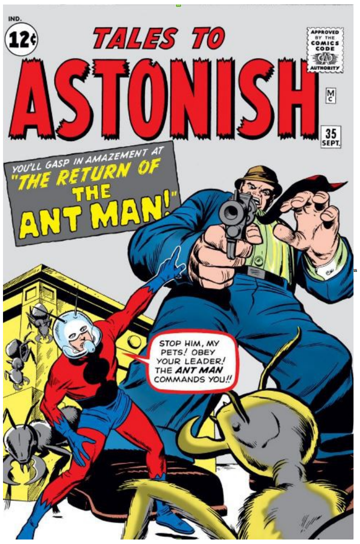
. The DVD cover of the film Microcosmos. Copyright Miramax

4 http://www.imdb.com/title/tt0070544/, (collected 19-12-2015)

5 https://en.wikipedia.org/wiki/Fantastic_Planet, (collected 2-2-2016).

And so do we».[6] [7]
The film is an inspiration for this work as it provides a unique source of references on the rhythm and the flow of the everyday action happening on a smaller scale, and also a reference on the colourful pallette that frames these realms.

Another film relevant to the topic of dwelling in the microcosm is ***Honey, I Shrunk the Kids***, a 1989 American science-fiction family film. The film, directed by Joe Johnston, tells the story of an inventor who while testing his electromagnetic shrinking machine, accidentally shrinks his and his neighbor's kids to ¼ of an inch. Unbeknownst to him, he throws them out into the backyard with the trash, where they must try to return home while fending off insects and other obstacles. Special effects were heavily used for the film, such as the electronically controlled ants and bees.



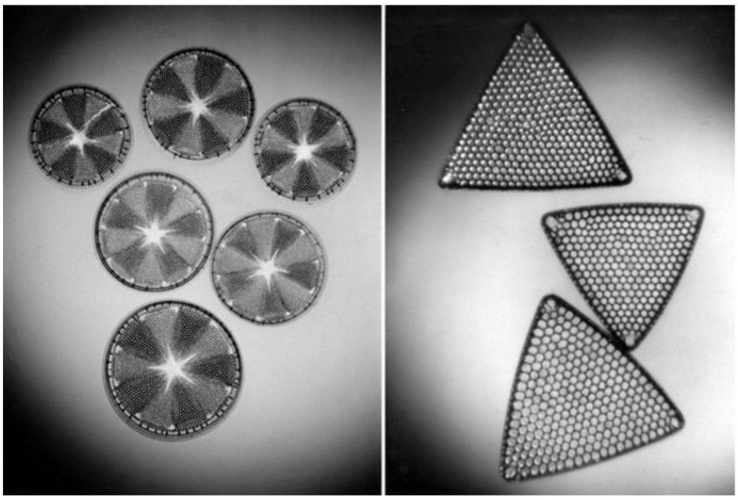
Cover of comic book Tales to Astonish #35

The comic book hero ***Ant Man*** appearing in books published by Marvel Comics is about Biophysicist and Security Operations Center expert Dr. Henry 'Hank' Pym who decided to become a superhero after discovering a chemical substance (Pym Particles) that would allow the user to alter his size and shrink down to the size of an insect to become the mystery-solving Ant-Man.

A live-action film, featuring Scott Lang and Hank Pym, titled ***Ant-Man***, was released on July 17, 2015. The film includes some very interesting CGI work that depicts the shrinking of the hero and his view of the world from this size in a stylized action film style. Double Negative, the creative team behind the execution of the design in order to create shrunken characters, incorporated macro photography and motion capture performances that were shot in principal photography, along with digital models of the characters. Visual effects supervisor, Alex Wuttke said, "It's like a little time echo. As Ant-Man shrinks in almost a stop motion way he would leave behind outlines of the poses he'd been in as he shrinks down... We'd have two CG cameras rendering the action from different points along the timeline with slightly different framings. One would be the main shot camera, the other would be a utility camera that would provide renders of static poses of Ant-Man at different points along the timeline". [8]

In photography, graphic designer and photographer, ***Carl Strüwe*** (1898-1988) is considered the father of microphotography as an art. He is a significant protagonist of early twentieth-century German photography and an important link to the international abstract photography so widely practised today. As a self-taught photographer, Carl Strüwe made his first photograph through a microscope, called White Suspended over Grey, in 1926. This served as the beginning of his three-decade artistic masterpiece comprising of 280 microphotographs collected in a 1955 book: Formen des Mikrokosmos. Carl Strüwe's purpose was not to present microphotography as scientific evidence. Rather, he wanted to emphasize the geometric structures present in microscopic living creatures and life forms, similar to the images of Cubism and Constructivism. He achieved that by creating and using a rectangular lens frame that was based on the standard format used in Western painting and drawing.[9]

6 Roger Ebert , Microcosmos Review, http://www.rogerebert.com/reviews/microcosmos-1997, (collected 4-2-2016).
7 https://en.wikipedia.org/wiki/Microcosmos_(film), (collected 2-2-2016).
8 Seymour, Mike (July 19, 2015).
9 Artforum.com, (collected 20-12-2015)



Mr. Strüwe, a broke amateur photographer, saw the potential to turn science into art. Photographs of diatoms: Actinoptychus heliopelta, left, 1928; Triceratium favus, right, 1930. Credit Carl Strüwe

Rose-Lynn Fisher is a photographer that utilises both aerial and microscopic views in her work. In her 2010 book of images, by using powerful scanning electron microscopes, she magnified a bee's microscopic structures to such an extent that she revealed startling, abstract forms that are far too small to see with the naked eye. She also has another project entitled "Topography of Tears" where she photographed with a specialised microscopic camera over a hundred tears, her own and others.[10]

Toyama-based artist ***Susumu Nishinaga*** has also utilised a scanning electron microscope in his work, offering images of nature unseen by the naked eye. There are 95 black and white close-ups in his book entitled "Micro Cosmos", which he later colorised, that observe insects, flowers and shellfish. The images afford a close look in different graduation sequences and fine images of texture.

Radiolaria.org is an online database containing information about radiolarians (holoplanktonic protozoa widely distributed in the oceans) and fossil. On that online database we can also find the work of artists inspired by the forms of these protozoa. ***Artists as Dagmar Borgwart, Barbara West, Eva Bjerke, Robert Kraus, Gerhard Lutz, Miik Green, Alan Ross*** all incorporate these forms in their works of art**.**

Robert S.Cornnett "MICROVERSE II" (2015)

In the field of painting, the work of Los Angeles based artist ***Robert S. Connett***, portrays microscopic life in a dark and mesmerising world. His images present rare and overlooked creatures, from aquatic organisms like shrimps, and crabs, to butterflies and grasshoppers, that he best describes as miracles of life. Each organism is rendered with painstaking detail, based on books of scientific illustrations, and brought back into a vibrant living environment. [11]

10 Smithsonianmag.com, (collected 20-12-2015)
11 hifructose.com. (collected 21-12-2015)

Peta Clancy is an artist who has worked with the mediums of performance, bio-art, sculpture, video and installation. VisibleHumanBodies was inspired in a genetics laboratory, using live bacteria as a drawing medium. The artist's purpose was to create a metaphor for the fragile and changing human body. Using different strains of pathogenic bacteria (those that cause disease) the artist drew the outline of the human figure onto the surface of agar in a Petri dish using needle-like instruments. The dishes were incubated for several days, during which time the image constantly changed creating a fascinating photographic development.

Visible Human Bodies (VHB), detail 2005 80 x 80cm

2. Microscope – Stereoscope

2.1 The first microscopes
2.2 Types of microscopy
2.3 Stereoscopy

It is important to examine the mediator between the human and the microscopic world and the instrument for the observation of the microcosm has long been the microscope. The types of microscopes can examine different types of materials and their results can give us the feeling of the subject that we study. It can be fascinating and interesting to try to achieve the same similar aesthetic results with the use 3d software.
In many parts of these first chapters we use analytical scientific terminology for the explanation of methods and tools in order to achieve an elementary familiarization of the reader with these topics for a fuller understanding of this work.
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2.1 The First Microscopes

A microscope is the optical instrument that enables the user to see objects that are too small for the naked eye. The word is derived from Ancient Greek and is combination of two words: μικρός, mikrós, wich means small and σκοπεῖν, wich means to look or to scope.

Humans from early on were able to understand that the visible world was not the only existing world. Humans' wish to enhance their vision in order to have a better understanding of the world's mechanics and natural order compelled them to invent the first microscopes. It is important to mention in this essay the first attempts that humans made in order to have visual access to these hidden worlds.

The early microscopes were common lenses that were used for insect observation and they were called flea glasses.

Leeuwenhoek's microscope (image taken from http://www.visioneng.com/)

In the 1590's, by father and son, Zaccharias Janssen and Hans Janssen created the first microscope by placing lenses in a tube and noticing that the object near the end of the tube appeared enlarged, much more than any magnifying instrument of the time. The maximum magnification achieved was around nine times the original object but without significant clarity.

Antony Van Leeuwenhoek was the first to make and use a real microscope in the late 17th century. Was the firs to see inside a drop of water, strange animals and other particles moving around. The idea that another world truly existed in minute things was revealed for the first time.

In 1893 August Köhler first developed the early illumination for microscopes setting the foundations for microscopy. This method regulates the light in a way it produces acceptable contrast. Phase contrast and contrast illumination were both discovered in the 1950s by Frits Zernike and Georges Nomarski. Their discoveries produced clear and focused images.

2.2 Types of microscopes

It is essential for this essay to examine the types of microscopes as they provide us with different aesthetic results which we will later apply as references and texture samples for the 3d visualisation.

As we will examine later on, some microscopes give us a top down or orthographic view of the microscopic samples while other give us a perspective directed frame. In my opinion, the best 3d representation of the microscope would be complete by the combination of all the different types of the provided images. Let's examine some of these types:

The grouping of the different categories of microscopes is accomplished with two different methods:

a. The first grouping method examines the medium that interacts with the sample. For example optical microscopes use light or photons, electron microscopes use electrons and scanning probe microscopes use a probe.

b. The second grouping method examines the way the microscopes analyse the sample. Whether it is scanned by a single scanning point (confocal optical microscopes, scanning electron microscopes and scanning probe microscopes) or if it is scanned all at once (wide field optical microscopes and transmission electron microscopes).[12]

In this research we will use the first method as the medium that microscopes use defines some of the qualities, of which we can take advantage, while implementing the 3d digital application.

Optical Microscopes

The function of optical microscopes (or else “light microscopes”) is based on using visible light and a system of lenses to magnify images of small samples. Light-sensitive cameras are used in optical microscopes to generate the images. Although in the beginning, photographic film was used to capture light and translate it to image, nowadays digital cameras have replaced this classic medium. More specifically, the image now can be shown directly to the computer screen, making eyepieces unnecessary. [13]

We can divide the optical microscopes in two categories. The first one includes all the single lens microscopes, which are called “simple microscopes”. The second one includes the microscopes that utilise a series of lenses to achieve higher magnification and finer detail, which are called “compound microscopes”. The compound microscopes are the ones used in the research laboratories, as multiple lenses provide versatility in focus and a finer ability to adjust to the specialised samples. It is important to mention that in optical microscopes used for research, the sample is illuminated by various different techniques. These techniques provide a wide range of visual style images, which can be utilised in 3d software applications. **This utilisation extends from the use of these images, as texture maps, to the use of them as an artistic and stylistic reference, due to the variety of the gamma, of the colour and the intriguing formations.**

In order to enhance the sample images and to increase the available information, many different techniques are used. These various techniques utilise the behaviour of light, as each one of them depends on different light properties. More specifically, they change the contrast values of the sample and they reveal to us, each time, different patterns.

The four major techniques so as to achieve **contrast variation**, used in optical microscopy, are the following:[14]

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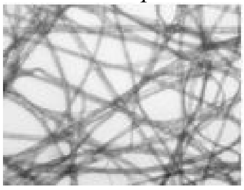
12 https://en.wikipedia.org/wiki/Simple_microscope, (collected 13-2-2016).

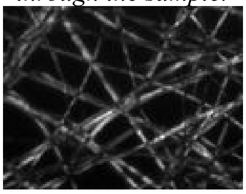
13 http://www.biozentrum.unibas.ch/fileadmin/redaktion/Events_2013/Block_Course_Structural_2013/Manual_BK_Mikroskopiekurs.pdf (collected 13-2-2016).

14 https://en.wikipedia.org/wiki/Optical_microscope (collected 13-2-2016).

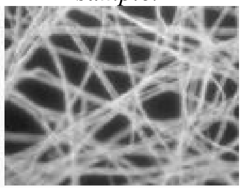
Bright field illumination, *sample contrast comes from absorbance of light in the sample.*



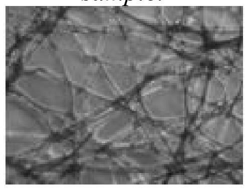
Cross-polarized light illumination, *sample contrast comes from rotation of polarized light through the sample.*



Dark field illumination*, sample contrast comes from light scattered by the sample.*



Phase contrast illumination*, sample contrast comes from interference of different path lengths of light through the sample.*



Images and text taken from https://en.wikipedia.org/wiki/Optical_microscope (collected 13-2-2016).

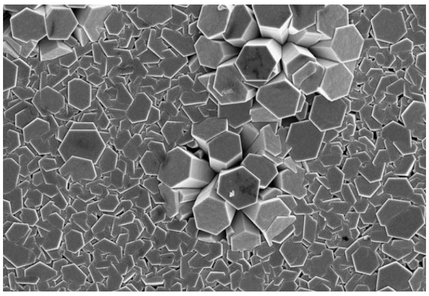
Finally, we should mention that optical microscopes, with the aid of additional optical tools, are able to gather information from a wide range of the electromagnetic spectrum, using different techniques (such as: Ultraviolet microscopy, Fluorescence microscopy, Near-Infrared microscopy, Epifluorescence microscopy and Confocal microscopy). The essence of electromagnetic spectrum and the procedure of the above mentioned techniques will be examined, with more details, in the following paragraphs of this essay, as they provide us with qualities, essential to a virtual, artistic representation of microcosm.

Electron Microscopes

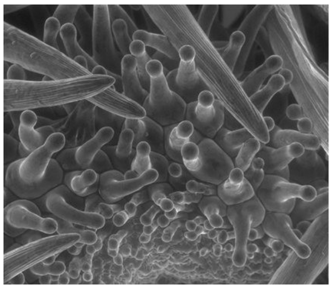
In the electron microscope the scene is illuminated by a beam of concentrated electrons. The wavelength of the electron is much smaller than that of physical light. As a result, it is able to achieve significantly greater magnification and clarity to the image of the sample than the optical microscopes. The types of microscopes are the Scanning electron microscope (SEM), that uses electrons to scan the sample and the Transmission electron microscope (TEM), that uses electrostatic and electromagnetic lenses to form a spectrum over the image, that is similar to the lenses of an optical microscope.

The power of the electric microscopes can give us access to the super micro structure of a variety of specimens from metals, minerals and other inorganic materials to biological samples, blood-cells and a multitude of microfossils, micro organisms up to their molecular structures. We should mention that in some techniques of the Scanning electron microscopy the sample is coated with an ultra thin layer of gold, so -in these cases- the sample is profoundly altered and in most cases we loose the transparency that they may have. In other cases, the sample is entered in a liquid environment and the alteration is reduced.[15] Some of the micro organisms that we will study for this essay are sampled using electron microscopes. **The most interesting function of the scanning electron microscopes for us is that they can produce micro-graphs of the sample, so in addition to the classic top down view of micro samples we can view them in an almost natural perspective view. This function is very useful for the digital creator as he can view the sample in a photographic manner and the perspective form of each object.**

15 http://www.biozentrum.unibas.ch/fileadmin/redaktion/Events_2013/Block_Course_Structural_2013/Manual_BK_Mikroskopiekurs.pdf (13-2-2016).

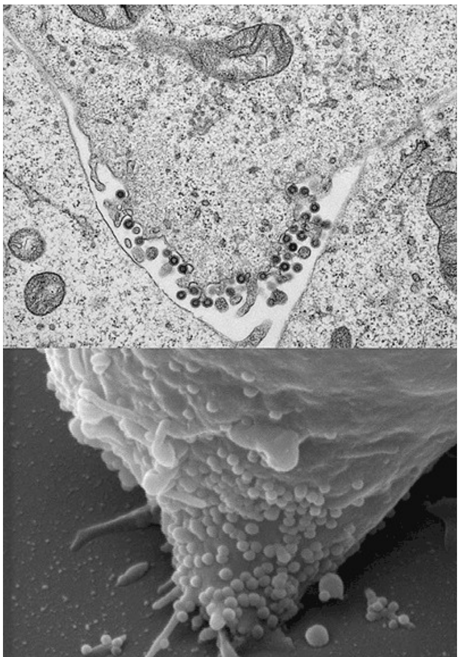


Rami R M LoucaGiant's causeway SEM micrograph of Zinc oxide micro crystals. Not enhanced in any way.



ESEM image of the surface of a flower

The images produced by electron microscopes are in the majority black and white and grey-scale. The colourisation happens afterwards by specialised software or by hand by artists but does not contain valid information about the sample. Sometimes multiple colours can be applied in secondary electron signals by assigning different colour to them, but again, this is done for structure understanding purposes and it is not valid colour information. This is a sort of **false colour technique,** which we will examine later in the macroscopic and microscopic observation similarities paragraphs.



This is a comparison of thin section transmission electron microscopy which the visual result is much closer to the optical microscopy(top) and scanning electron microscopy which gives us a perspective view closer to the classical photography aesthetic(bottom).
Both images show virus budding from mammalian cells. Image taken from http://cammer.net/historical/aif/gallery/sem/sem.htm

Scanning probe

In Scanning probe microscopy (SPM) the sample is scanned by a probe and later the microscope forms the image. It is a relatively new branch of microscopy as it first appeared in 1981, when a microscope that created visualisation of the atomic level was created. The tip of the scanning probe creates a feedback loop with the specific sample and they can create impressive results in the atomic level. The constitution of this microscope makes it in some cases even more accurate than the electronic ones. The data are collected as a grid of data point that are later visualized in the computer using another kind of false colour technique. As this microscope is mainly used in atomic level observations we will not draw reference images for the work of this project.

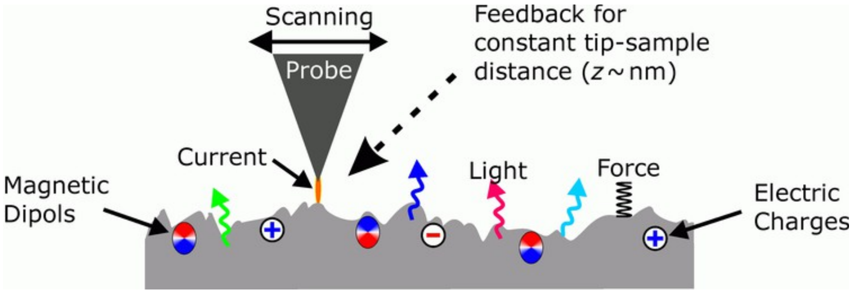


Image taken from https://www.sxm.uni-bonn.de/research/spm/scanning-probe-microscopy-spm

2.3 Stereoscopic Observation

View of Boston, c. 1860; an early stereoscopic card for viewing a scene from nature

Even though the **stereoscopic microscopes** are another type of optical microscopes we will view them in a separate paragraph as I find that in many ways it is the grand father of **virtual reality.**

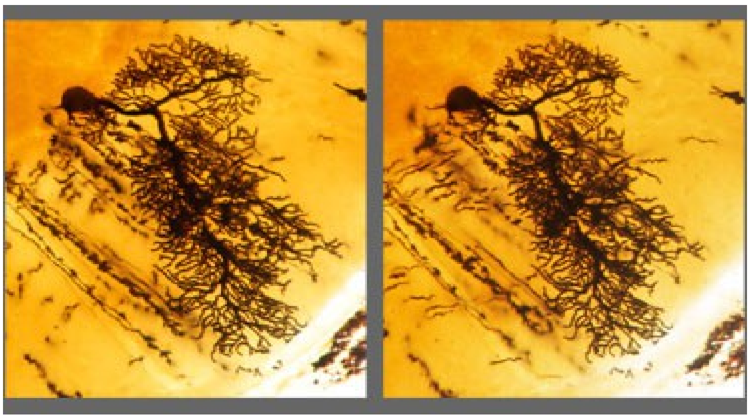
The word **stereoscopy** comes from the two Greek words στερεός (stereos), meaning "solid, concrete", and σκοπέω (skopeō), meaning "to look, to scope". Stereoscopy is a method for achieving the illusion of depth in an image by placing two slightly altered images, one to each eye, to create an illusion of three dimensional viewing. These accurately, slightly altered images are called stereo images. The pair of images that are viewed together using a stereoscope is a stereogram. The feeling of the 3d space is a perceptual illusion and it is different than the actual 3d display where we can draw information about the three dimensions by the movement of the head, as in a way is the virtual reality in our days. As we mentioned above, the stereoscopic microscope is an optical microscope, which means that the illumination is done by visible light. The magnification is usually relatively low, as the purpose is the three-dimensional observation of not too small elements. The image is created by collecting information from two different lenses with a small angle difference, that give slightly different data, one for each eye.

Stereo microscope image from http://www.microscope-detective.com/

Picture of a common moth taken with a stereomicroscope - about 15X magnification

The use of stereomicroscopy is essential for the better understanding through 3d viewing of the sample, but in many cases, it is used for interactive work with the micro sample, such as inspection of samples, micro surgery and electronic circuit board creation. The stereoscope is the basic tool of entomology as the scale of the insects allows them to be viewed through a stereoscope.

As in most of optical microscopy the importance of the illumination applies to stereo microscopy as well. The observed samples can be viewed either with reflected light or transmitted light or even both resulting to a variety in the illumination choices. The placement of the light sources is as important as in any type of microscopy.[16]



A fully focused stereo 3D image of the nerve cell

We could consider a virtual observation of a sample as the next step in stereoscopy. In the next chapter we will examine the way the tools for observation bring to our point of view these parallel universes, utilising the light behaviour and how these tools affect our aspect of the reality on these macroscopic and microscopic worlds.

16 http://www.microscope-detective.com/stereo-microscope.html#sthash.Ub7xwaf8.dpbs, (14-11-2015)

3. Behaviour Of Light
Utilising light and other techniques used for the study of worlds that differ human size

3.1 General Light Behaviour
3.2 Visualisation techniques in Microscopic and Macroscopic observation
3.3 Utilisation of the artistic qualities that derive from the microscopic and macroscopic representation.

In this chapter we examine the basic principles of light behaviour and the utilisation of it as a medium used by instruments for the observation of events in different sizes than the human scale. We will also examine other techniques used in microscopic and macroscopic studies that produce images and animation that depict these states. It must be emphasized that both microscopes and telescopes capture these images inside a certain frame, which is always the size of the viewing area of the instrument. These instruments provide to us knowledge of surface formations, mass volumes and actions by translating data into images of a certain gamma that the human eye is able to process and understand. **It is essential to study the visual product of the scoping devices by the means of the aesthetic result that they produce. Given that an actual first person encounter could not be possible in these states, both microscopic as well as macroscopic, we depend on these tools for thaw comprehension of their reality.** But before we deal with specific terminology we must have a general understanding of the basic principles of light.

3.1 General Light Behaviour

In this quest for the understanding of the principles of light that connect the optical instruments but also play a major role to any visual artist that wants to dig deeper, every research started with the duality of light.

This duality of the nature of light has always puzzled scientists and because of this duality, the great discoveries, with probably this of quantum mechanics being the most important, were made. Light possesses both the properties of a wave, as well as the ones of a particle.

In the real life scale, light passes through lenses and bounces of reflective surfaces.

Nevertheless, a wavelike theory must be used to depict fine-scale behaviour, such as interference and diffraction, that come about when light passes through petite openings or by sharp edges. The wave length and the intensity of light are not relative to the speed that it moves while, carrying energy without carrying mass.
This wave-like nature of light is the basis of physical optics and describes the interaction of light with media.
Light reflects, refracts, diffracts and undergoes interference with the exact characteristics of any other. But the probably the most obvious wave pattern of light is the Doppler effect.

And as we dig deeper to the patterns of light interaction the more we encounter the basic wave definition. The mathematical rules of reflection diffraction and refraction are all complacent with the states that light exhibits while encountering an obstacle. If the wavelength of light is larger than the obstacle it is facing diffraction will occur around the obstacle. The laws of reflection apply to light as it applies to water and sound waves. We are so used to seeing the angle that light is reflected of a flat surface and forming an image. But the law of reflection that state that the angle of the wave as it enters a flat surface equals to the angle that the wave leaves the surface are perfectly valid in the case of light reflection. All these behaviours are validated by the mathematical equations and physics principles.[17] [18]

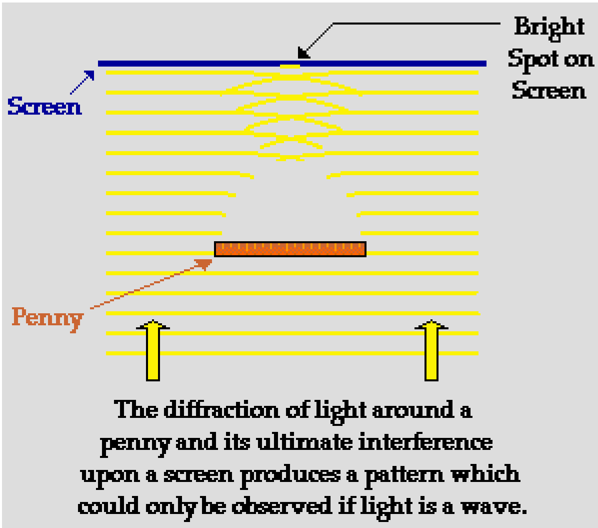


Image taken from www.physicsclassroom.com/

The wave carries light energy with it and as it moves forward it produces both an electric and a magnetic field. The complexity of the light waves consists to the factor that they are composed of mutually perpendicular electric and magnetic fields with wave motion at right angles to both fields.

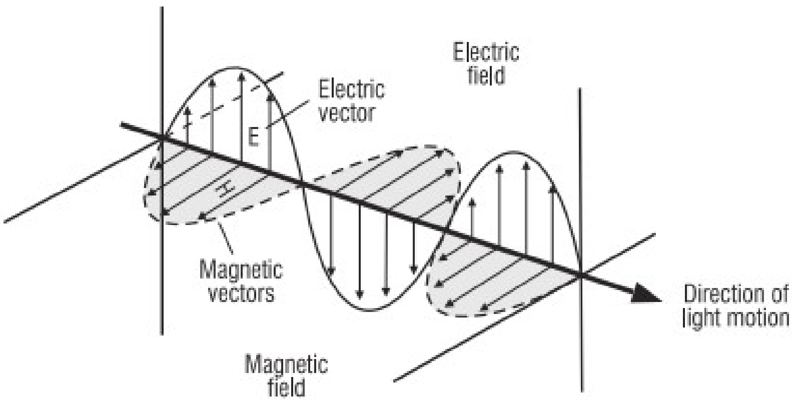


Image taken from Linda J. Vandergriff, Fundumentals of photonics

The main characteristics of electromagnetic wave behaviour are:

• Polarization

17 Mingyu Li, Wavelike Behaviors of Light, http://edla615summer.wikispaces.com/Science+Reading+2 (11-10-2015)

18 http://www.physicsclassroom.com/class/light/Lesson-1/Wavelike-Behaviors-of-Light, (12-10-2015)

• Superposition

• Reflection

• Refraction

• Diffraction

• Interference [19]

All these characteristic properties are utilized by the optical micro and macro devices but also by 3d software in order to accurately produce photorealism.

The Electromagnetic Spectrum and the Spectra of Light Sources

All electromagnetic radiation has similar wavelike properties differing only in wavelength. Electromagnetic waves range in wavelength from very long (e.g., electric power line radiation at 60 Hz) to very short (e.g., gamma ray radiation). This entire range is called the electromagnetic spectrum. The visible spectrum is only but a small part of this wide range.

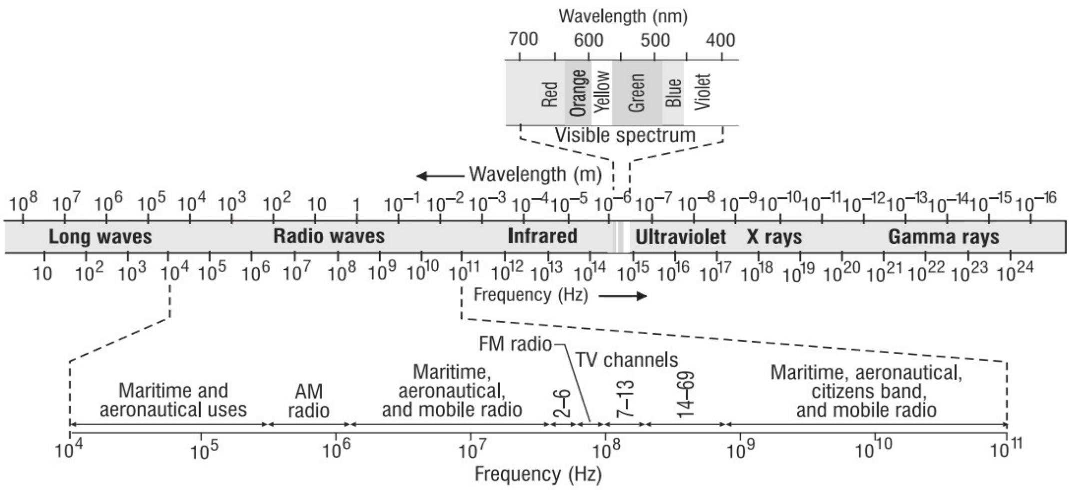


Image taken from Linda J. Vandergriff, Fundumentals of photonics

White light is a mixture of light of different colours. Each of these colours has a different wavelength and, when passed through a transparent medium, refracts differently. Thus, a prism can separate white light into its component colours.

19 Linda J. Vandergriff, Fundumentals of photonics, page 11

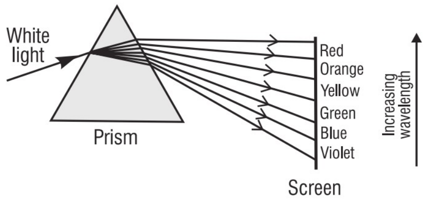


Image taken from Linda J. Vandergriff, Fundumentals of photonics

Electromagnetic radiation can either be found in natural phenomena, like the sun, the solar plexus, space and every living organism or other material that has a temperature over zero or it can be man made. Various sources of electromagnetic radiation are almost every electric and electronic device. The development of modern quantum theory was driven by the understanding that every atom and every molecule has its own spectral identity as every material that emits electromagnetic radiation has its very own "special" spectrum. This understanding led to the conclusion that every light wave that is emitted by atoms has its own wavelength and characteristics. Every time an atom or a molecule changes state or vibration it emits different light in different radiation wavelength. [20]

Interactions of Light with Matter

By the interaction of light with an object, light can be absorbed by the object and it can scatter. The absorption of light transfers energy to the atomic and molecular structure of the object. This energy can alter the state of the atoms and transform them to higher energy states by rotating and vibrating them. This transformation is depended on the previous state of the object. The level of absorption is what gives to us the understanding of colour in every object. This is called selective absorption. **For example a green apple appears green to us, as it absorbs every other colour in the spectrum and reflects back the green.** [21]

Ultraviolet, infrared, and other forms of light of the spectrum translated by the optic instruments reveal to us the hidden truths of the world, in every perceived scale. Below, we will examine the common ground of these images given to us, that a visual creator can utilize so as to recreate the vast range of actions happening to these states.

A very interesting article about the quantum behaviour of light by Marcus Woo[22]:

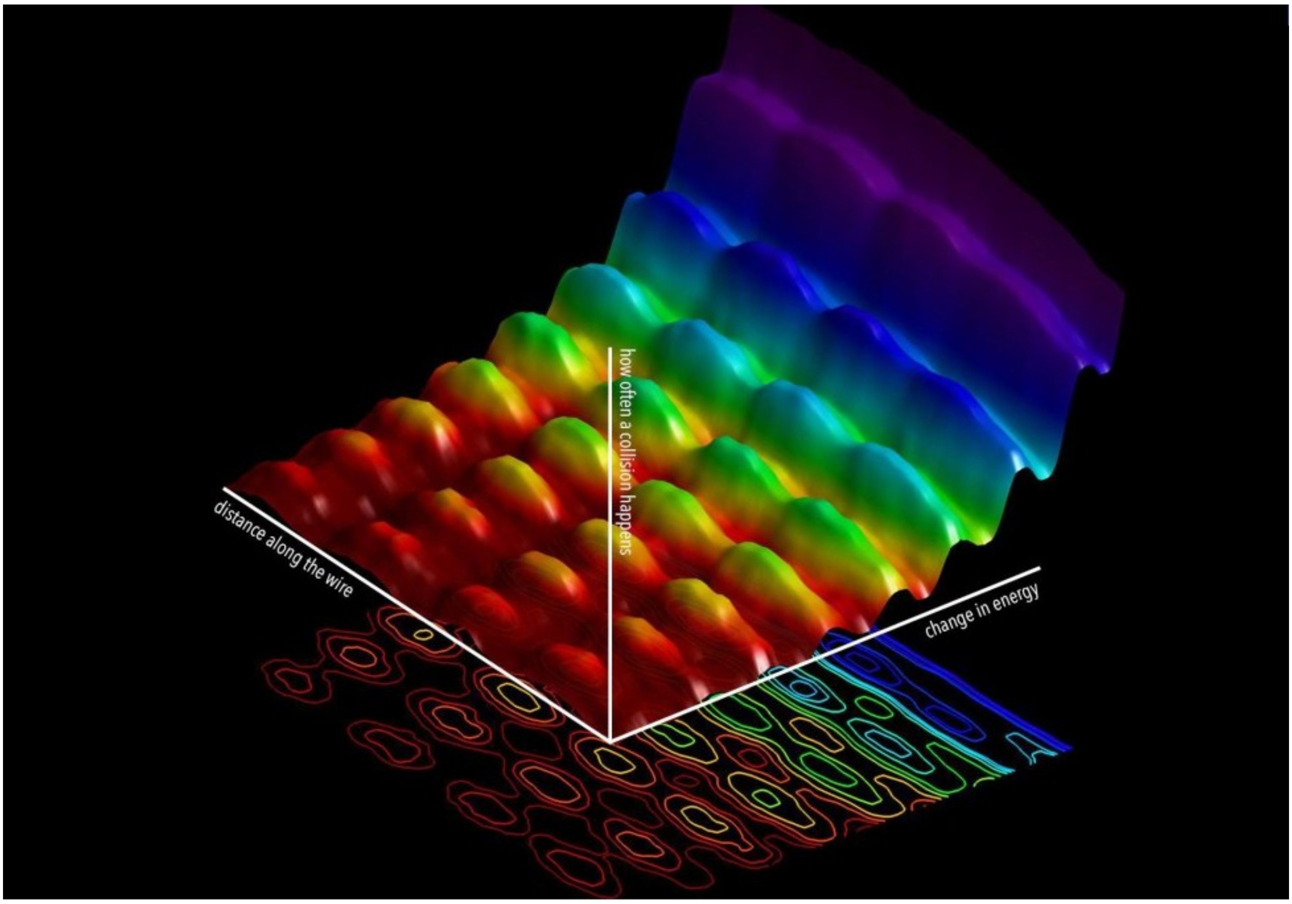
“The Weird Quantum Behavior of Light, Captured in a Lab

SUBATOMIC PARTICLES—PHOTONS, LET’S say, or electrons—sometimes also act like waves. And waves sometimes act like subatomic particles.

Other experiments have confirmed this two-faced behaviour. As far back as the 19th century,

20 Linda J. Vandergriff, Fundumentals of photonics, page 20
21 Linda J. Vandergriff, Fundumentals of photonics, page 26
22 Marcus Woo, The Weird Quantum Behavior of Light, Captured in a Lab, http://www.wired.com/2015/03/weird-quantum-behavior-light-captured-lab/, (18-11-2015).

physicists learned that if they shined a dim light—which is to say, few photons—at two super-narrow slits, a screen on the other side shows that photons go through one or the other. But crank up the amount of light, and the screen shows alternating dark and light bands, the interference patterns of waves crossing each other. The same thing works with lasers. "However, all of these experiments have exposed these two things not at the same time," says Fabrizio Carbone, a physicist at the Icole Polytechnique Fıdırale de Lausanne in Switzerland. But in the new experiment, Carbone captured both wave-like and particle-like behaviour in one shot.



The picture isn't exactly a photograph. It actually shows light trapped inside a 40-nanometer wide length of silver wire. Carbone's team blasted the wire with electrons, which means one of two things would happen: Either the light field in the wire would kick some energy into a colliding electron, speeding it up, or the electron would pump energy into the light and slow down. So the speed and location of the electrons actually tells you where the light is in the wire and whether it's taking or giving energy. So in the image, the axis pointing toward the left shows peaks and valleys of the light trapped in the wire. That's wave-like behavior. But in the axis going off to the right, you can see energy imparted to the electrons. Now, light only gains or loses energy in discrete amounts (those would be "quanta"). In light's case, that amount is a photon. Bumps along the rightward energy axis are individual packets of energy the electrons got from photons. In other words: particle-like behavior. The fact is, every object has wave-like properties—even you. From a physics perspective, you're just a big particle with a super teeny tiny wavelength. Call it 10-26 nanometers, give or take. That's too tiny to measure. But as a particle gets smaller, its wavelength gets bigger. Down at the subatomic scale, wavelengths are about the same size as the particle itself. It's a basic property of *the universe, and it's where duality comes from".* [23]

3.2 Visualisation techniques in Microscopic and Macroscopic observation

The microscopic and the macroscopic techniques make use of some light behaviours that allow us to examine the images and depictions of macroscopic scale and microscopic scale in a similar manner. The most famous compound optical instruments in science, the microscope and the telescope were invented by the Dutch in the late 16th century. The aim of this study in both of those instruments is to understand how they both take advantage of the whole electromagnetic spectrum in order to achieve the visualization of either the macrocosm either the microcosm, and to highlight the style of the resulting images.
The human eye of the 21st century human is so accustomed to the style of these images (an x-ray, an infrared image, or a UV multicolour image) that it would be almost unthinkable not to take advantage of them in an attempt to digitally create a virtual space in the microcosm. The better understanding of their creation can lead to the optimal way of utilizing these visual styles.

Basic Properties of Digital Images

Every capture of an image by an optical device may it be a camera, a microscope or a telescope creates an array of tonal or colour information that its continuity creates the visual result. All analogue devices capture the image with a vast spectrum of colour, hue, saturation, dark and light varieties that are blended uninterrupted. These type of images are referred as continuous-tone. The way to project these analog or continuous image on a computer or another digital device must be translated into a digital readable format. Whether the image is in colour or grayscale – black and white the same procedure applies.

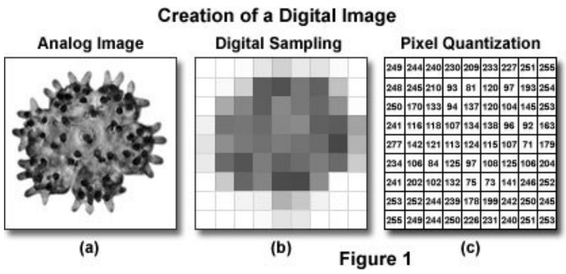


Image taken from Microscopy Research Center
http://www.olympusmicro.com/

The conversion of an analog image to digital is done by dividing the image to continuous tone segments and after assigning it an integer value. This is called **digital sampling** and pixel quantization. The two words that are important to clarify as all medium of observation are depended are intensity of the image and the brightness of it. The **intensity** refers to the amount and the quantity of light energy that is emitted into the instrument by the reflection of the imaged object . The **brightness** of the image is referred to the measured intensity that is translated and quantized by the instrument into the computer and afterwards displayed as a digital image. The importance of the image brightness is that it is the factor that can be altered to adjust the visual result of the image. After the quantisation each integer that is given to each sample represents a digital brightness value

23 Marcus Woo, The Weird Quantum Behavior of Light, Captured in a Lab, http://www.wired.com/2015/03/weird-quantum-behavior-light-captured-lab/, (18-11-2015).

of the pixel. Each device has a bit depth and the higher this is the more accurate the resulting will be. The more intermediate levers of grey the more the **dynamic range** and **bit depth** of the image will be. [24]

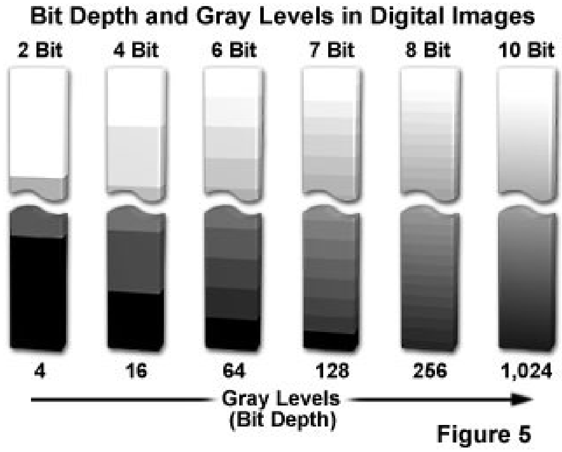


image taken from Microscopy Research Center
www.olympusmicro.com

The importance of clarifying these basic notions is important in this part of the essay as we will dive into the various details of digital imaging in order to achieve the understanding of the translation of microcosm and macrocosm to our own point of view. The next step after that is to utilise all these conclusions to any artistic configuration of a digital creation.

Microscopic and Macroscopic observation

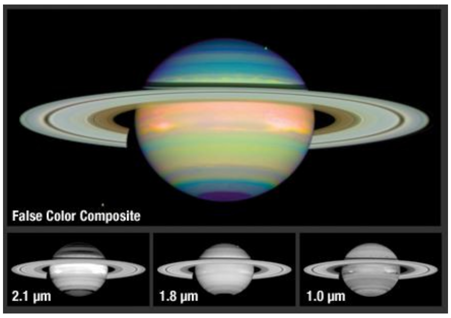
Many of the coloured images of planetary systems and microscopic systems that we are so accustomed to have nothing to do with the actual colouring that we would perceive if we were to see them in a first person observation. Yet in our understanding these coloured images are imprinted as the "actual and natural state of them.

False Colour, Representative Colour, And Composite Images

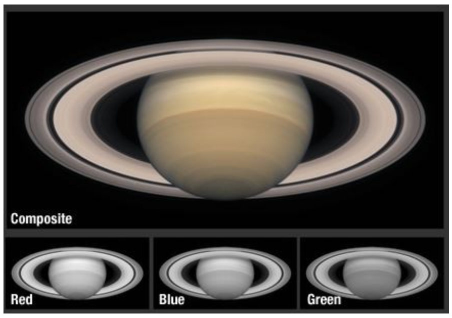
As we are informed at the Nasa Reasearch Center site missionscience.nasa.gov **false color**, or **representative colour**, is the way to create images from data of the electromagnetic spectrum that exceed the visible light values. This is used to capture data that are beyond our eye percieving capabilities. We encountered before the term false colour in the examination of the imaging of microscopes.
On the other side the satelite images that are sent to us from the Satelites collect data from the visible part of the spectrum with values of red, green and blue and combine them to create the true, **natural colour** that we would see I we observed the same scene from the space ship. In the images below we see a natural colour image and an image of Saturn taken using **infrared wavelength** of the electromagnetic spectrum. **This is a false colour image that reveals textures and alterations we would not be able to see in any other case.** [25]

25 http://missionscience.nasa.gov/ems/04_energytoimage.html, (20-11-2015)

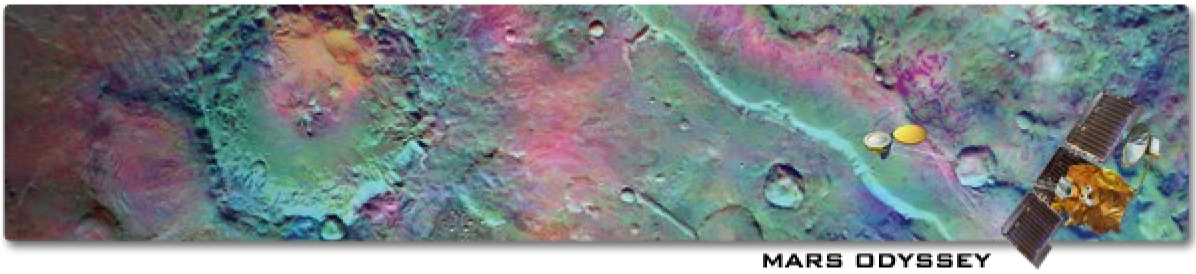
24 Basic Properties of Digital Images, http://www.olympusmicro.com/primer/digitalimaging/digitalimagebasics.html, (18-11-2015)



False colour image Credit: NASA/JPL/STScI



Natural colour image Credit: NASA and The Hubble Heritage Team



The soil of Mars

Thermal Emission Imaging System (THEMIS) provides us with this infrared image shows us the composition of minerals in the surface of Mars Image taken from http://missionscience.nasa.gov/ems/04_energytoimage.html

Credit: NASA, ESA, CXC, JPL, Caltech and STScI

The image on the right of the page shows us the galaxy Messier 101 and it is a combination of infrared, visible and x-ray light taken from three different space telescopes. It is a **Composite Image**. The red is the infrared, the yellow the visible and the blue the x-ray light.[26]

The red shows the heat emitted from the stars, the yellow shows dust and the blue gas, dead stars and material affected by the black holes.

The amazing thing in this image is that provides the viewer with "ultra vision" as it reveals multiple hidden materials and energies all at once.

26 http://missionscience.nasa.gov/ems/04_energytoimage.html, (20-11-2015)

Such composite images are available also in the microcosm, but in the end of the microscopic and macroscopic study we will see how they can be utilised as an educational tool in a virtual reality representation.

The utilisation of waves in the electromagnetic spectrum by optical devices

As we saw in the above paragraphs the electromagnetic spectrum is the key for the revealing of the hidden formations. Lets see more specifically, what each one reveals and how can a visual artist and creator utilize them.

Radio waves length begin from a football and reach further than the diameter of our planet as they are the longest waves of the electromagnetic spectrum. They reveal to us pulsars, quasars and supernova remains of the universe. If we were to look at the night sky with radio wave vision the

Credit: VLA & NRAO, Farhad Yusef-Zedeh et al. Northwestern

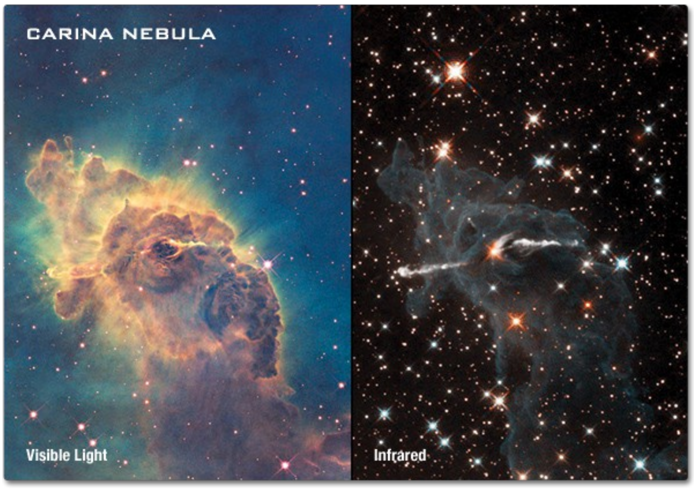
sight would be really different. In the picture above we see the data that are collected from the space telescopes using radio waves.[27]

In **acoustic microscopy** we utilize high frequency ultrasounds to penetrate solid materials and reveal cracks and deformations in their constitution as quality check.

Three different pictures of the surface of the Earth using microwaves. Image taken from http://missionscience.nasa.gov/ems/05_radiowaves.html

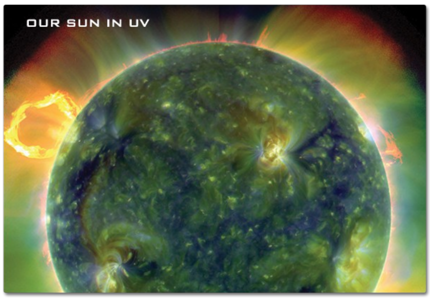
Microwaves are used by scientists to provide information about the Earth's surface as the are known to penetrate dust, smoke, rain, clouds and in general everything with low density. Different kind of microwaves penetrate materials with different density.

27 http://missionscience.nasa.gov/ems/05_radiowaves.html, (19-11-2015)



Credit: NASA, ESA, and the Hubble SM4 ERO Team

Infrared microscopy is a technique that is used for research on minerals and dive into the microscopic structure of the crystals. **It is called infrared spectroscopy**.

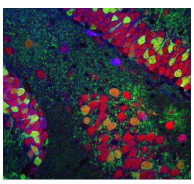


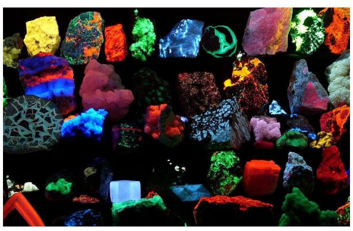
Credit: Image is courtesy of: NASA/SDO/AIA

UV light or Ultraviolet light is utilised vastly in microscopy as well as in macroscopy and it provides us with some of the most amazing impressive images. First we will examine the use of UV light in the observation of space and then in the observation of the microcosm.

UV light is visible to insects and other creatures of the microcosm. The spectrum of the sun provides us with the full spectrum of UV radiation, which we cannot see as it is mainly absorbed by ozone in the atmosphere. **Ultraviolet microscopy** is associated with florescent microscopy which can provide to us great analyses in the examined images due to the short wavelength of the ultraviolet light. UV light is ever-present in the microcosm as birds, reptiles, bees and various insects can see ultraviolet light. Some minerals are known to produce florescent colours under ultraviolet light.

Here we see a series of images that use UV light to cause florescence. The most interesting thing with these images is the colour pallete that they provide as this visual style could be used in the 3d digital creation to indicate different material constitution.





X-Rays are utilised by telescopes to collect photons from any part of the sky. These photons are processed by a detector and can provide with information about temperature masses and far away celestial worlds. Also gasses in the universe produce x-rays and are the way to trace masses of gas in space. The first composite image, that we saw above, contained samples of those observed gasses. In microscopy, x-rays are used to observe the mass and the density of the objects as they are known to penetrate at some extent most of the known materials. Also x-ray samples need no preparation so they can be used in many cases instead of electrons. X-rays can cause florescence to many minerals so it can be used to examine their constitution.

3.3 Utilisation of the artistic qualities that derive from the microscopic and macroscopic representation.

Now that we have a better understanding of the function of waves in the optical tools is the time to view the different visual styles of the methods we saw earlier.

In the following images taken from the site of Olympus Microscopy, we will see the different visual styles that some methods of microscopy has to offer.

Brightfield Illumination

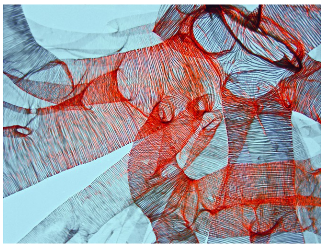


Image by Michael Gibson

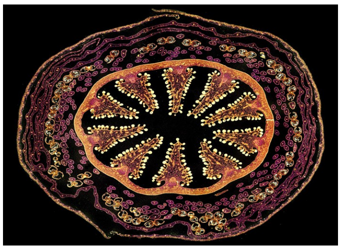


Image by Harold Taylor

Stereomicroscopy

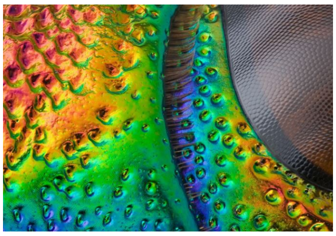


Image by Charles Krebs

Image by Dr. Csaba Pintér

Polarized Light

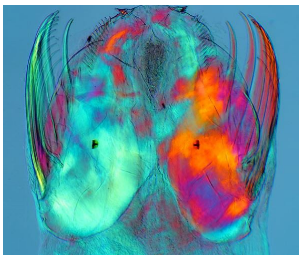


Image by David Walker

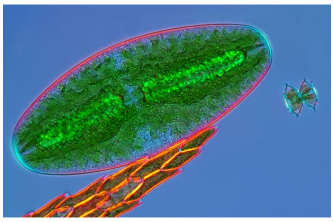


Image by Marek Miś

Florescence

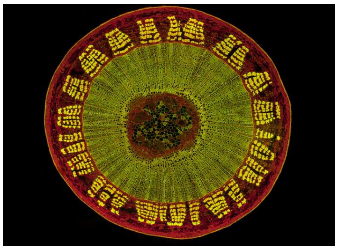


Image by Nathan Pallace

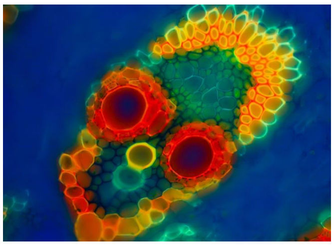


Image by Gerd A. Günther

This comparative study between the macroscopic and microscopic observation provides us with some very valuable elements that could help us decide about the artistic and visual depiction of a virtual take on the elements of the microcosmos.

The conclusion of this section of the research is that the image that we have on these worlds depends entirely on the medium on which we study them. We are used to viewing the microscopic and macroscopic reality with colours and tone that would differ from an eventual first person viewing. So the visual style that in my opinion should define a virtual application that would take advantage of all the above qualities is the one that would simulate a composite image.

For example:

The use of x ray vision for the indication of mass

The use of infrared vision for indication of energy.

As we saw above a compount image can provide to the viewer an **ultra vision** that can show at the same time information about **heat, density, energy and material constitution.** This, in a virtual reality educational application would be visually impressive but it could also provide very useful information about the world around us and reveal visualization of patterns and relationships, of energy and materials that are present in the world around us. The use of these images can serve as a helpful research and reference tool. In the terms of 3d visual creation, they could also be used as textures in the models of the microcosm. The vivid colours that in a real world scale would be strange to see, in a miniature world are dominant and should be used fearlessly, as the inhabitants of these mini worlds visualise their world in infrared, UV and microwaves. **Why should we not try to visually recreate a vivid and colourful gamma in the Virtual space, containing information that our perception has never had the chance to visualize in reality?**

4. The Elements that constitute the microscopic environment

4.1 Fractals – Patterns in microcosmos and their omnipotent presence
4.2 Fractal structure in the particles
4.3 The Inhabitants – Study of form, of structural and behavioural patterns, of movement - The Tardigrade - The Mite

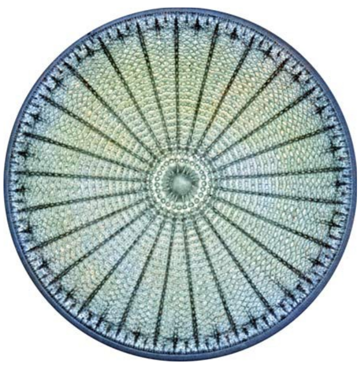
So far we have examined the ways and the methods of studying the microcosm and the visual and artistic style that could be derived from these methods. In the following paragraphs we will examine the content of the microcosm that we choose to include to the Virtual Reality application. Firstly we will examine the background landscape that mainly consists of forms and patterns that we encounter in fractals. We will try to underline the similarities of fractals with the structure of forms in microcosm and finally we will examine the living organisms that will appear in the VR application.

4.1 Fractals
Patterns in microcosmos and their omnipotent presence

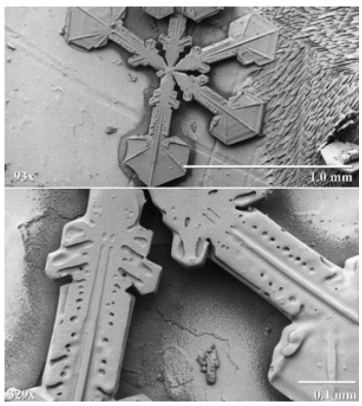
Fractals, otherwise known as the patterns of chaos, are patterns formed from chaotic equations and contain self-similar patterns of complexity that increase with magnification. The fact that the division of a fractal pattern into parts produces a nearly identical reduced-size copy of the whole makes fractals the perfect example to verify our first definition of microcosm, as a small world inside another world. Patterns in nature are visible regularities of form, recur in different contexts and can sometimes be modelled mathematically. Natural patterns include symmetries, spirals, meanders, waves, tessellations, cracks and stripes.[28] The same patterns are found in the microscopic world. We will examine some of these patterns more closely as the use of them and their recreation with digital 3d tools could provide us with an accurate visualisation of the microcosm.

Symmetries

Symmetry is overwhelmingly present in living things. Bilateral or mirror symmetry is found in the animal kingdom, and it is also found in leaves of plants and some flowers such as orchids.[29] Plants often have radial or rotational symmetry, which is also found in marine life. Fivefold symmetry is found in also many forms of marine life like starfish, sea urchins, and sea lilies.[30] Six fold symmetry is most often found in inanimate things, with the most striking example this, of the snowflake as in the process of crystallization, almost instantly six identical arms are created with the exact same pattern.[31] The symmetries in crystals can be cubic or octahedral but in a strange way a true crystal cannot have fivefold symmetries. Symmetrical patterns are also typical in diatoms, a type of algae, and are the most commonly found phytoplankton under the microscope.



Radial Symmerty of diatoms. Image taken from http://www.britannica.com/

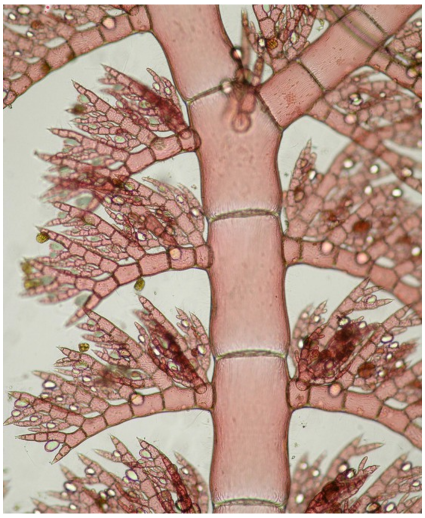


Snow crystal symmetry magnification. Image taken from http://epod.usra.edu/

28 Stevens, Peter. Patterns in Nature, 1974. Page 3
29 Stewart, Ian. 2001. Pages 48-49
30 Stewart, Ian. 2001. Pages 64-65
31 Stewart, Ian. 2001. Pages 82-84

Trees

Trees are natural fractals, and have several patterns that repeat continually smaller copies of themselves. They are a copy of the one that came before it from trunk to tip and on each branch. Fern-like growth patterns occur in plants and in animals including leafs, crystals, the structure of corals, hydrozoa like the air fern, Pterothamnion plumula, and in non-living things, formations of rivers, energy paths, that are found in electrical discharges. Lindenmayer system fractals are the prefect tool to for modelling patterns of this kind of fractal growth by varying the branching angle, the distance between points from branch to branch, and number of branches per branch point.[32] Typical L systems can be found in almost every type of algea and moss formations under a



Pterothamnion plumula (J.Ellis) Nägeli (Image Ref. 12713)microscope, Spain, Galicia, Lugo, San Ciprián, 2006; main axis© Ignacio Bárbara (barbara@udc.es)

microscope.

Spirals

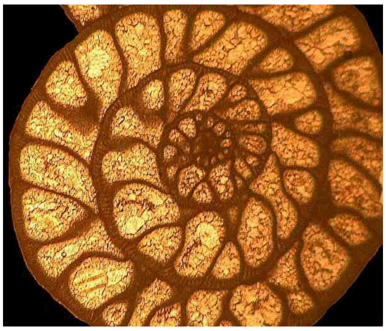
The self-similar spiral curve which often appears in nature is called a logarithmical spiral. Jacob Bernoulli called it the marvellous spiral as he was amazed by its property to increase its size but to keep its shape unaltered in each successive curve. The logarithmic spiral must not be confused with the Archimedean spiral as in the logarithmic spiral that the distances between the turnings of a logarithmic spiral increase in geometric progression, while in an Archimedean spiral these spacings are invariable. The same formations, such as the Fibonacci Spiral, shown below, are found in both the macro universe as well as on the micro and sub-atomic level.[33] From the point of view of physics, spirals are lowest-energy configurations which emerge spontaneously through self-organizing processes in dynamic systems. [34]This pattern can be seen in plant growth, in geological and meteorological phenomena and in numerous microscopic organisms and organic formations. Numerous fossils are found throughout the world bearing the exact same pattern.

32 Rozenberg, Grzegorz; Salomaa, Arto. The mathematical theory of L systems. Academic Press, New York, 1980

33 Livio, Mario (2002). The Golden Ratio: The Story of Phi, The World's Most Astonishing Number. New York: Broadway Books.

34 Douady, S; Couder, Y. (March 1992). "Phyllotaxis as a physical self-organized growth process". Physical Review Letters 68 (13): 2098–2101.

Part of an Anglerfish ovary. Entries to the Nikon Small World competition



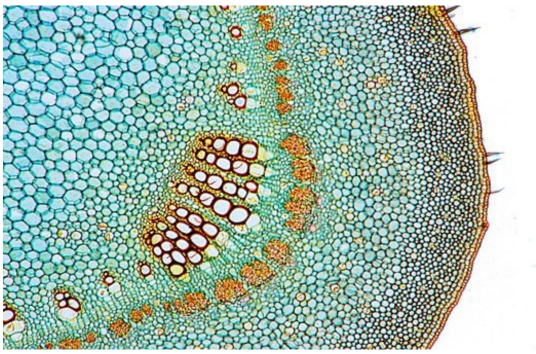
Vitamin C crystal. Image taken from www.microscopy-uk.org.uk/

Chaos, foams

Chaos theory describes the interaction that can occur between two seemingly independent systems, if the initial state of one of the two is altered.
In mathematics, a dynamical system is chaotic if it is (highly) irritable to initial states, which requires the mathematical properties of topological combination and concentrated periodic orbits. Alongside fractals, chaos theory ranks as a fundamentally universal influence on patterns in nature. Some cellular automata, simple sets of mathematical rules that give patterns, manifest evident chaotic behaviour.

Plateau's laws depicts the constitution of soap films. Joseph Plateau generated those laws from his experimental observations in the 19th century. Many patterns in nature are based on foams obeying these laws. [35]The flowing pictures are cross sections of cells which show foam patterns as well as cellular automata behaviours.

Dicot Root Cross Section



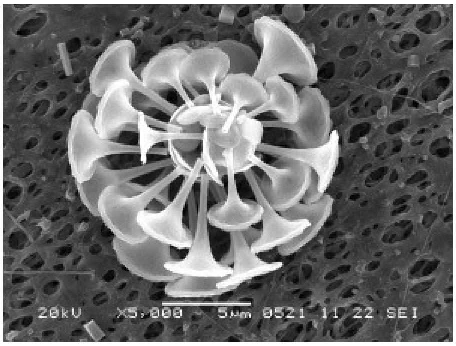
Ficus stem cross-section

4.2. Fractal structure in the particles

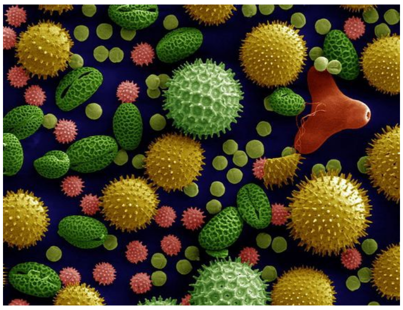
The microscopic particles that float in the empty space of the micro verse have characteristics of

35 Ball, 2009. pp. 66–71, 97–98, 291–2

fractal structure and are morphological very similar to the 3d representations of the **Mandelbulb**, which is the 3d version of the most famous fractal equation, the 2D Mandelbrot set, named after the mathematician Benoîst Mandelbrot of Yale University, who gave the name “fractals” to the resulting shapes in 1975. Here we see pictures of these particles of pollen, of protozoa, diatoms, radolarians and other microfossils with their evident fractal-like structure.

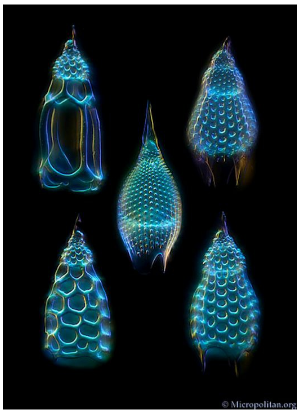


Diatoms as seen through a scanning electron microscope.Photo Credit: Dr. Jim Nienow and The Deep C Consortium

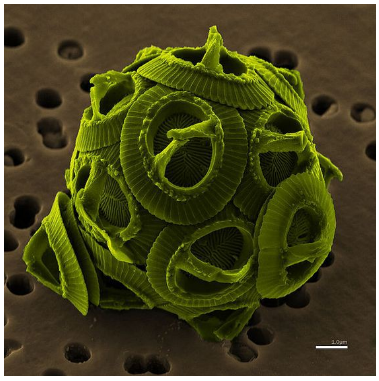


Pollen from sunflower, morning glory, lily and castor bean magnified some 500 x by Dartmouth Electron Microscope Facility and colorized by William Crochot

Scanning electron micrograph of a species of Parmales. Photo: AAD Electron Microscope Unit

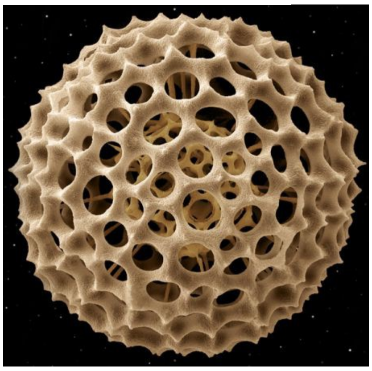


Radolarians. Image taken from microscopy-uk.org.uk

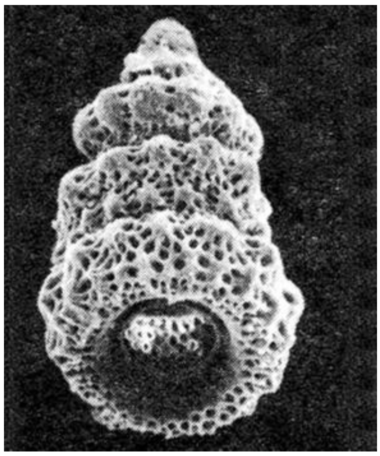


A single celled algae.

Lysandra bellargus egg. Image taken from http://www.micronaut.ch



Fossilised Radolarian. Image taken from linearphotography.com



Fossilised Radolarian. Image taken from http://geomaps.wr.usgs.gov/

Here we see a visualisation from the 3d software **mandelbulb 3d** which we will examine in later chapter as to how it can be used to reproduce these intricate patterns of the particles in the microverse.

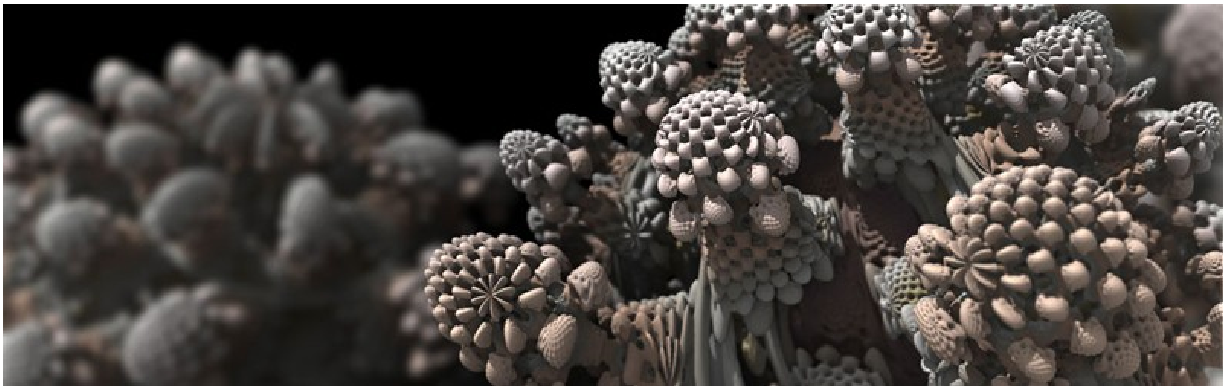
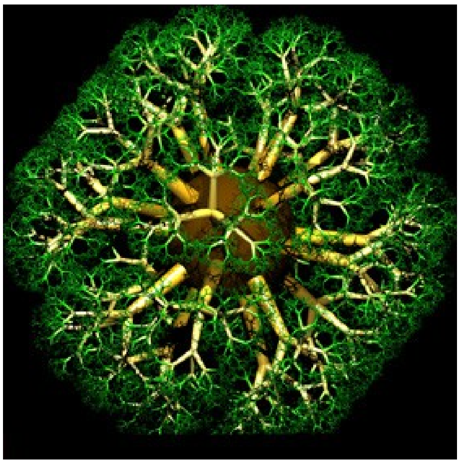
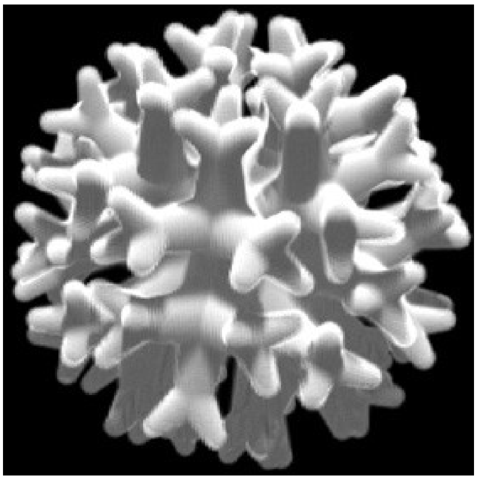
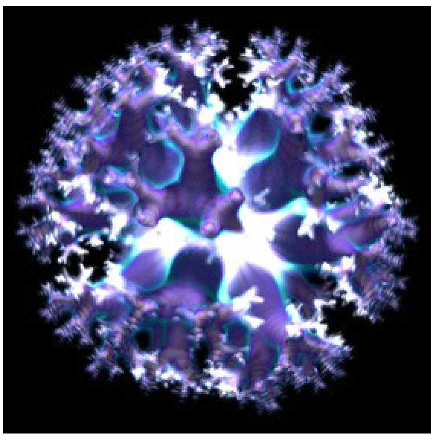
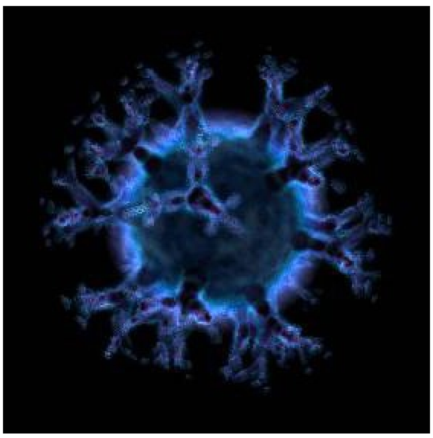


Image taken from http://mandelbulb.com/

Some more computer generated images that bear amazing resemblance to the actual microparticles.
These 3d trees are found in Paul Nynanders site http://www.bugman123.com/
They are cloud-like 3D tree fractals were rendered using a volumetric technique.

4.3 The Inhabitants – Study of form, of structural and behavioural patterns, of movement -
The Tardigrade - The Mite

In this part we will examine the lifeforms that appear on the virtual application. We will examine the form and the patterns that are useful for a faithful digital reproduction of them.

The Tardigrade

Image taken from http://www.dailymail.co.uk/

In this colorized electron micrograph (EM), which has the feel of a museum diorama, a tardigrade emerges from under a moss leaf to hunt for food or a companion. EMs are produced by layering a molecular film of metal on a sample. The technology gives a false sense of the "hide" of this tardigrade. In actuality, tardigrades are translucent and display a variety of colours—white, green, orange, red. In the microenvironments made by water that coheres in the fissures of mosses and lichens due to surface tension, tardigrades thrive by feeding on smaller organisms and by sucking contents out of plant cells. Their moist realm is transient, and in response tardigrades have evolved an array of strategies based on induced cryptobiosis—the suspension of metabolism by drying or freezing. In their cryptobiotic state, desiccated or frozen, they are astonishingly durable. These organisms survive extreme conditions—of temperature, pressure and radiation—to a degree unparalleled in nature.
Eye of Science/Photo Researchers. image and text from http://www.americanscientist.org/

My interest in this animal first emerged when I read an article about how the tardigrade, otherwise known as the water bear, was the first animal to survive in deep space conditions. Tardigrades (Latin: Tardigrada) are microscopic animals (their body size varies from 0.05 to 1.2 mm). They are considered as one of the invertebrate Phyla (that means they are not insects, mites or crustaceans, they are just tardigrades). There are over a 1000 described species so far, however it is estimated that the total number of tardigrade species may exceed ten times as many. The evolutionary history of tardigrades is mostly a mystery. Their bodies are tiny and soft, they do not fossilise easily and finding any fossils is very rare. However, both molecular and traditional taxonomy suggests that they are most related either to Arthropods or Nematodes. The oldest known fossil is half a billion years ago.[36]

Their anatomy and physiology is similar to that of larger animals, including a full alimentary canal and digestive system. Mouth parts and a sucking pharynx lead to an esophagus, stomach, intestine and anus. Tardigrades have a dorsal brain atop a paired ventral nervous system. (Humans have a dorsal brain and a single dorsal nervous system.). [37] [38]

Tardigrades are able to survive in extreme environments that would kill almost any other animal, including harsh temperatures, pressure, dehydration, radiation and toxins. In 2007, a tardigrade became the first animal to survive exposure to space. It prevailed over sub-zero temperatures, unrelenting solar winds and an oxygen-deprived space vacuum.

Tardigrades earned the " hardiest animal on earth" tag having evolved elaborate dormancy strategies that allow them to shut down all but the essential biological processes when conditions are not conducive to supporting life.[39] [40] [41]

Tardigrades earned the "hardiest animal on earth" tag having evolved elaborate dormancy strategies that allow them to shut down all but the essential biological processes when conditions are not conducive to supporting life.

In the following pictures we see some types of tardigrade eggs. We can notice the 3d fractal resembling form of the eggs.

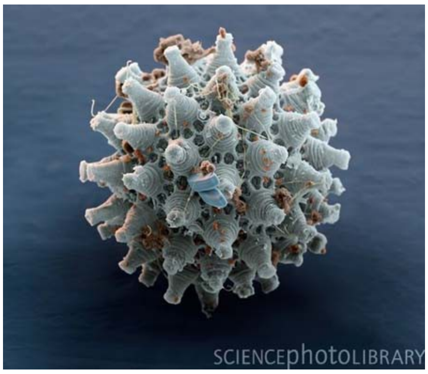


Image taken from EYE OF SCIENCE/SCIENCE PHOTO LIBRARY

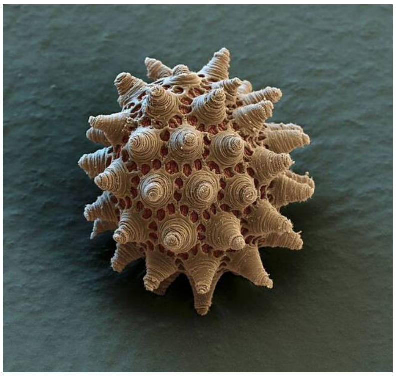


Image taken from http://funytrack.blogspot.gr/

36 Andrea Gagyi – Palfi, Larentiu C. Stoyan,A short review on tardigrades – some lesser known taxa of polyextremophilic invertebrates. P22

37 Lukasz Michalczyk ,"What are those... tardigrades???" ,http://www.tardigrada.net/ (2-1-2016)

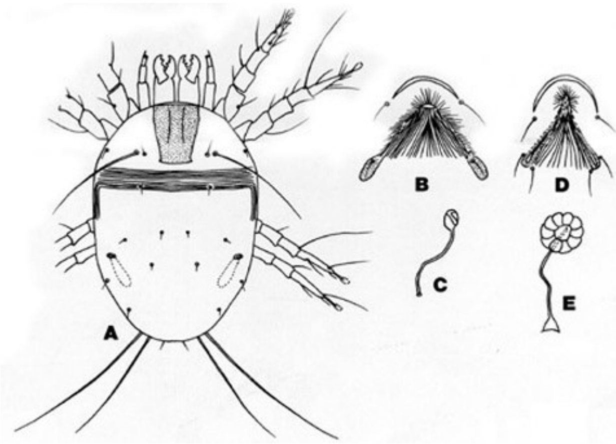
38 William R. Miller , "Tardigrades", http://www.americanscientist.org/ (14-11-2015)

39 Lukasz Michalczyk ,"What are those... tardigrades???" ,http://www.tardigrada.net/ (2-1-2016)

40 William R. Miller , "Tardigrades", http://www.americanscientist.org/ (14-11-2015)

41 Emma Brennand , "Tardigrades: Water bears in space",http://www.bbc.co.uk/ (7-11-2015)

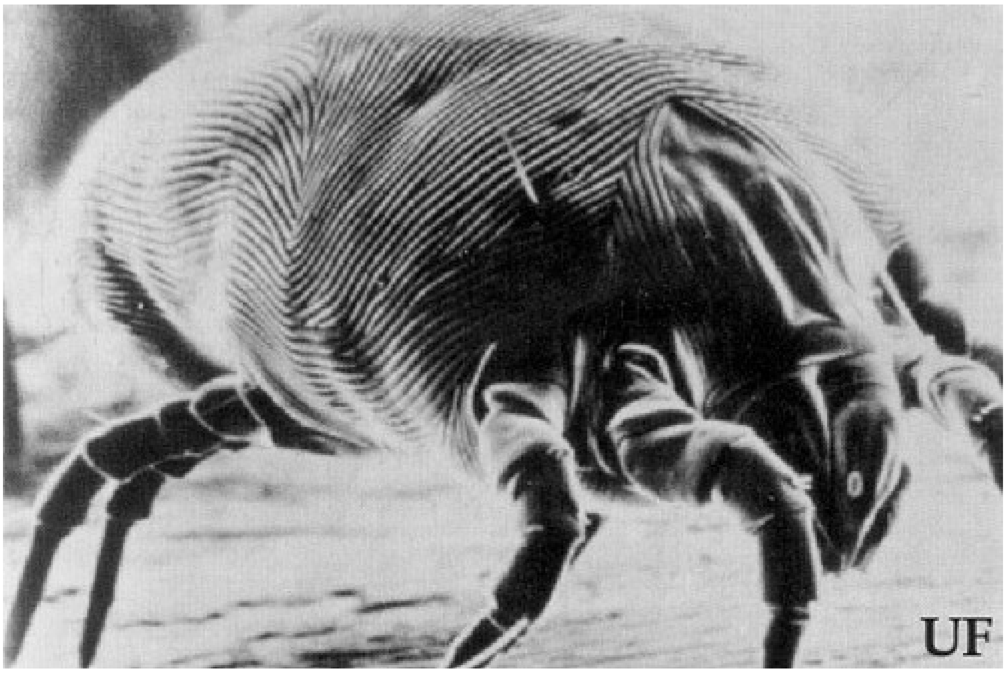
The mite



Dermatophagoides spp. A) Dorsum of Dermatophagoides farinae Hughes. B) Female genital opening. C) Bursa copulatrix and seminal receptacle D) D. pteronyssinus (Trouessart) female genital opening. E) Bursa copulatrix and seminal receptacle. Graphic by Division of Plant Industry. image takem from http://entomology.ifas.ufl.edu/

The second inhabitant of the microcosm that will occupy our attention is the mite. There is a multitude of mites but the ones that we will occupy our attention are the house dust mite and the water mite.

The house dust mite (HDM) lives in human habitation. Dust mites feed on organic waste, such as flakes of shed human skin, and flourish in the stable environment of dwellings. House dust mites are a common cause of asthma and allergic symptoms worldwide. The mite's gut contains potent digestive enzymes that persist in their faeces and are major inducers of allergic reactions such as wheezing. Unlike scabies mites or skin follicle mites, house dust mites do not burrow under the skin and are not parasitic. [42]

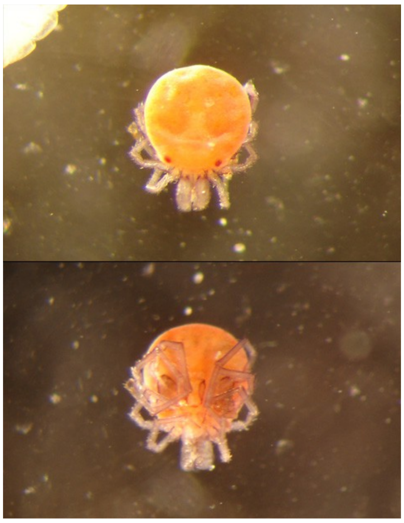


Scanning electron micrograph of a female house dust mite, Dermatophagoides farinae Hughes, approximately 2000X magnification. Photograph by G.W. Wharton.

House dust mites, due to their very small size and translucent bodies, are barely visible to the unaided eye. Both male and female adult house dust mites are globular in shape, creamy white and have a striated cuticle. The female measure approximately 420 microns in length and 320 microns in width. The male is approximately 420 microns long and 245 microns wide. A pair of suckers on

42 Barb Ogg. "Managing House Dust Mites". University of Nebraska-Lincoln. http://lancaster.unl.edu/(9-11-2015)

the ventral posterior idiosoma of the male is used to grasp the female during copulation.[43]
We will use the water mite to study it aquatic characteristics and its parasitic nature.



A fresh-water mite (Hydrachnidia), Sperchon sp.; 0,7 mm in diameter. Image taken from https://en.wikipedia.org

They parasite and lay eggs inside stone moss and plant tissue. They swim to the surface of the water after hatching and seek a living animal, usually insects to host. They usually begin to parasitize upon encounter. They are found in lakes, swamps in great variety. Not so much in salt water. They are often hidden in vegetation or under the gravel or mud of the water bed. They change colour in order not to reveal their parasitic nature.

CHAPTER 2

Description of the creative process of implementing the virtual world

A. Modelling the microcosm

1. The Micro organisms

1.1 Modelling and texturing software
- Description of the process
1.2 Rigging, Skinning, Animation software
- Description of the process

In this chapter we will describe the workflow pipeline that I used to create the low poly models that are used in the interactive application. We will describe the software for modelling and texturing and the way it was used in order to produce accurate models.

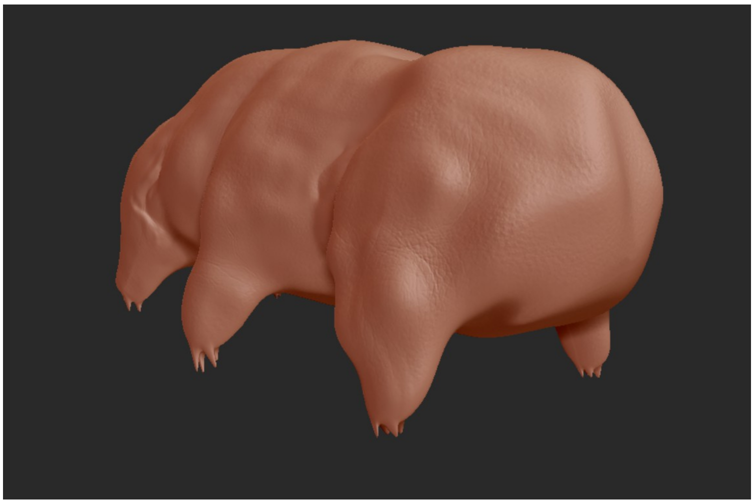
43 http://entomology.ifas.ufl.edu/creatures/urban/house_dust_mite.html (14-11-2015)

1.1 Modelling and texturing software
- Description of the process

The software that was used for modelling and texturing is **Pixologic's Zbrush 4R6** and for the adjustment of the low poly model I used **Autodesk's 3ds Max 2015**. For the preparation of the texture images I used **Adobe Photoshop CS3**.

I will describe the process for the two main models of a Tardigrade and a Mite. The steps that are used are identical and we will examine with detail every step of the process.

Here we see the finished high poly models made on Zbrush.

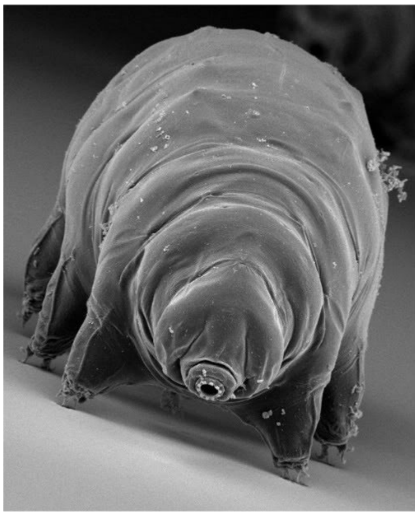


Model of the Water Bear or Tardigrade

Model of the Dust Mite

Step no1
Reference Images

This step is very important for the modelling process because the choice of the reference image will be the defining factor for the final form of the 3d model. I chose two images for my main references for each of the micro animals. It is important for the reference image to have good quality so we can be able to find details that will give to our model a more realistic feel. These images are all taken from an **electron microscope** and the ones in colour were coloured with **false colour** technique. The choice of these images was made due to the fact that the electron microscope images give a **feel of directed image,** as this conclusion derives from our research in the first chapter. Although the specimens are covered in the gold coating that we saw earlier, the are much more familiar to our own eyes than a top down, transmission image or an image from an optical microscope. We can see the perceptive of the image. The gamma and the brightness add to the scanning electron microscope pictures the air of **"old Black and White" portrait** photography. The mites and the tardigrates have motion to their posture, which is very helpful for images that are to be used for reference.



I also find very helpful to make some **rough sketches** of the models as to better understand the structure and also to point out the most interesting parts of the forms. I keep a multitude of more images to consult in case we have to clarify something that is not clear in our main images.

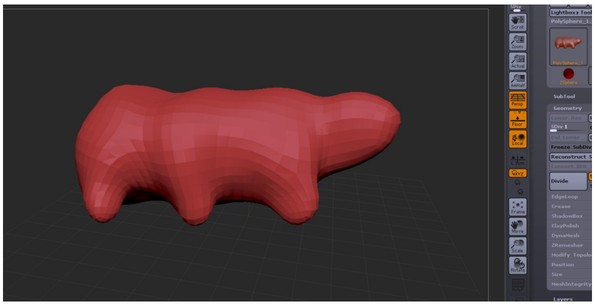
Step no2
Dynamesh modelling in Zbrush

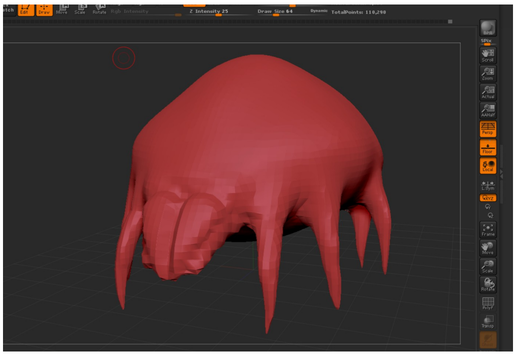
One of the most important reasons for choosing Zbrush is the ability to control the topology of the model by using **DynaMesh.** This powerful tool allows us to sculpt the model without worrying about the uneven topology of the vertices. DynaMesh is a perfect solution for free-form sculpting because it removes all need for focusing on topological constraints. It's possible to change the overall shape of any DynaMesh by pushing or pulling, adding various pieces of geometry to combine into one, or even removing geometry in a manner similar to what you can do with Boolean operations.
Every time we render the geometry with DynaMesh, ZBrush will only adjust the surface that has

been edited. This means that areas that already had nice polygon distribution will keep them even, after the re-topology operation.

All DynaMesh commands and options are located in the **Tool > Geometry** sub-palette.

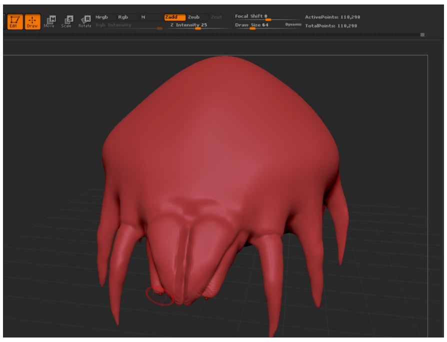
The first stages of sculpting is to try to achieve an average shape volume in low poly without worrying about the detail.



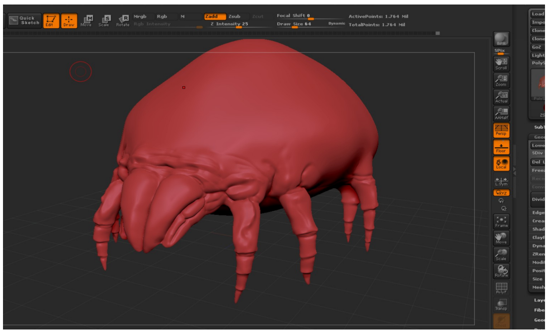


Step no3
From low-poly to high-poly
Adding details - Polypainting

After creating the desired form we add more subdivisions to the model in order to achieve the finer details.



In the following pictures we move from 110.000 vertices to 1,7 million.



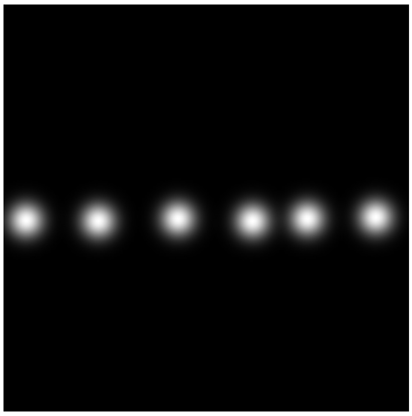
Now the number of polygons is sufficient for us to sculpt the desired details. The dents and the caves are characteristic of an area that resembles the shell of oyster, shrimp or a beetle. The characteristic waves in the back of the mite will be created with the use of a custom **alpha brush.**

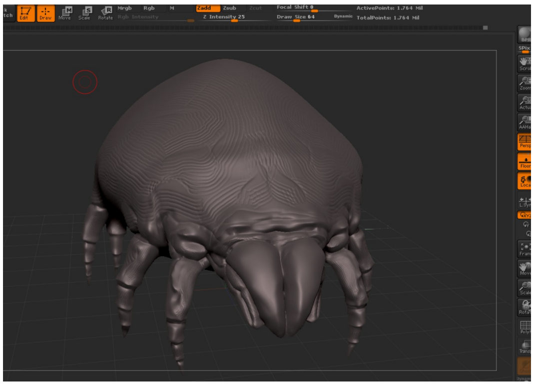
The **Alpha palette** contains a variety of gray-scale images known as Alphas. These images look like nautical depth soundings used to map the ocean floor — nearer portions are lighter, more distant portions are darker.
When used with painting tools, Alphas determine the shape of the brush being used.
When used with 3D objects, Alphas can be used to sculpt the objects in unique ways, or as displacement maps.
Alphas can be added to this palette by importing images from disk files, or by grabbing depth information from the canvas (using the MRGBZGrabber Tool). We can export any Alpha as an image file, in various formats.

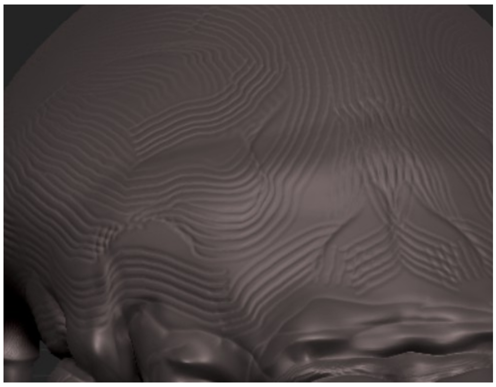
Unlike standard 8-bit gray-scale images which contain 256 gray levels, ZBrush-generated Alphas are 16-bit images which contain over 65,000 gray levels.
Alphas can also be converted to Stencils, Textures, or even 3D meshes. They can also be modified using the Alpha Adjust curve.

We use a custom brush that we made in adobe Photoshop and we saved it as psd in order to contain an alpha layer.

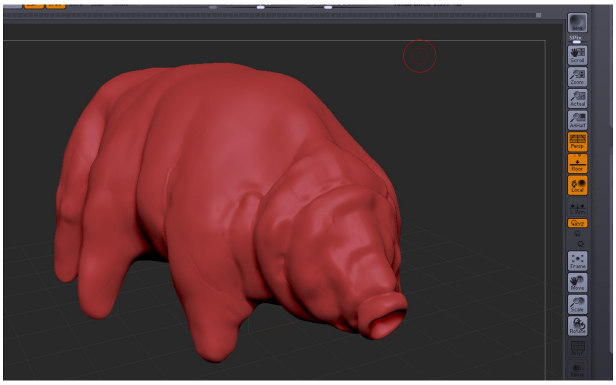
The dots that we use as brush are not perfectly aligned as we try to avoid a completely symmetrical effect. Again for the pattern on the back of the mite it is best to view multiple reference images.

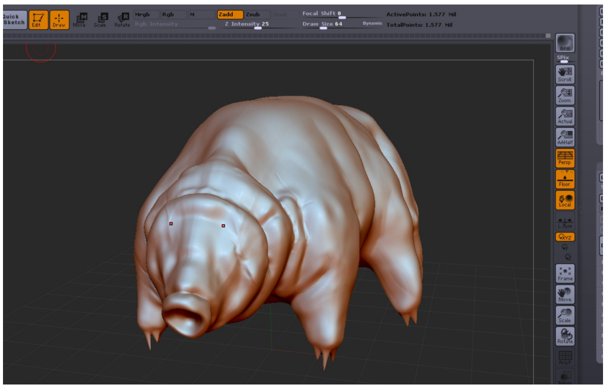






We do the same procedure to the high poly model of the water bear but instead of **custom** we use **standard** alpha brushes as we want to achieve a variety of folds and dents. We must keep in mind that the Tardigrade, as we saw earlier, is **semitransparent** without a striking texture. The images from the electron microscope show the colour solid, because of the coating. This is why I do not use a picture as texture but only sculpt with alpha brushes. In the possible future development of the virtual application, we could probably use a subsurface scatter material to switch from different visual styles, like from a stereoscope to an electron microscope, resembling light and material configuration.





Another important thing to remember, while sculpting, is to turn the symmetry off by pressing x in order to differentiate the two symmetrical sides. It will look uncanny and unnatural if the left and right side are an absolute mirror of each other and I find that it is best to sculpt the detail separately to each side.

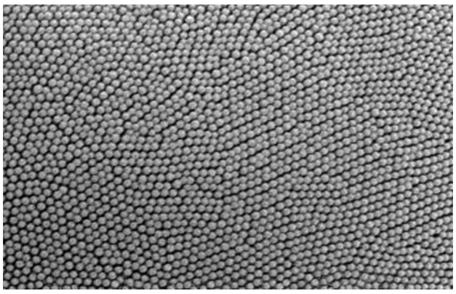
The next step is to add some texture to the mite that will give a more realistic feel to the surface of the shell. To do this, we will use the **Spotlight tool** which can be found in the **Lightbox tab.**

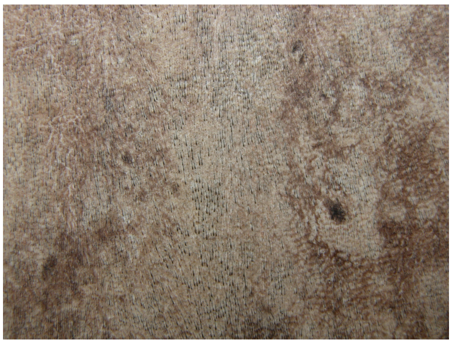
SpotLight is a projection texturing system, which allows you to prepare your source texture directly in ZBrush, then paint your model with it in 3D. It is similar in some ways to the ZBrush Stencil feature.

We first need to load our textures using the Texture palette or Light Box. We can then use SpotLight to change their scale, rotation and position; nudge them to match any sculpt; clone parts of the texture; fill colours; change the hue to match another texture's hue and more.

To utilize the previous research we will use a texture of cell taken from an electron microscope.

To achieve the result that we need we will use a combination of three different textures: a cellular texture to produce light bumps, an elephant skin texture to produce some light cracks and a leather texture to give an organic feel.





After I project the textures to the model, I apply them with enough opacity, in order to create a composite map. Then I paint each texture at the exact surface of the model**.**

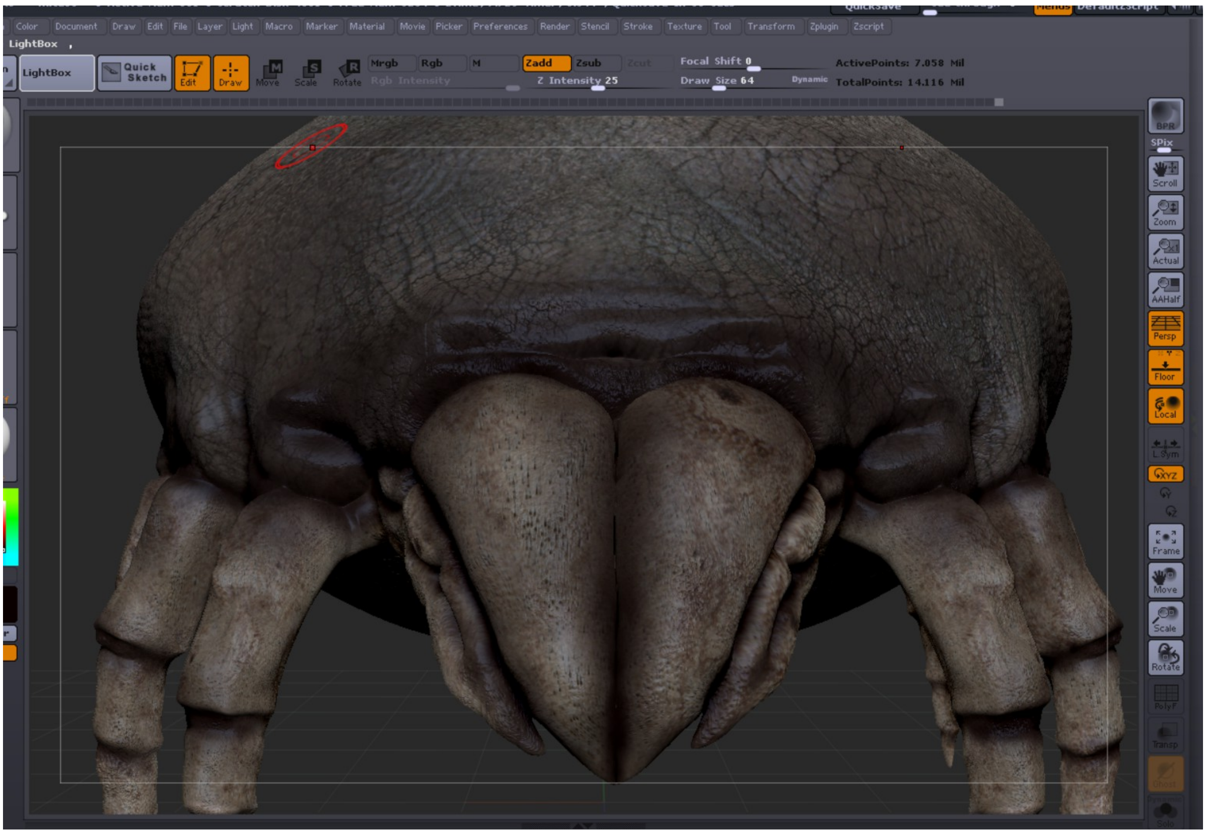
The Spotlight Dial

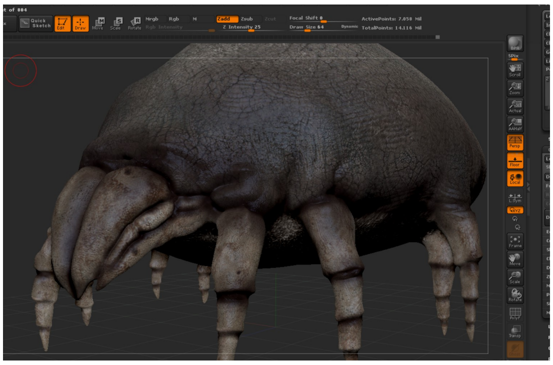
The spotlight can act also as a displacement tool so it is best to use low values to the **z add,** that affects the **normal maps** of the model. The result can be seen in the following pictures.

The final step of the high poly modelling is to use **Polypaint** to pain directly onto the model in the part where the ambient occlusion would normally be. **Polypaint** allows painting on a model's

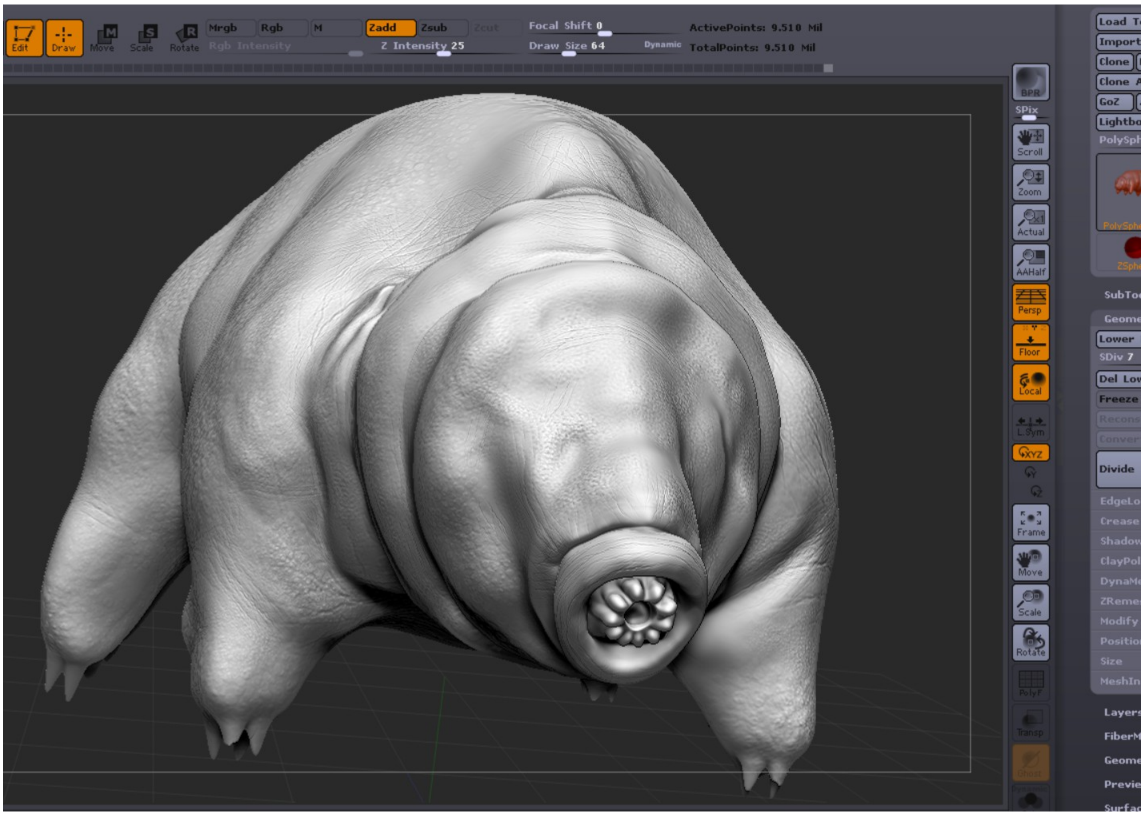
surface without first assigning a texture map. A texture map can be created at a later time, and the painted surface can be transferred to the map. Polypainting offers significant advantages compared to standard work-flow: The resolution of the texture map needs not be decided in advance. This is particularly valuable if you find that you need more detailing on an area than you thought you would.

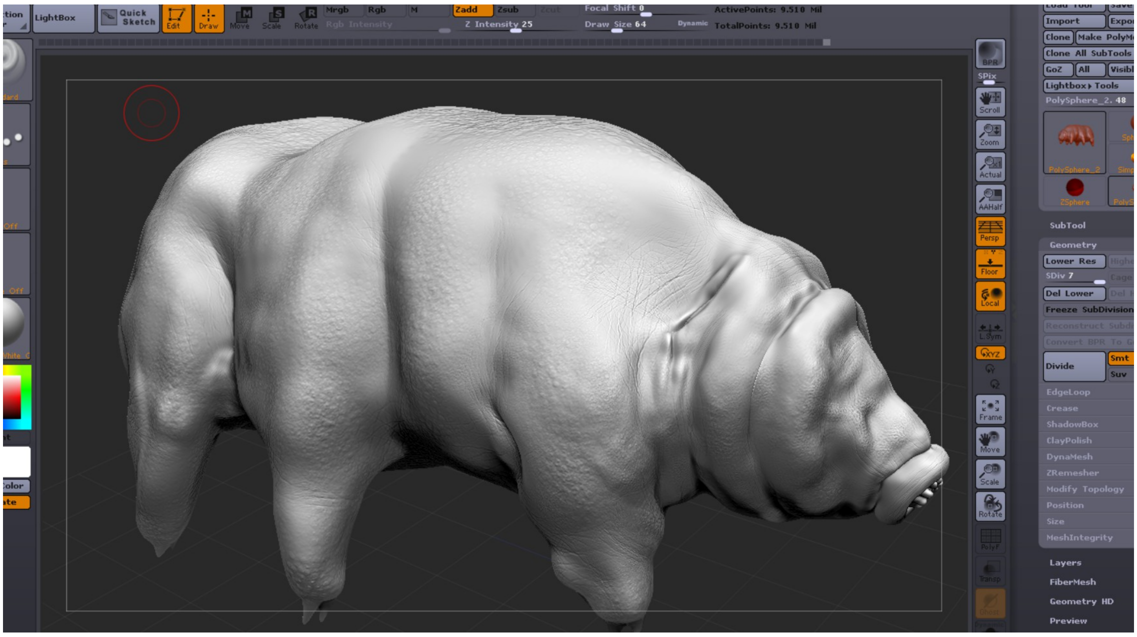
In this case I have already applied the texture map and we will just paint in the areas where the AO would be. I also use the normal brush to smooth the rough surfaces.





For the water bear I only use polypaint and alpha brushes. In the previous chapter we saw that the water bear is semitransparent in the real time observation although the electron microscope gives us a solid texture because of the gold film coating. I will export different polypaint maps and the decision will be made on the **Unreal engine**. It will be decided by the visual result of the real time render maps. The high poly model can be seen in the following images.





With the export of the maps, as well as the low poly mesh with the Uvs, we will be occupied in the chapter of the real time engine.

1.2. Rigging, Skinning, Animation software - Description of the process

For rigging, skinning and animation we will use the 3ds Max 2015 software. For the rigging we will use the CAT system. We will examine the procedure of animating the water bear in order to be able to import the animation to the Unreal Engine.

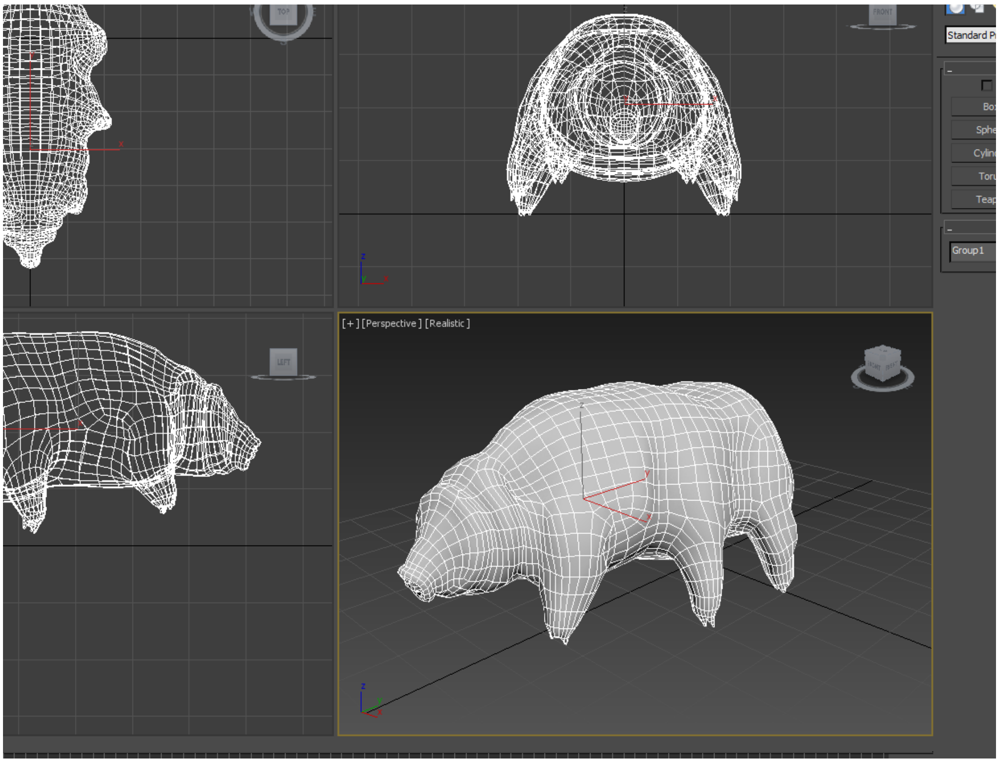
The first action for the rigging is to bring a low poly model from Zbrush to 3ds Max.
It is important for the model to have it's UVs ready. For this, we can use a very helpful plug-in for Zbrush, that is called **UV master**.
We can find it under the Zplugins tab.

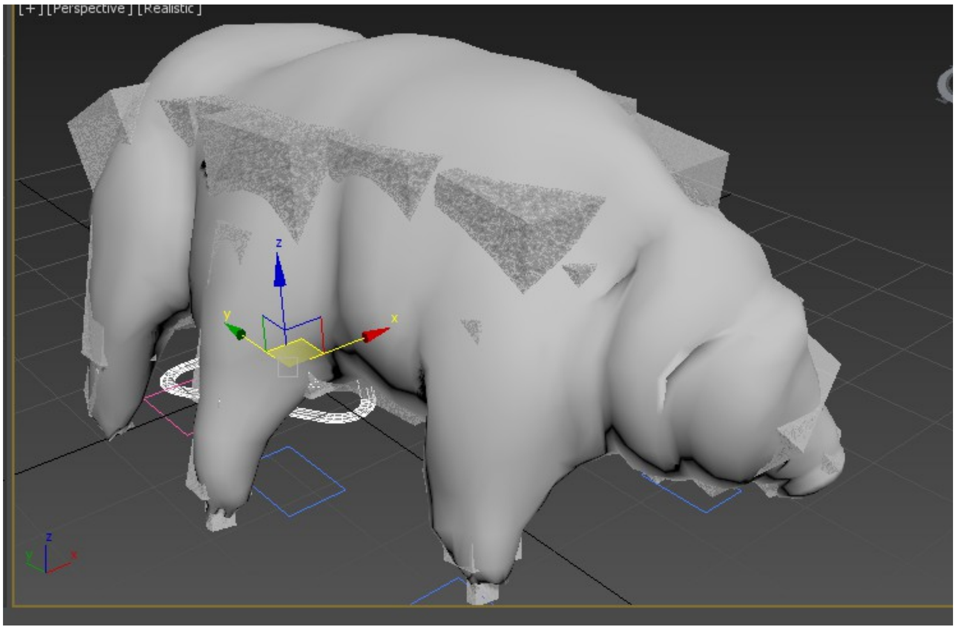
The process is pretty straight forward. We press the unwrap button and we have the UVs ready. If we have problem with the seams of the UV map, we can paint directly to the low poly model as to protest the areas that we don't want the seams of the UVs to be visible. In our case the auto generated UVs are fine.

As for the modelling, I used reference images for the placing of the bones. I watched some videos that are very easy to find online that were showing the movement of the water bear. This was very helpful as to were to place the bones in order to create the joints.
A very interesting conclusion that I made by watching the videos is that even though the typical water bear has eight legs she uses only the six big ones. The movement is fast forwarded in most of these videos as the movement of the tardigrade is typically slow. The images were taken from classic optical microscopes, with backlight illumination. Even though, they are not as artistic as the electron microscope images, they provide a truly graphic and helpful reference tool, as the movement can be analysed thanks to the provided transparency.

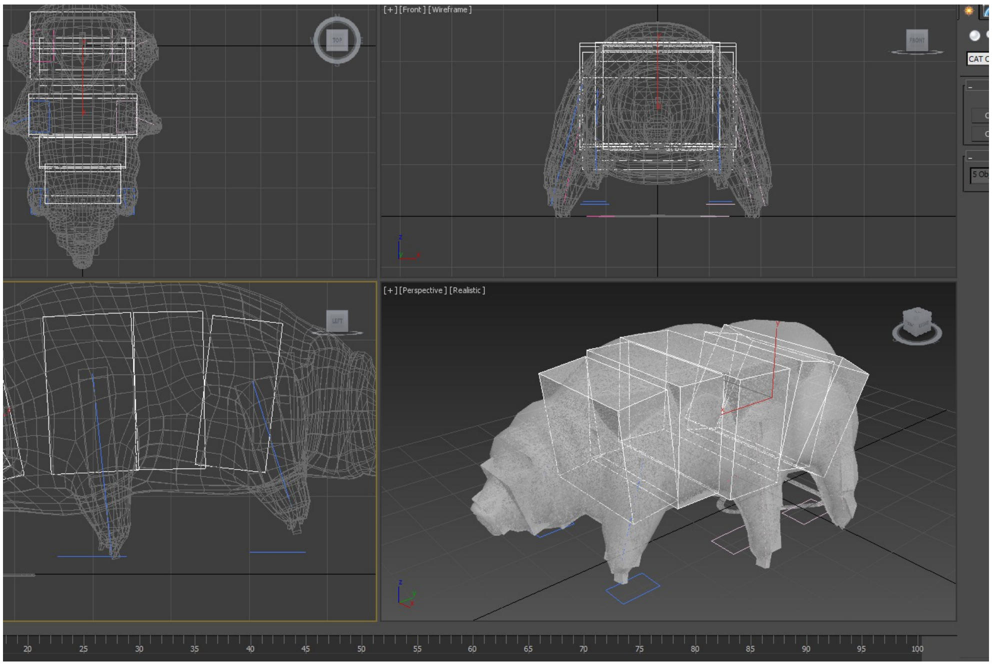
Source of videos: https://www.youtube.com/watch?v=F5fg64rmFHE
https://www.youtube.com/watch?v=aHsVyb_VfeA

Once we export the low poly model with the UVs we import it to 3ds Max.
The next step is to open the CAT systems and start placing the bones to the model. The cat system in this case is very helpful, because as we do not have a very common figure like a biped, we must conform the bones to fit the model. This is done very easily with the CAT bones as it is possible to scale them and fit them to the model very easily.

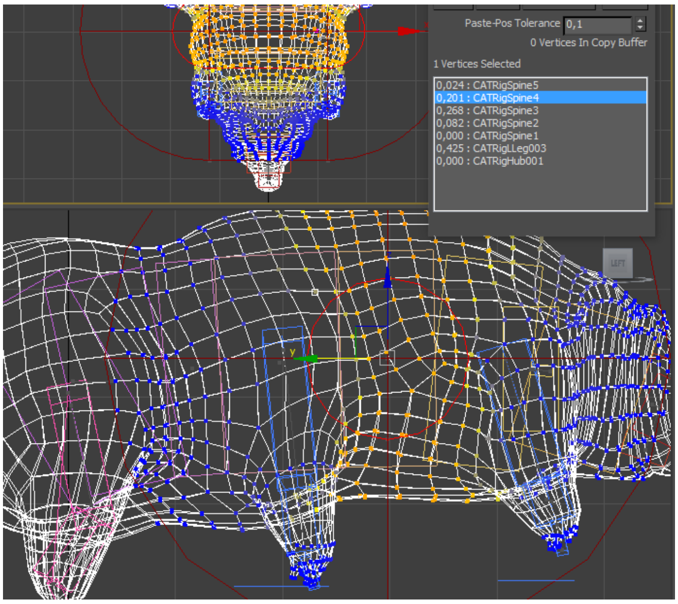




I found very helpful to freeze the model while placing the bones. Also by pressing **Alt + X** the model becomes semitransparent in the view port and the placement of the CAT bones to the precise needed place becomes very easy to do.

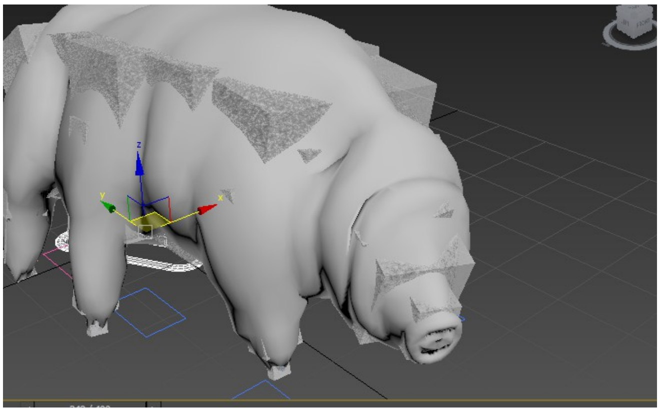


The placement of the bones is done according to where the joints will be.
After the placement of the CAT bones, I placed a **skin modifier** in the model. The skinning process was done by blending the vertices of each in-between area of the main bones in order to achieve the liquid movement of the water bear. As we can see from the reference videos, the movement of these animals is very fluid and it is important for this to be depicted in the virtual representation.

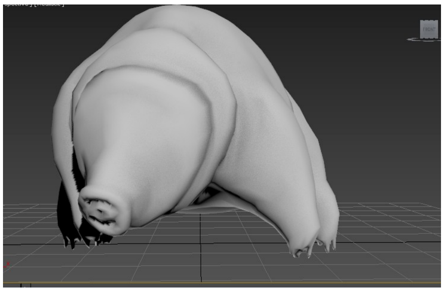
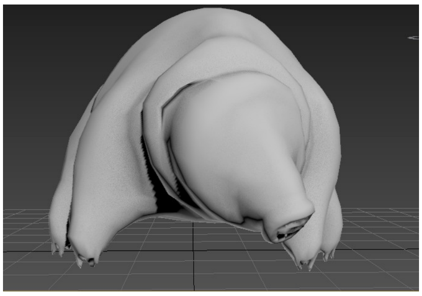
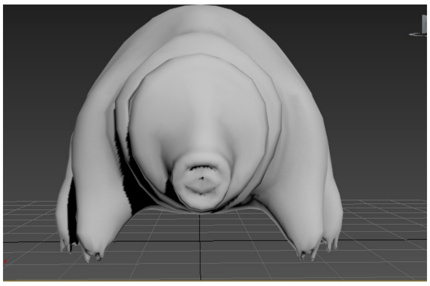


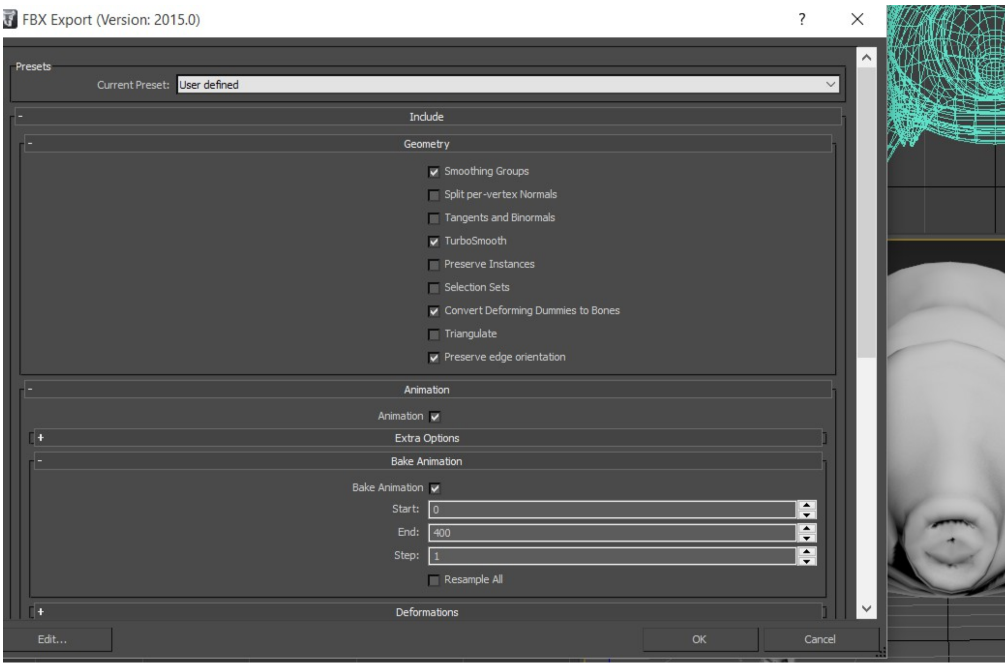
After the skinning is compete, the next step is to make the animations and export them to FBX in order to be imported in the game engine. The animations will be very subtle as these animals are moving inside the water and their movements are quite slow. I used the CAT animation system and created some different animations to export. The animations will be imported in Unreal and will be played as baked into the model, as the user will only view the animals and not interact with them in the application.

I animate the model by moving the CAT bones to the desired place in order to complete the movement. I use keyframes for every state of the bone.



The final step is to hide the bones and check the movements of the model.
Here we see the different keyframes of the animation and the fbx export screen of 3ds Max.



2. The environment

Creating the fractal microcosmos
– Software and techniques used for the creation of the environmental elements

Particles and ambient environment

In the following paragraphs, I will describe the work flow I used in order to achieve the fractal like structure and texture that is characteristic of the microcosm, as we saw in the above chapters. I will describe the technique and the software that I used to create the landscapes and the particles that we would encounter if we were to duel in a microscopic habitat.

Creating the fractal microcosmos
– Software and techniques used for the creation of the environmental elements

The habitat that I try to simulate is this of a drop of water as seen through a microscope. The scale will be determined by the size of the animals that we would encounter, as I need to achieve the overwhelming feeling that we have when we stand next to a gigantic animal. This animal for us will be the Tardigrade. It will be the size of a large elephant. With this in mind, the viewing of a tiny micro piece of moss will be an enormous landscape for us. The structure of these little foliage all obey to fractal structures as we saw in the above chapters.

My first thought was just to create these landscapes in a chaotic manner that could be similar to a fractal structure. After the research I did in the software available, I decided to use it to achieve the basic forms for the interactive applications landscapes and background, so **true fractal** formations can be the basis of the models.

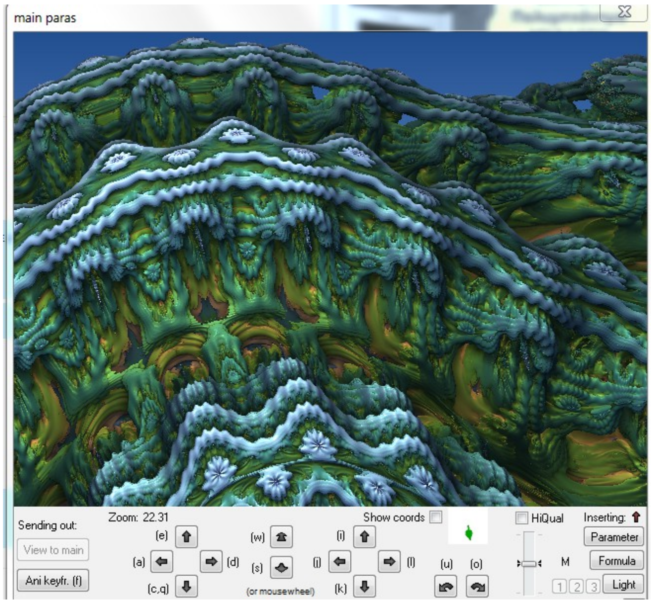
Software

The software I used in these experiments were **Mandelbulb 3d**, **Fiji** and **Zbrush**.
Madndelbulb 3d is an amazing software that allows the user to visualize 3d fractal equations. It gives you the ability to crate spectacular visualizations, stills and animation inside of these 3d fractal worlds. From the first viewing of this software I instantly thought that it would be amazing to export some of these visualizations as 3d models, in order to use them in the application. The two problems that I encountered were, **firstly** that the software does not export directly 3d models and **secondly** that even if I could export them, the polygon count would be huge. The solution came from a video I found by 3d fractal artist Don Whitaker that suggested the use of **Fiji** to create the 3d model and of **Zbrush** to reduce the polygons.

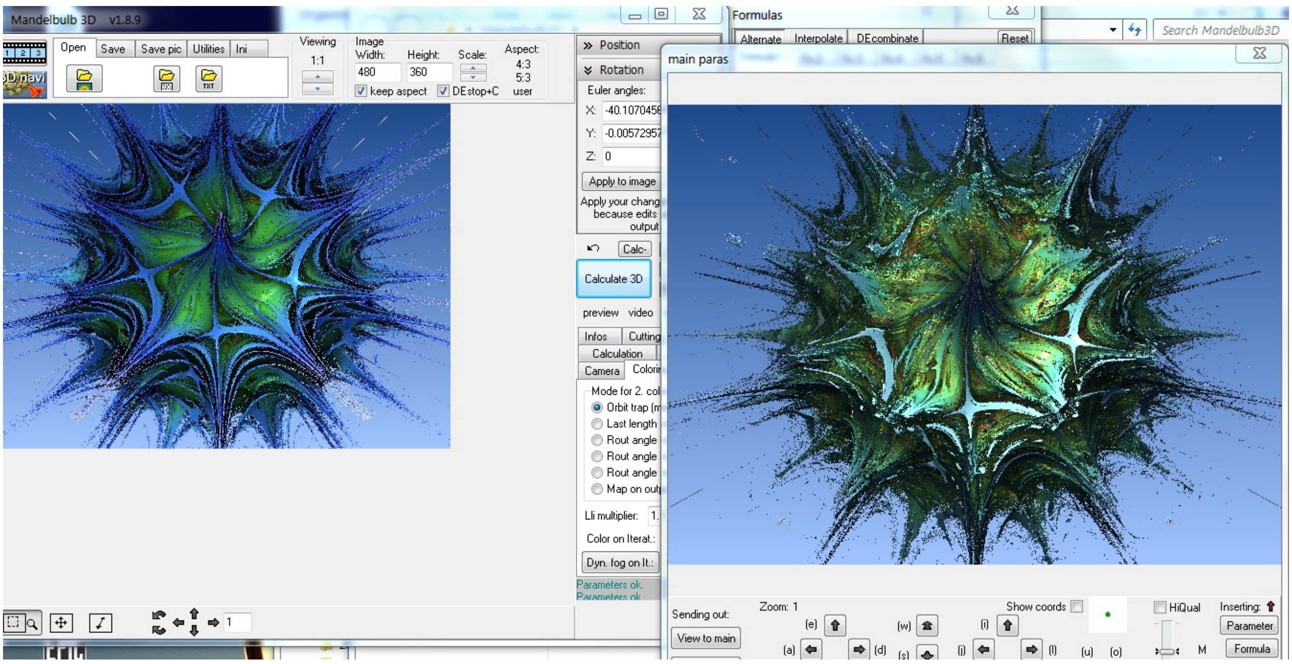
The workflow

The first step is to run Madndelbulb 3d. It is a standalone.exe and you can download it for free from the company's site.

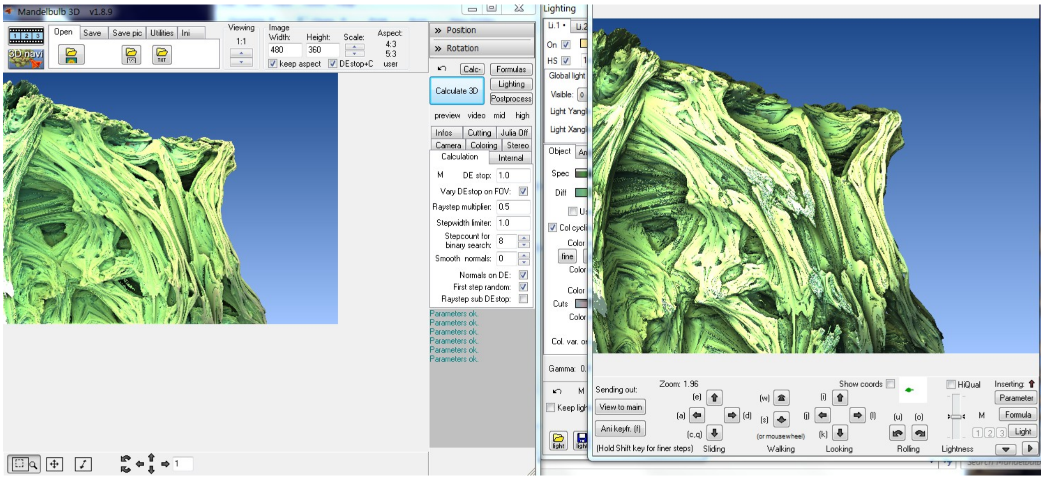
The first screen shows us the classic formula of the mandelbuld shape.
We can choose from a multitude of fractal formulas that we can view through the main window.
The program gives us many choices in colour and the general gamma, but since we will export the model and we will change its topology, we can leave the colours as they are and concentrate on the desired formations.
Here we see a detail of the classic mandelbulb image.

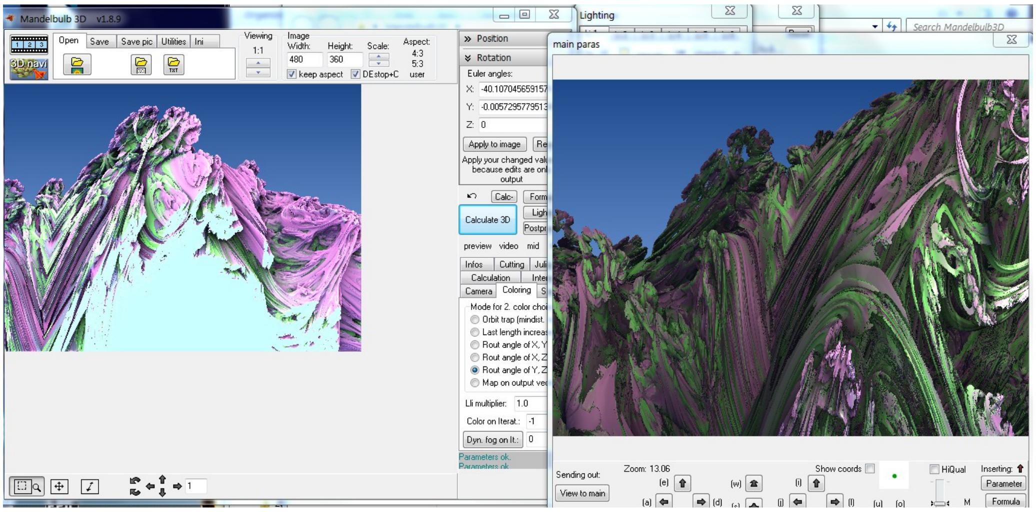


On the right window we can navigate inside the 3d fractal of our choice.

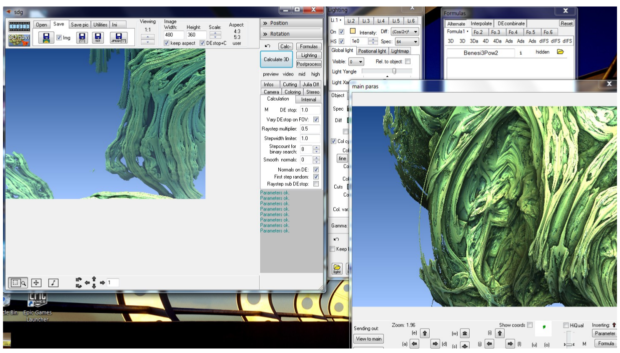


We can compare the images of the mandelbulb with our reference images so we can find similarities in texture and form.

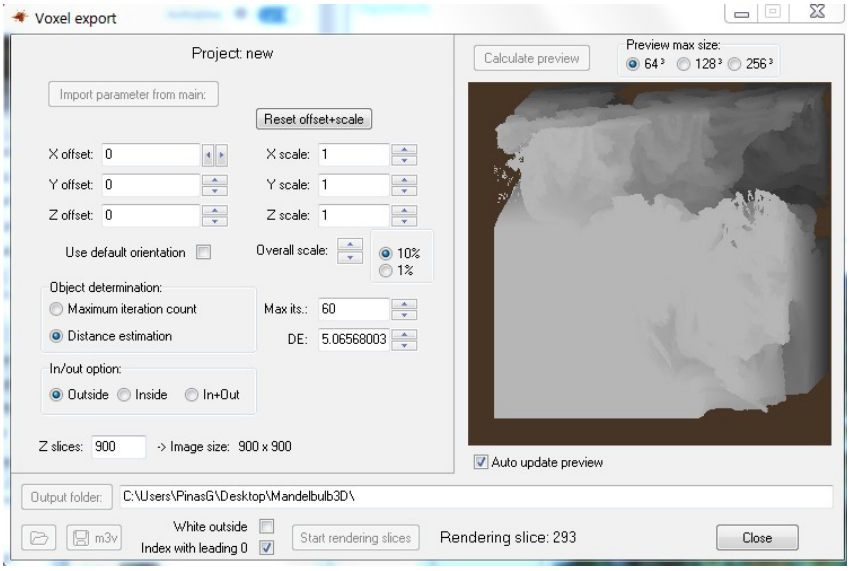




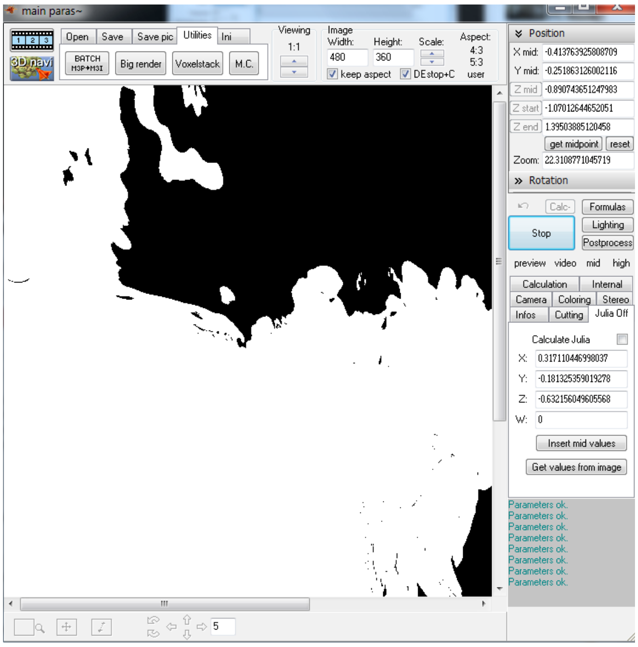
After a few hours of navigation inside a multitude of fractals, I decided to use this part of the 3d fractal.



The next step is to use the ability that we have from the program to create a **Voxel stack**. This is sequence of images that scan the part of the fractal that we have on the navigation window. We can control the resolution of the images as well as the number of them in the stack by changing the number of the Z slices. If for instance we choose 900 Z slices and image resolution 900 x900, we have a perfect cube. Like an x-ray, this sequence will capture the form not only of the surface of the fractal but inside the caves that are created.

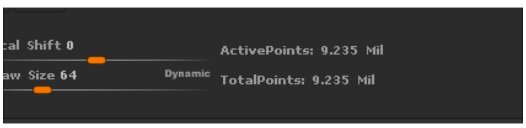


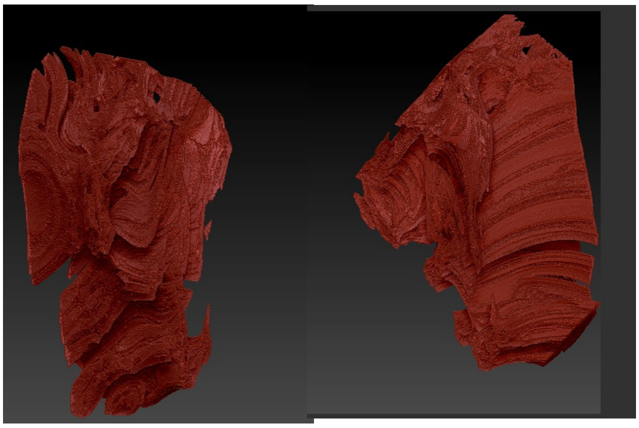
The image is a black and white image that we will use to recreate the 3d model.



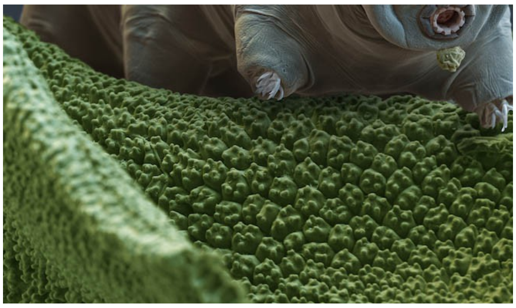
The files are saved in a folder with alphabetical order.

The next step is to run another freeware to create an .obj from the voxel stack. After we run Fiji we have a very high poly image that then, we must insert in **Zbrush** to **retopologize**. The polygon count will be reduced as 9 million polygons are too many even for Z brush.

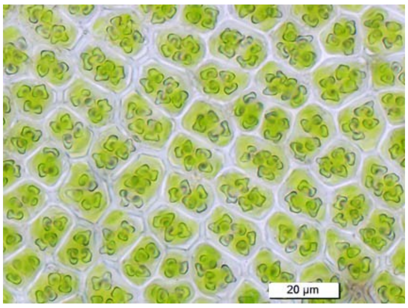




After reducing the polygon count, we keep only a part of the mesh which we will texture with the same technique we used for the previous models. We will use the spotlight and the textures will be the cells from a piece of moss captured by a scanning probe microscope. The texturing process also includes the use of alpha brushes for finalizing the details in order to be as close as possible to the desired result.



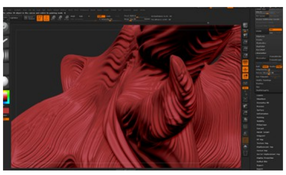
One of the reference images for the detail of the moss

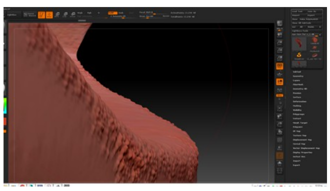


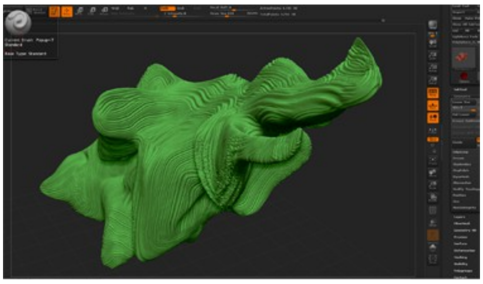
One of the images of moss cells I used for texturing

Using the Spotlight to create the texture in the model

The following are stills from the procedure of texturing in Z brush.







After the texturing, we run a technique in Z brush to create a low poly model. This is done by creating a high poly model in Z brush and then we run **Z remesher** to create a low poly model then we increase the tesselations and we project the first high poly model to the new one but this time we have the textures as well as the low poly version with the projected details.

After that, we will export the low poly with UVs and the texture maps in order to import them to the game engine. We will examine the steps of exporting the maps with more detail in the next paragraphs.

Particles and ambient environment

As we saw in the previous chapters the microcosm is filled with particles of micro organisms, whose forms have patterns in their structure like spirals, symmetries and a variety of other elements that could be reconstructed with a multitude of 3d software programs.

The specific habitat that we will create will be an aquatic one. More specifically the action will take place inside a drop of water. Even from a simple search in YouTube we can see that inside a drop of water is a multitude of tiny particles.

Splash of sea water magnified 25x, photo by David Littschwager.

For our VR application we will create two types of Radolarians that will swim around our water bears.

For this, we use the same procedure as before and the software 3ds Max and Z brush.

B. Real Time conduct of sightseeing in the microcosm

1. Game engine – Importing models and animations - Experimentations
2. Virtual implementing – VR hardware
3. Educational Application of the Virtual Experience

In this section we will examine the workflow of implementing part of the research and the models into the game engine in order to create the Virtual experience.
My decisions for the visual style of this first attempt of the representation will be the combination of a **scanning electron** and the **bright field** illumination technique of a microscope, which means that the shades and the lights will resemble this of our everyday experience. Shadows will be cast and there will be solid textures without subsurface scattering or transparency. The main micro animal will be the tardigrade with some parasites leached to its surface. As we don't have sufficient information for these parasites, even though we know they exist, I decided to use the model of the mite. The terrain will be the moss which we know that is a common terrain for the tardigrade.

1. Game engine – Importing models and animations

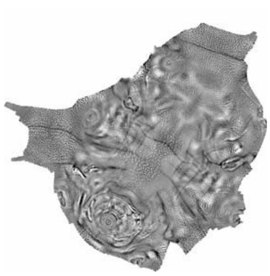
For the game engine the choice was the Unreal engine and this is due to the advanced graphic display of physical based shaders. Even though the Unity 5 engine uses as well a physical based shader and the work flow is clearly more customizable, the defining fact for my decision is that the Unreal engine has used these physical based shaders from the UDK years, it has better AO rendering system, better Antialising and for someone who wants immediate visual results, I believe the optimal choice is the Unreal engine. The code expectation will not be great as I need the game engine to provide me with a basic walk through and good visuals, so there are low code needs and customizations. My basic skills in blueprint system are enough to create a first draft of this Virtual walk in the microcosm.

Importing models and animations

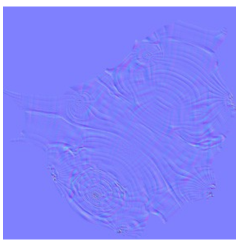
The first step is to import the exported models and apply the textures and normal maps. From Z brush we have exported the necessary maps and the low poly model with the UVs.

The maps that we have exported are an Ambient occlusion map, a cavity map a texture map, a normal map and the low poly model.

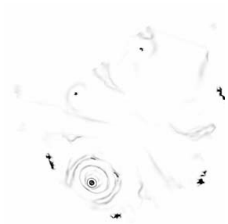
The maps for the Tardigrade:



Cavity Map



Normal map

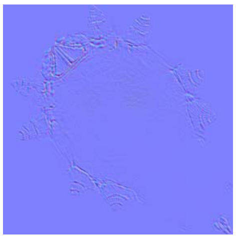


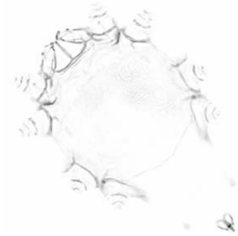
Ambient Oclusion Map

Texture Map

The maps for the Mite:

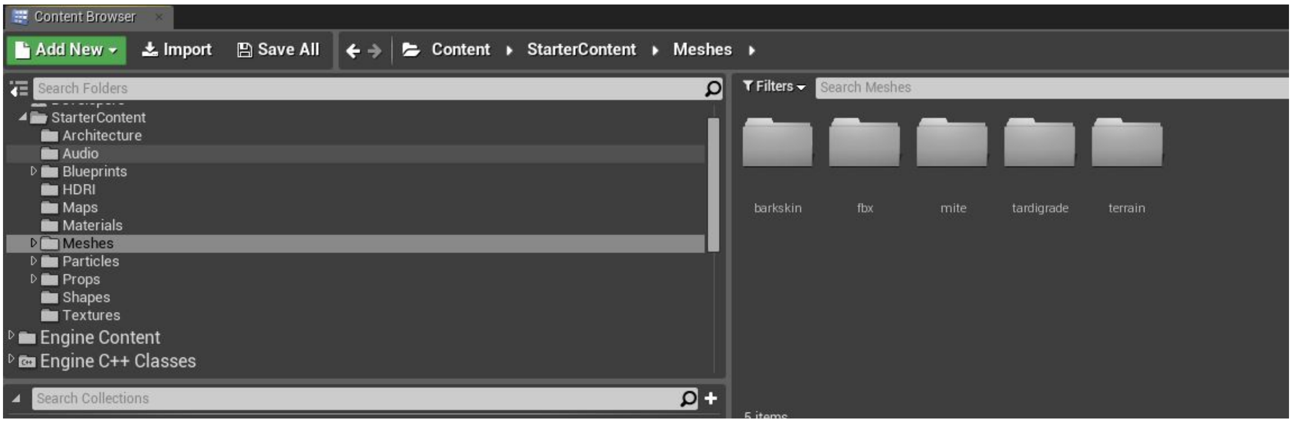

Cavity Map


Normal Map


Ambient Occlusion Map

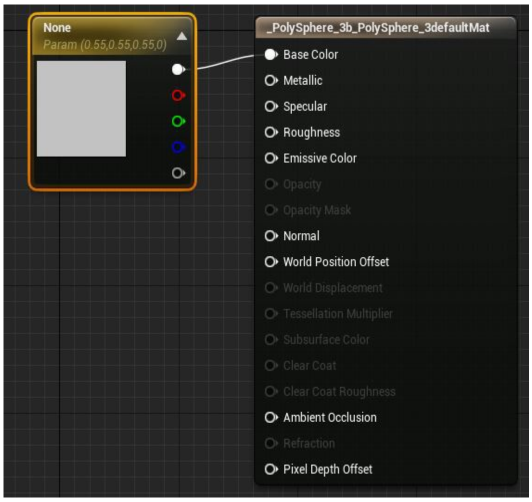

Texture Map

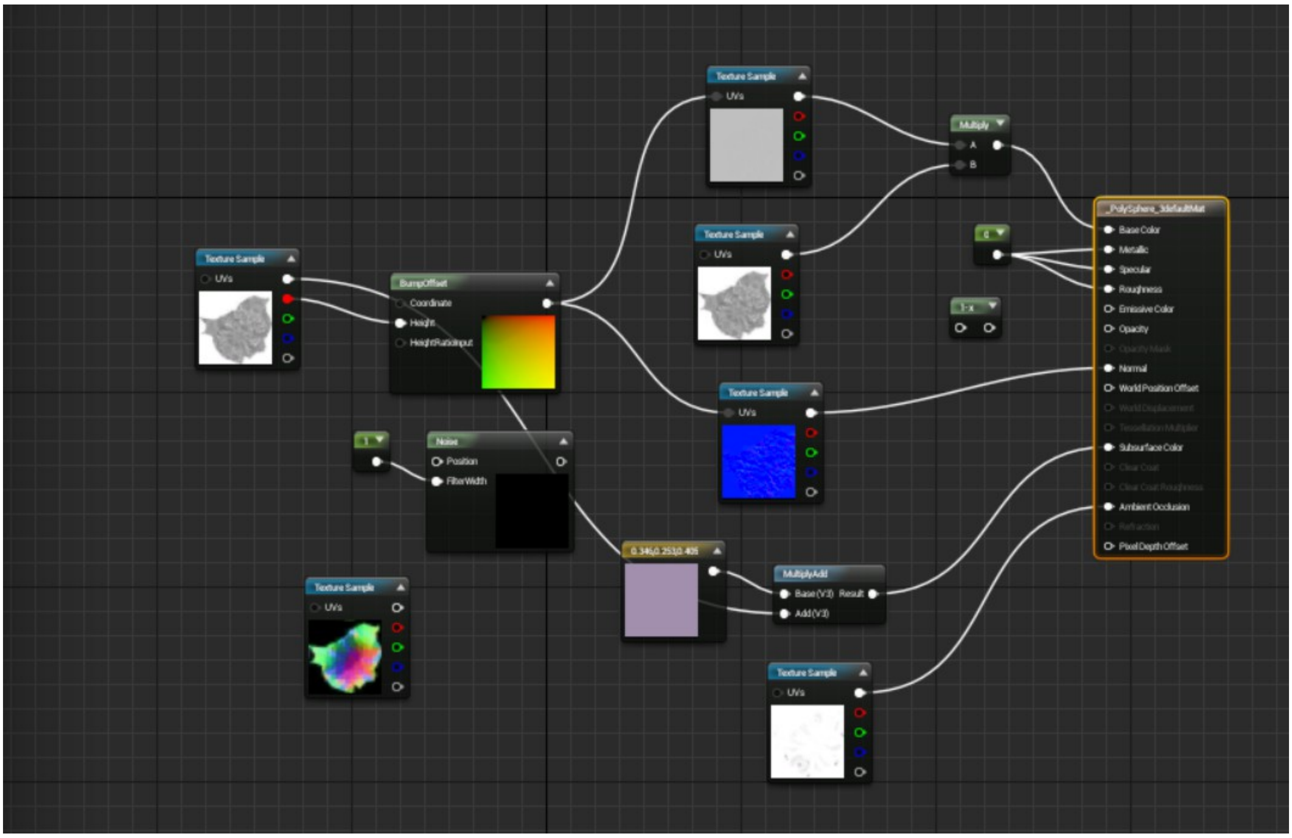
The part of importing the maps is pretty straight forward: We make a new folder to the Contents folder that we will call meshes. There, we create a desperate folder for each of the models that we will use and we drag and drop the maps as well as the low poly model.



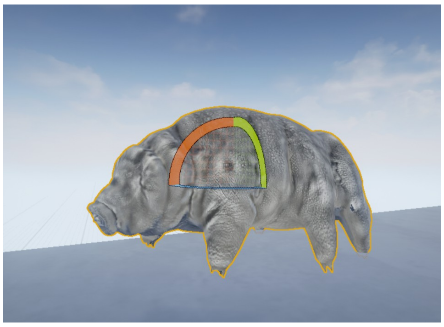
The next step is to create a material and using the node based system the Urneal engine provides to connect the materials with the specific controlers.

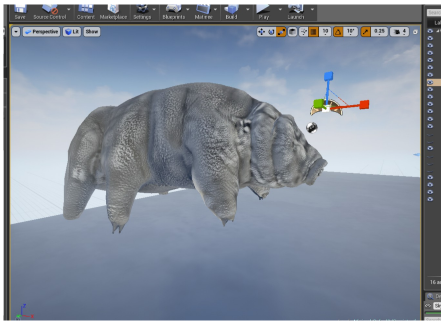
After a lot of experimentations and tutorial referencing, the best results for the tardigrade came from a node tree looking like the following picture





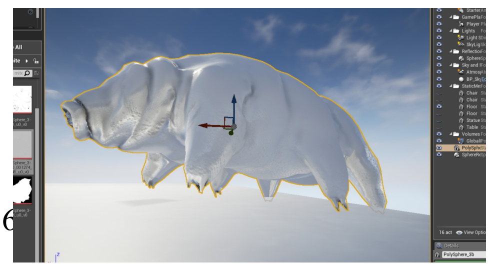
I used a **BumpOffset** to connect to the normal map that used the **Cavity map** as a height multiplier. I used a **Floater** to control the **specularity.**
Some of the test images, where I used the cavity map for a base texture:



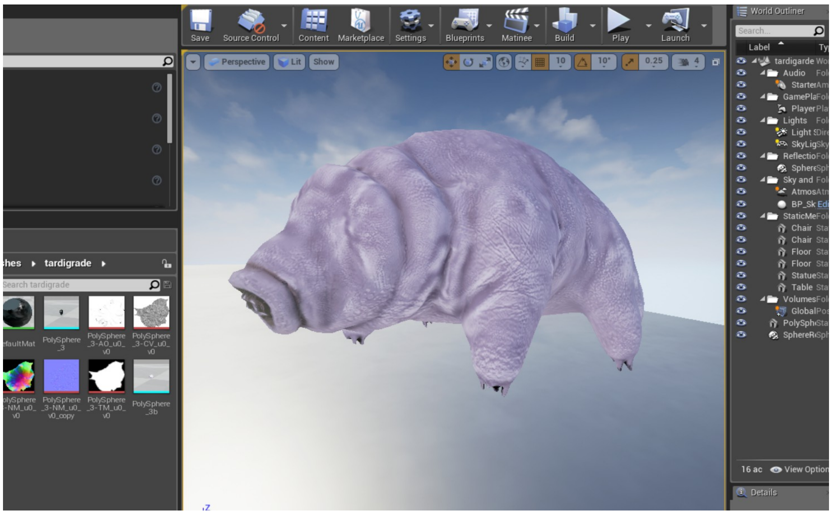


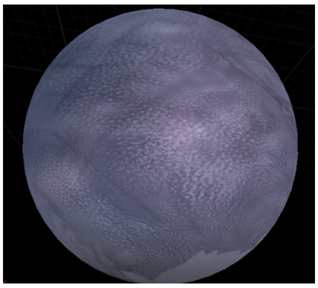
Seeing that these textures where too rough I decided to remove the cavity map from the base colour and to place it to the roughness slot.

The final texture is something like that:

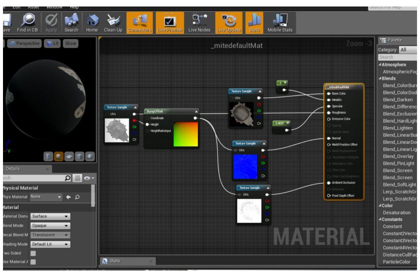


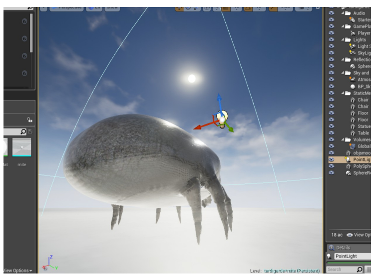
After that I reduced the specularity from the float controller and added some red hue to the base as the research on the tardigrade indicates that it is a colourful animal.

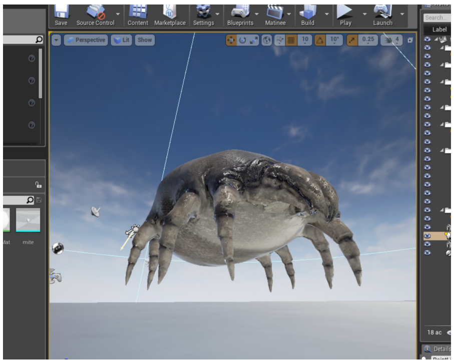




The same procedure was followed to the texturing of the mite with the difference that the base for the mite was the texture map. The specularity and the glossiness was higher as I wanted to give the wet feel of a hard glossy shell. So the metallic and specular values where a little higher.
The node tree is as following and we can also see the low poly mite with the final glossy texture.





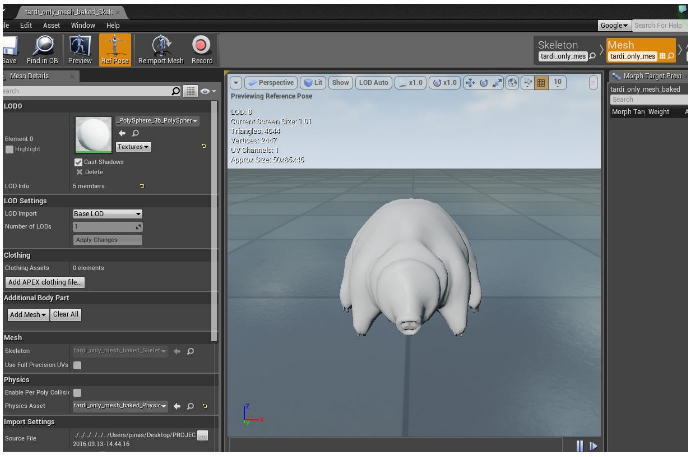
 

The same process was followed for the moss terrain as well as for the particle folliage.

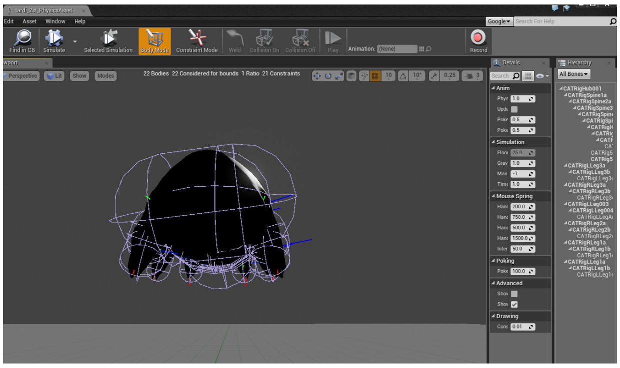
After I created the node texture maps I inserted the fbx that included the animations of the tardigrade. This was also a straight forward process as the animations were baked in the fbx.
I inserted three different animations,

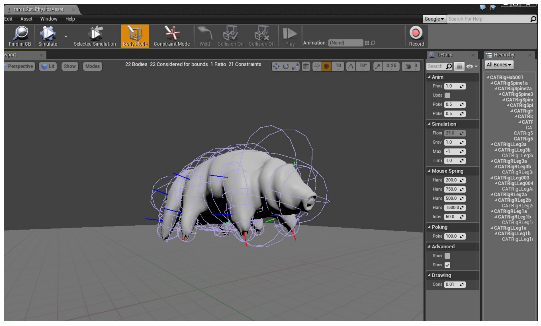
and for each fbx the Unreal engine creates four different files. A skeletal mesh, an animation sequence, a skeleton and a physics asset.

This is the baked skeletal mesh:

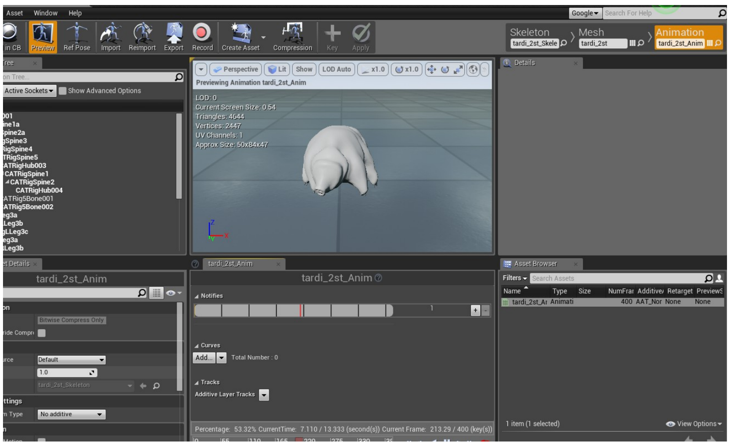


here we can see the physics assets:



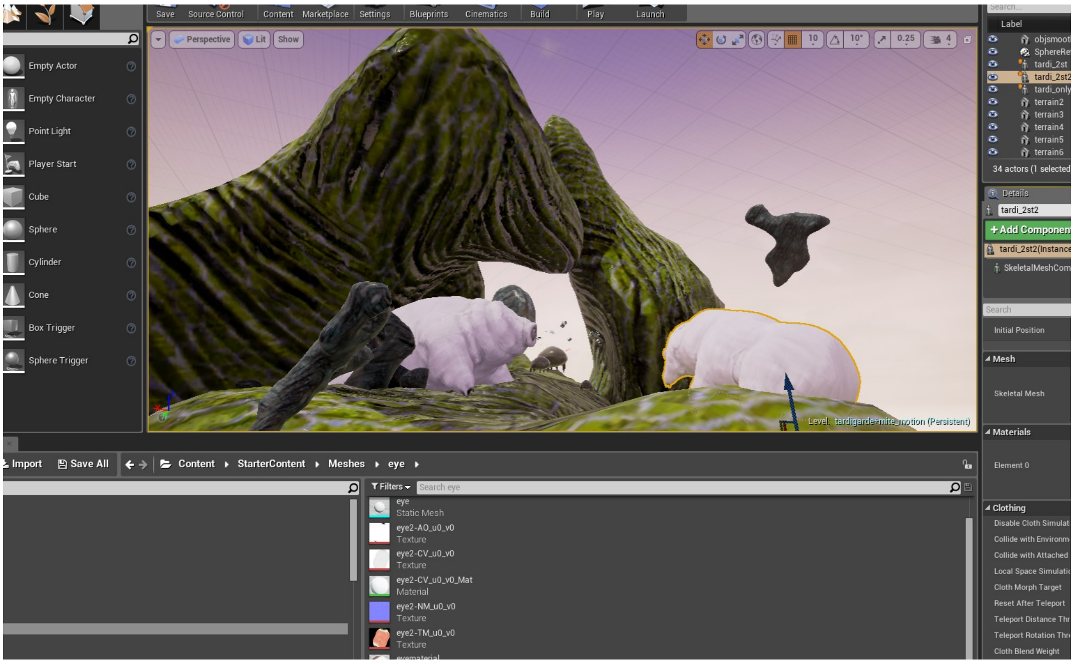


here we see the animation sequence as well as the hierarchy of the bones.
The Animation Sequence is a single animation asset that can be played on a Skeletal Mesh. These



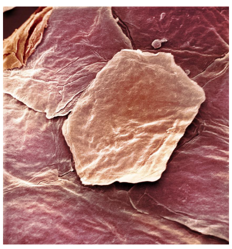
contain keyframes that specify the position, rotation, and scale of a bone at a specific point in time. By playing these keyframes back in sequence, with blending between them, the bones of a Skeletal Mesh can be smoothly animated.

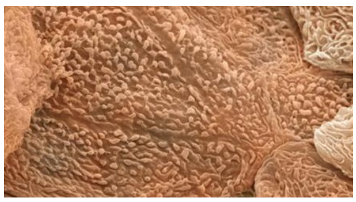
The final visual result can be seen in the following images:



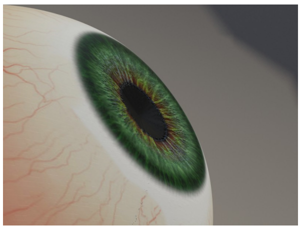
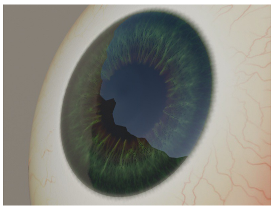
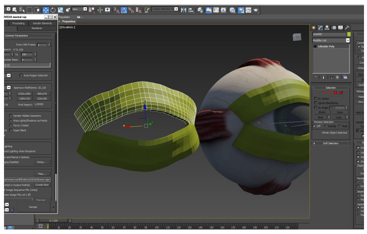
After the importing of the models in the Game engine and seeing a walk-through, I was interested to see how a **real word object** would appear **viewed from a miniature scale**.

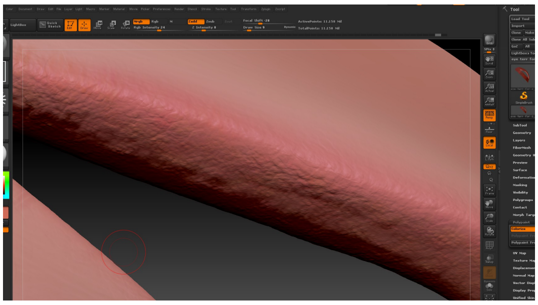
The idea was to create an eye and view it from a mini scale from the eyelashes as a micro organism. The eye was for me an ideal example as we can utilize the **fractal pattern of the cornea** of the eye, as well as utilize as texture some images created from a microscope showing **flakes of skin.**



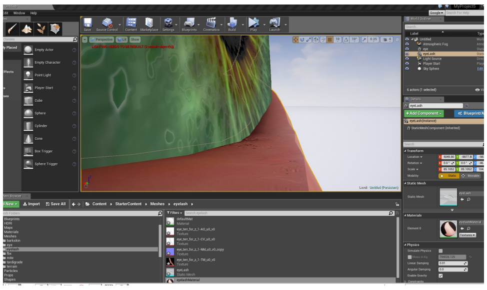
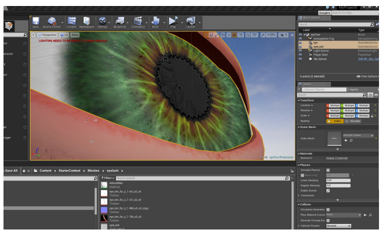


It was like a rough sketch for a future development of the Virtual app where we could change scale and see the relativity of various sizes.
For that I created a model of an eye using Z brush and 3ds max. For the model of the eye I used an image of the cornea taken from a microscope, and creating a normal map afterward.
After modeling the inside of the eye I modeled the eye lids and used for the scale of the viewer the picture of the skin flakes. As I mentioned before it was a rough sketch so I didn't put much attention to the photo-realistic feel of the models.



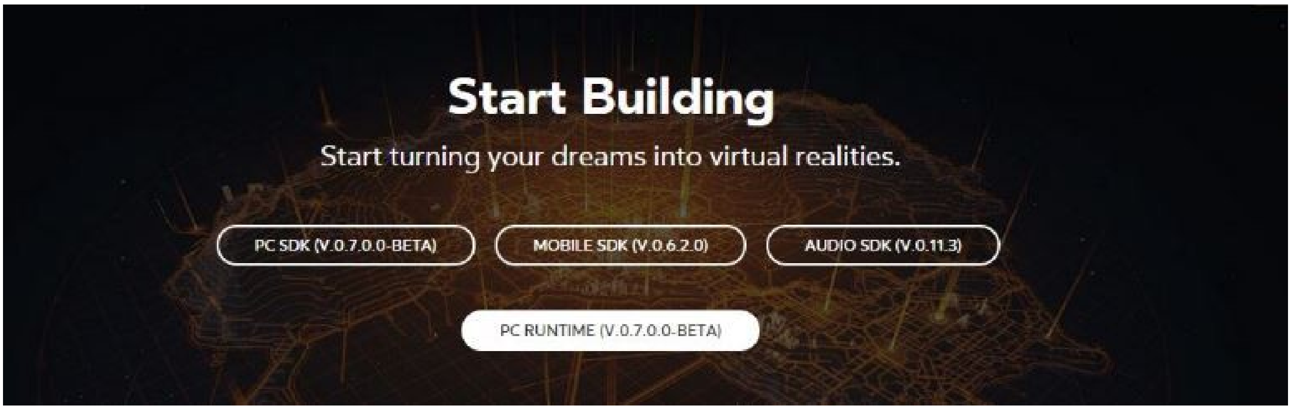
The final step was to put the model in Unreal and see how much I could increase the size of the eye model and minimize the first person viewing by the relativity of these two.

The blow up resolution after a while is not sufficient and pixels and artifacts appear on the model.
My conclusions were the following:
We can either create a large terrain map (which I must admit holds up pretty good the resolution in the Unreal engine if we consider that I stretched it in a size that would be that of three football fields), or we should create two different scenes: one from the point of view of the eye as a human and from the point of view as a mite. The first will contain the eye textured as a whole and the other only the terrain that we would move, where the eye would appear as a giant lake.

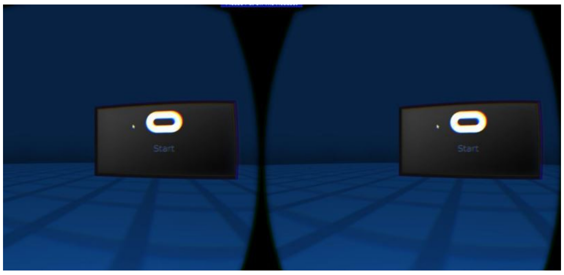
2. Virtual implementing – VR hardware

The hardware that we use for the Virtual Reality experience is the Occulus Rift.
The virtual implementing is done by the use of the drivers for Occulus Rift for the Unreal Engine.
After we register as an Occulus user we downloading the occulus content.



After the download we agree to the terms and restart.
The next step is the necessary configurations.

We run the micros cosmos application through the unreal engine.
After that we can run the occulus choosing direct HMD from apps.
We are good to go.



3. Educational Application of the Virtual Experience

An immersive virtual walk in the microcosm can have lots of benefits a s an educational tool. All the meaning of different visual styles, all the fractal patterns, minerals, various lifeforms that dominate the microcosm have a direct connection to the mathematics, physics chemistry and art. What better way for one to comprehend the natural order hidden in these things that are offered in the microcosmos but really being there? The effects of realizing the composition, the movement and the physics relations of the microcosm can be achieved by being transported to a drop of water inside a crystal, inside a colony of ants or even the human body. The educational experience is transported to the game realm and all this knowledge is communicated through the first person viewing. This type of application can be utilized in schools, museums, art and art classes. When gaming mindset is overlapping with learning the learning process the result can provide with a continuous need for knowledge.

Conclusion

This research has been an attempt to achieve a step in the joining of the actual microcosmos universe with the digital reality creation. An important deriven conclusion from this creative process is that the creator is always bound to depend on already given knowledge. This extends from the technical necessities to the effect of given imprinted images that affect the creative composite thinking.

The research of this master's essay, as well as the practical experimentations, have shown that the connection of the microcosm with virtual reality can be achieved by utilising the lighting techniques and the patterns as textures that could characterise the form of the models used for the virtual representation as well as the variety of the visual style of it.

The hidden artistic and educational dynamic of these miniature universes can be exploited by the creator as a work of art containing this content and revealing these intricate patterns, landscapes, forms and lifeforms that are so alien to our everyday experiences but are completely real. The Virtual Reality equipment and technical digital image know-how through the selective and always creative view of a creator could eventually transfer the viewer to these places where fractals, monsters and fluorescent materials with glowing lights all around us are not science fiction but merely reality...

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