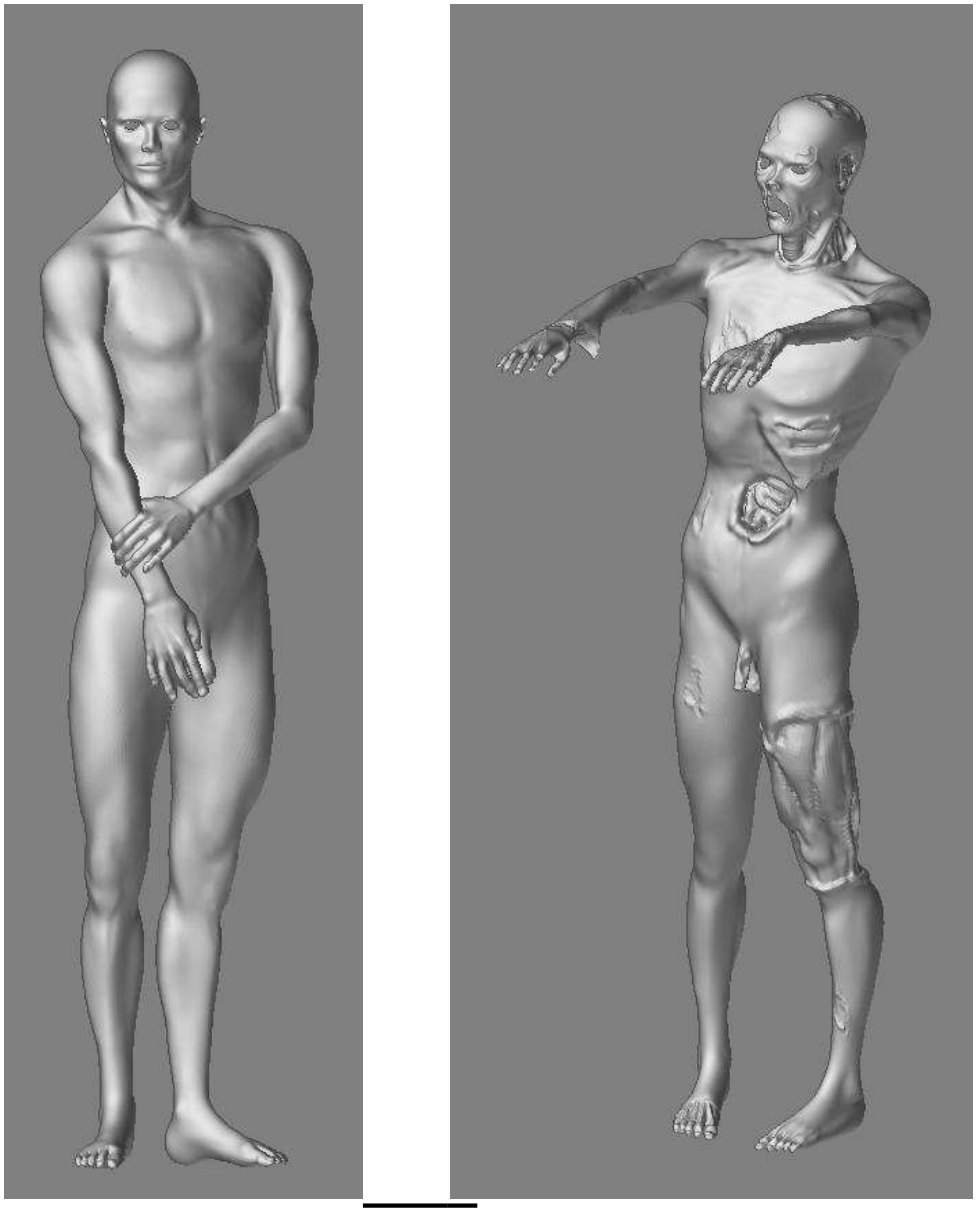
A study of the importance of anatomy in character modelling and design



An Innovations report by Christian Bull

NCCA 2006

Contents

Abstract

This project is a study of the importance of anatomy in character design. The practical side is essentially six different characters created out of the exact same mesh, each with a different physique based on a real body structure, with only slight changes made to create a character - thus the character is largely defined by its anatomy. By morphing between these, the final product (a thirty second animation) displays how the body changes. This mean that the viewer can see the muscles weakening, or the bones growing, or fat forming, or whatever change they are viewing, thus helping them to understand how many different characters can be created out our existing natural design, and hopefully educating them in an entertaining way. It should be stressed that this is not a study into character design - any of the characters in this project could be infinitely more fleshed out, but one of the ideas behind the project was to have as minimal change from reality as possible, to show how real anatomy can be the basis of many characters.

The following report is largely intended for other students who wish to create believable characters in their work, or understand how to go about doing so. It documents the findings made about the appearance of each body structure, and the reasons for why the characters look like they do. Reference pictures are not included, as they were too numerous to be included, but information about where to acquire useful reference for each character can be found in the report. Since most body types are covered in some way by the six characters, it is hoped that this overall documentation of the modelling process would be of use to anyone trying to create a realistic character. Given the artistic nature of the report, it was considered more appropriate to write it slightly informally and thus make it more approachable.

Introduction

It was not the intention of this project to just model clones of realistic body types, since you are already surrounded by reference more accurate and realistic than I could ever hope to achieve in a model (your own body, for example). Instead, I have tried to demonstrate how we can use the anatomy of the human body as a base from which to evolve our own characters. I cover the extremes of most different human body types (normal, muscular, obese, old/thin, young), and touch upon borrowing traits from other creatures. It should be noted that this is not a guide to human anatomy, there are plenty of those already (for details, check the reference section at the end), and a basic understanding of human anatomy is expected if the reader wishes to create their own characters. Included (figure 1) is a page from “Anatomy for the Artist” (see reference) showing the superficial muscles of the body, to use as

reference when reading this report.

For those interested in morphing, the techniques used are also covered at the end of the report. I feel that these are a solid base from which to explore more advanced morphing techniques.

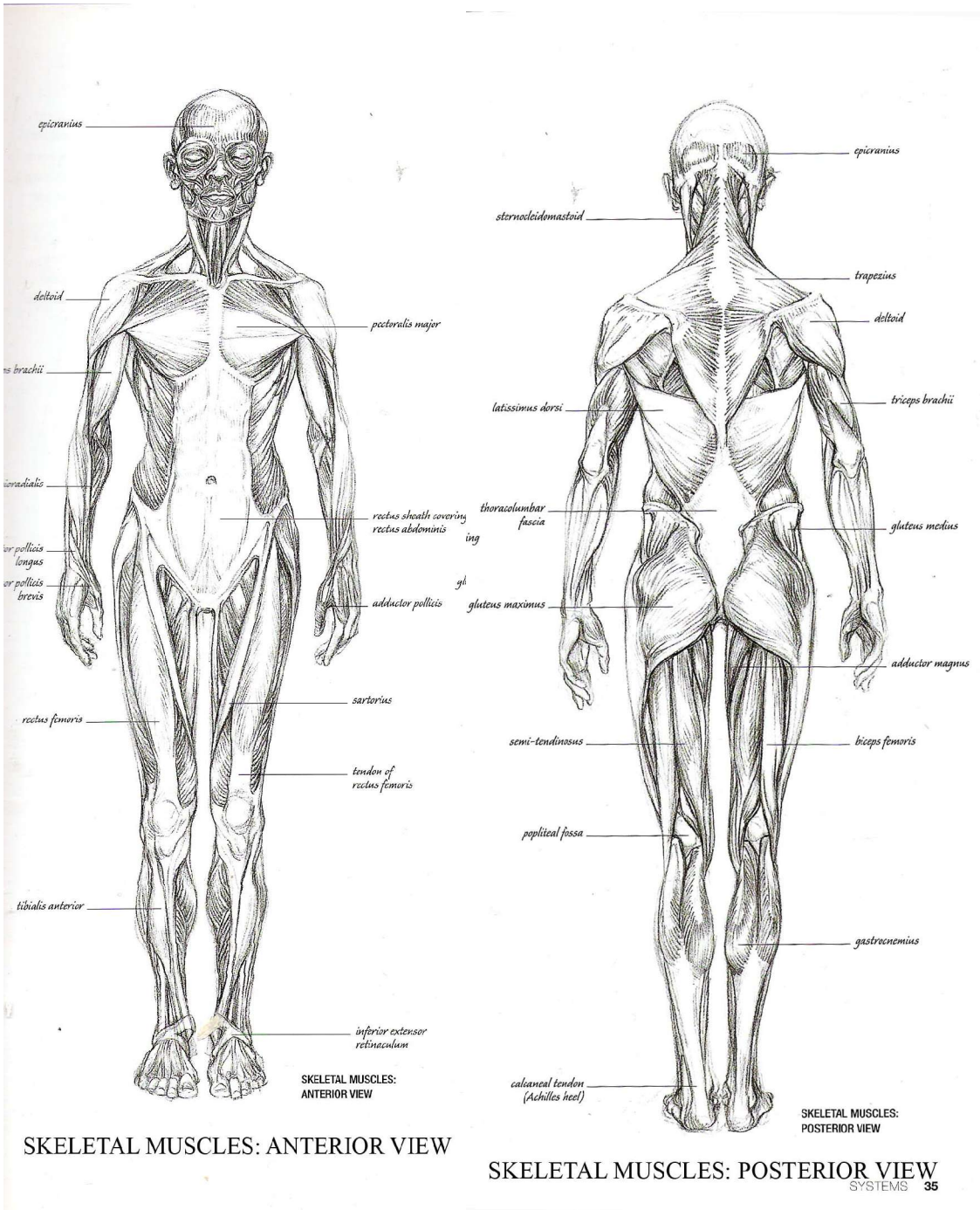


fig 1 (Superficial muscles of the human body front and back)

Building the mesh

Although this is a project in anatomy, and thus strictly speaking the topology of the 3d mesh is irrelevant, building a good topology based upon an understanding of the human body makes the modelling task easier, as the edges flow along the contours of the body. So understanding why the topology I made is the way it is will help in understanding why the characters are the way that they are, and visa versa. Also it is likely that if you are reading this for reference, you are building a character for animation, and thus a good topology is vital. Figures 1.1 and 1.2 show the way that the edges in the base model follow the defining features of the human body.

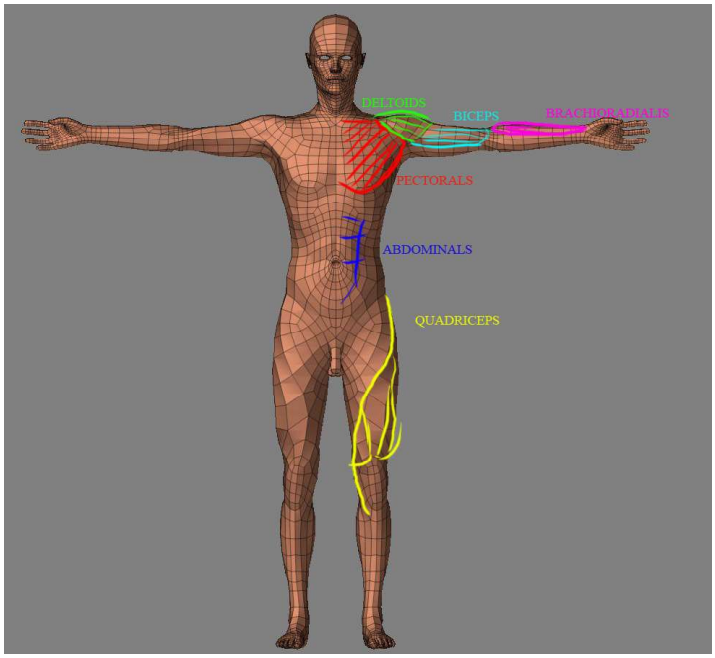
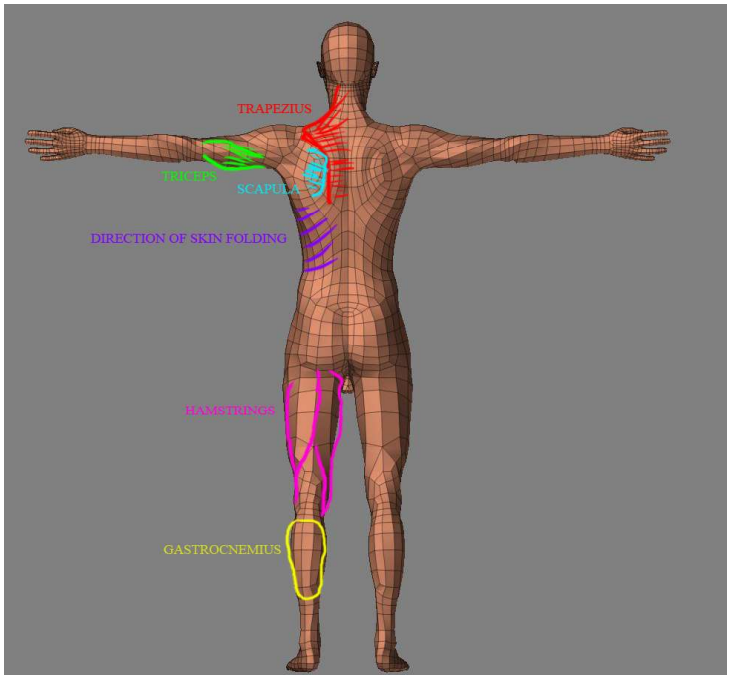


Fig 1.1 above, fig 1.2 below, outlining the reasons for certain edgeloops



Creating the Characters

This section will outline why each character looks the way they do. For clarity, the pictures are screenshots from the original models created in Zbrush, rather than renders in Maya, which lost some of the details (see conclusion). This does mean that certain elements (most notably eyes and teeth) which were created in Maya are not seen in these pictures. Please also note that they are orthographic, so there is no perspective distortion.

The description of the creation process is broken down in the following way – Firstly the age and body type of the character is defined, so that it is clear what type of physique has been the influence for that character. Then, if appropriate, a visual example of how this body type looks in reality. Each notable part of the anatomy will then be explained with reference to the finished models, so that the reader may fully understand what defines the shape of the characters.

The actual modeling itself is touched upon in the morphing section, but essentially each model is based on the same low poly mesh, which is posed in maya and the pose is then taken to Zbrush for shaping. Importantly, all characters were modelled asymmetrically, to create a more natural look rather than the perfect symmetry often seen in cg. This involved modelling the two halves of the body entirely separately, rather than modelling them with symmetry and then changing them to make them asymmetrical, which I felt could be rather forced.

Christian the Human

Age - 28
Body type - Athletic

The man was intended to be as close to a real man as could be modelled given the time constraints of the project. It was important for him to anatomically correct, because this allows the audience to follow the progression of his bones, fat and muscles, and observe how they change in different body types.

The starting man was made to be an athletic build for a couple of reasons. Firstly, it was appropriate to make a topology that catered for the main muscles in the body, as most of the characters in the project will have some degree of muscle definition. Secondly, the audience is able to clearly see the forms and shapes created by the human body, and track this as he morphs into different physiques. For the purpose of this report, I will go through the landmark shapes created by the athletic human body and why, so that the shapes of the other characters may be better understood.

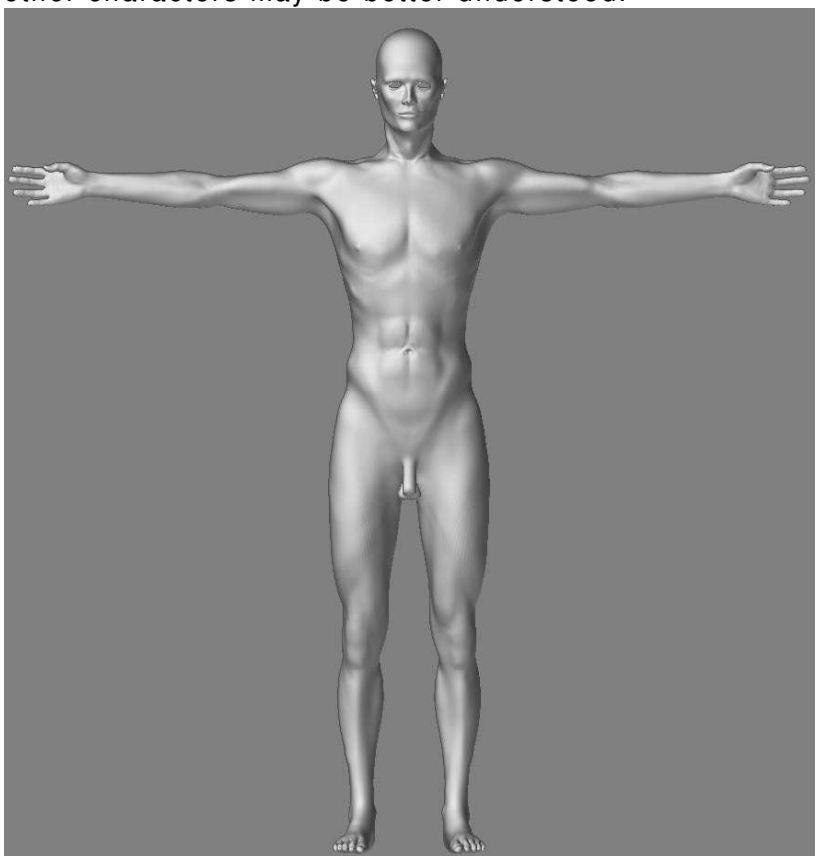


Fig 2 (Human front)

Front

From the front (fig 2), we see well defined abdominal muscles. It is easy and tempting to over define this area, but outside of very muscular or very thin physiques there is normally not a lot of sharp definition here, and a “six-pack” in a relaxed figure is rare.

Above them are the pectorals. It should be noted that these insert underneath the deltoid muscles (the shoulder), and thus are affected by arm movement. As the character has his arms outstretched here we see the pictorials are stretched too, as they are being pulled upwards. If the character had his arms by his side, we would expect to see slightly bulkier-looking pectorals.

The sternocleidomastoid muscle runs from the behind the ear to the clavicle at the front, creating a curve in the side of the neck.

From the front of the legs, we can see the shapes created by the quadriceps - three of them form shapes visible on the surface. The bulge above the knee on the inside of the leg is the vastus medialis, in the middle is the rectus femoris, although strong definition of this would only be noticeable in very muscular legs, and the vastus lateralis on the outside of the leg, defining the curved shape of the leg there. Also note the diagonal line slightly visible running from the outer hip region across the leg, down to the knee. This is the shape formed by the quadriceps, as they attach to the outer region of the hip. The sartorius muscle runs along this line, superficially separating the quadriceps from the muscles on the inside of the thigh. The muscles on the inside are much smaller, thus creating the appearance of that diagonal line. If you look on the inside of the knee, you can see the shape created by the sartorius as it wraps around the vastus medialis and inserts just below the knee.

The quadriceps are less defined in most people, and we would note expect to see their shapes so clearly, especially as most people have a deposit of fat just above the knee, but their size defines the shape of the upper leg on all but the most obese of characters.

Back

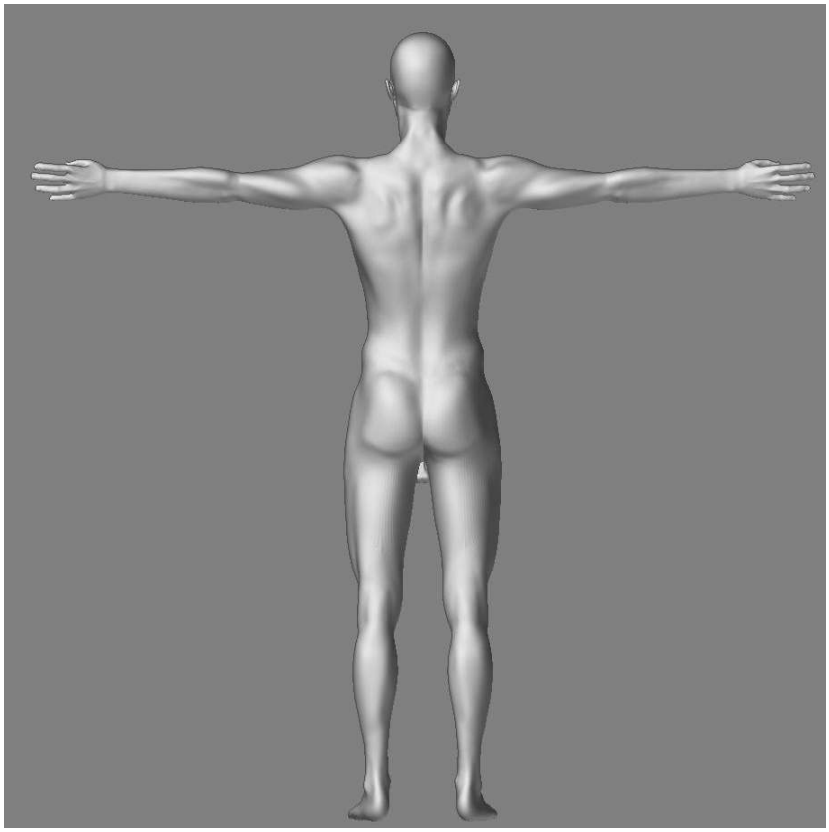


Fig 2.2 (Human back)

I have found the back (fig 2.2) to be the most difficult part of the body to create realistically. The problem here is that it looks very different depending on the build of the character, and the position of the body. In this instance I defined the scapula slightly (the shoulder bone - creating the two bulges in the top of his back, just lower than the arms) because of the position of the arms. We can also see the shape of his trapezius muscle, which goes up his neck, across to the deltoids, and down to the centre of his back. There is very slight definition of the spine in the centre of the very top of his back where it meets the neck. This is an area not covered by the trapezius, and often visible. Underneath his scapula, we can see his latissimus dorsi. This is generally not massively defined, but it is important to understand that it inserts underneath the triceps of the arm, meaning that it is very much affected by the movement of the arm.

The upper arm is defined by the biceps, the deltoid, and the triceps. As the name suggests, the triceps has three heads, and two of these will be clearly separate in a muscular figure, but then both attach to the triceps tendon which runs up from the elbow region along the back of the arm. Note that there is no muscular definition in this region.

The bulk of the forearm is created by the brachioradialis and the extensor

carpi-radialis muscles, which wrap around the arm, originating at that back of the arm by the elbow, and inserting near the thumb. This is important to note, because it creates the curve visible in the relaxed forearm. Also note that they originate slightly higher than the elbow, and higher than the insertion point of the biceps. This means that there is a flow from the upper arm to the forearm, and they should not be seen as two completely separate body parts.

Reference

There are many books that cover exactly this sort of thing, so reference is easy to obtain. The most useful I found was “Anatomy for the artist”. “Drawing the head and figure” was useful too, and also sculpture books are a good reference as figure sculptors understand the human form better than most. “Modelling the figure in clay” is particularly good, as it goes through building a human from the skeleton to the muscles and then finally the skin. Medical books are useful for understanding the purpose and origination and insertion points of all the muscles, but more important is to understand the shapes that they create on the human figure, and for this there is reference everywhere, especially for nude or semi-nude men and women aged 20-30. Fitness magazines and websites are a good starting place. See reference for more details of the books mentioned (and other books used in the production of this project).

Serrakor the Daemon

Age - over 1000 (although reflecting the body of a 25-35 year old human)
Body type - Very muscular
Example of body type in reality –
(sources: bbpics.com and the DVD “Pumping Iron”. See reference page)

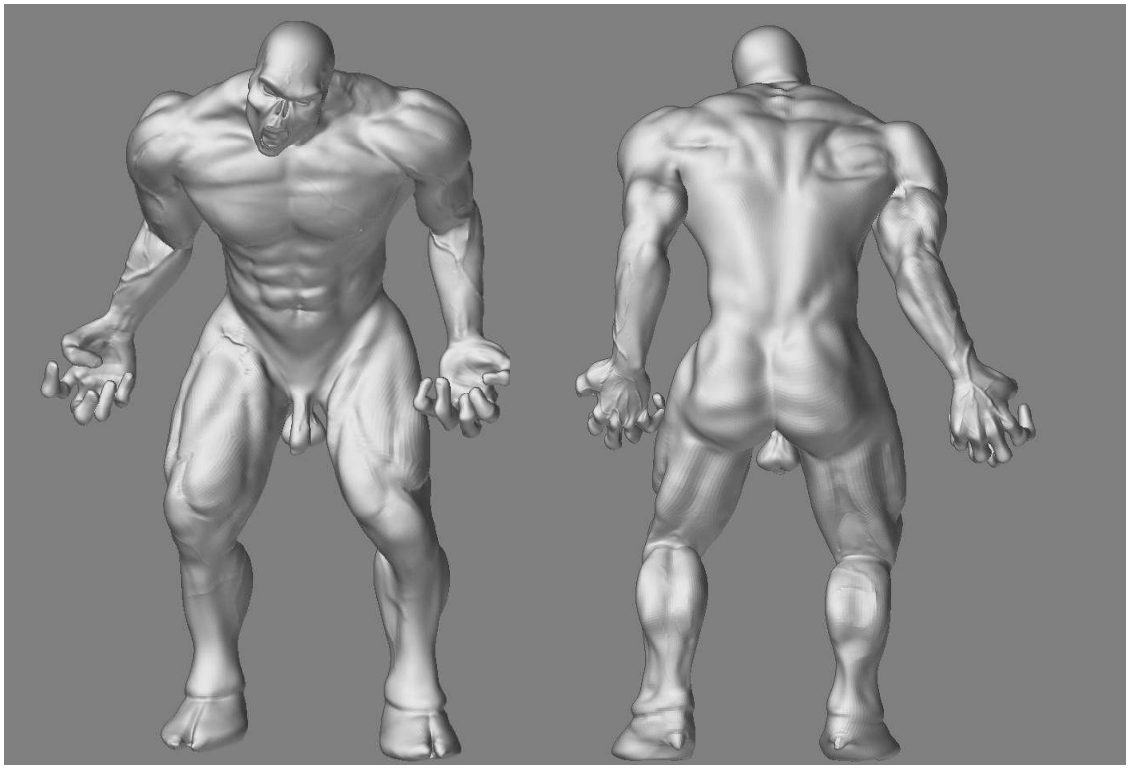


Fig 3(Deamon front and back)

Front

Excluding the head and hooves, we can see that the front of the daemon is not too different to an extremely muscular person. In fact, there is very little "design" to speak of. Reference for his muscles was largely taken off bodybuilders. I felt that in order to keep a degree of realism in the character, no matter how muscular they are, we should not go down the route of just defining every single superficial muscle in the human body. We have to bear in mind how much fatty tissue the character has (in this case not a lot, but some), the thickness of the skin (in this case thick), and what muscles are tensed (this of course is something that should be handled at the rigging/skinning stage in an animated character, but was important for this still, posed character). For example, the sartorius muscle that wraps from the outside of the hip to the inside of the knee is not normally visible, but in an extremely muscular person it would be. However, the muscles on the inside of the thigh are covered with fat, and thus not nearly as well defined. Also, if you watch bodybuilding competitions you will notice a massive difference in the appearance of muscles depending on which ones are tensed. In this pose, I felt the daemon's hands, arms, and upper body would be tensed, and so we can find more muscle definition there. Relatively speaking, there is a lot less definition around his obliques and serratus anterior (the muscles on the side of his torso), because these are not especially tensed, and his is bent forward, which would soften the definition of them somewhat.

It should be noted that on a very muscular physique such as the daemon's, understanding the muscle groupings is as important as knowing what and where the muscles are. Muscles are made up of many fibres, and these all flow in a certain direction along each muscle. In muscular physiques, they form quite noticeable clumps. To the unknowing eye, it might appear that he has lots of muscles along his shoulders and chest, but these are actually just groupings of his deltoid and pectorial muscles. These groupings appear to be especially noticeable along the chest, shoulder and back.

Notice that his veins are noticeable on a large portion of his body. This is again something that I observed in body builders (and even toned it down a little, since some reference of showed body builders covered in veins that it looked a bit over the top). The very large veins were based on the position of real veins within the body, as I felt people may subconsciously notice something as wrong if these were wrong. The smaller ones (which are on his arms, chest, shoulders, legs, and head) are approximations based on photographic reference.

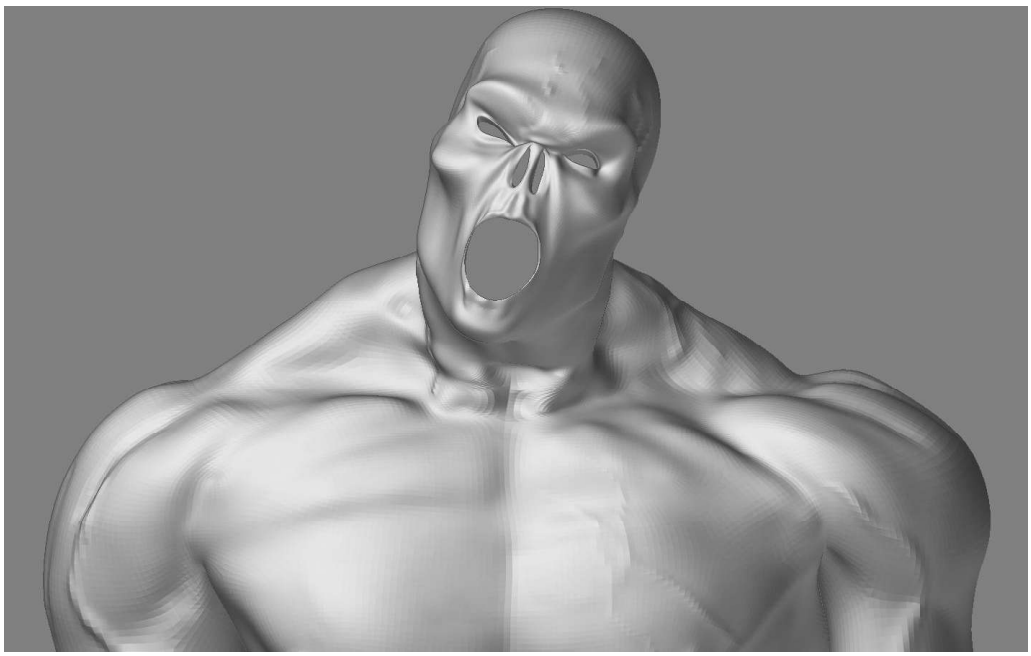


Fig 3.1 (Daemon face front and chest)

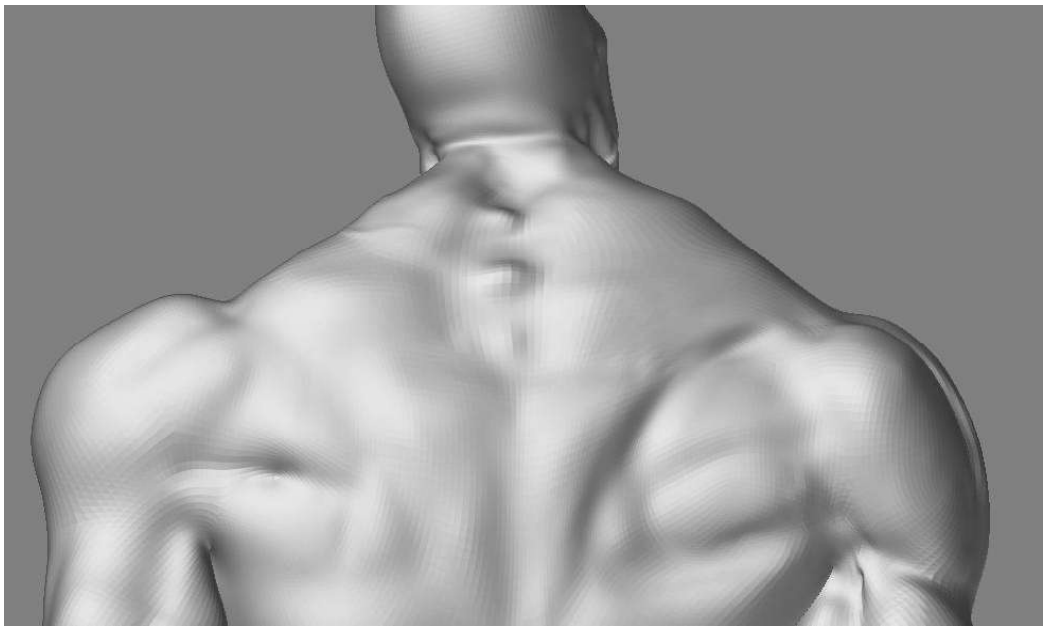


Fig 3.2 (Daemon Back)

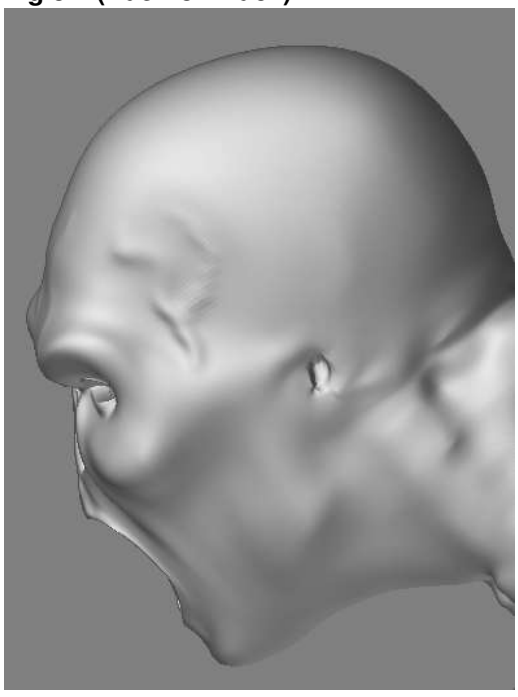


Fig 3.3 (Daemon face side)

Face

I felt the daemon's face (fig 3.1, 3.3) needed to be changed significantly from a human face in order to define him as something other than human. In order to make him scary, I tried to play on our natural fear of death by making his head quite skeletal. However, since he is so hugely built, it would look quite odd if he were to have a head that was too heavily influenced by a skull, so instead I just

borrowed a few skull-like features.

From the front (fig 3.1) we can see that he has no nose, just holes directly in the skull. His cheek bones are very noticeable and clearly defined, and around his mouth, the skin is dimpled in the same way that the underlying skull is to accommodate the teeth. However his brow is angry and furrowed, which indicates that there is enough skin and muscle there to achieve this look. Also creases either side of the nose reveal a reasonable amount of flesh.

Here we can't see the teeth (they were made as separate objects in Maya), but they are fairly sharp in order to allow the daemon to bite through fresh meat with ease (unsurprisingly, he is carnivorous). As with most predators (even humans), the canines are larger and sharper. This was exaggerated in the daemon, to give him similar canines to a lion, since he is a hunter.

From the side (fig 3.3) we see that he has no ear, just a hole directly into his head - the same as on a skull.

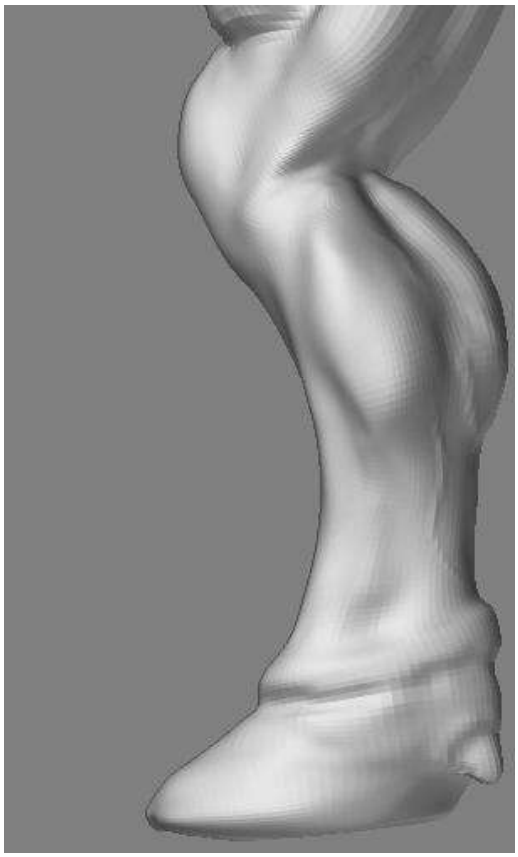


Fig 3.3 (Deamon Hooves)

Hooves

The choice to give him hooves was partly to get away from just creating a body builder, and partly as a consideration of his environment. Since he comes from hell, we can assume the ground will be hot enough to scorch flesh, and so with a little imagination it is feasible that one might evolve to grow hooves if living there. The transition from lower leg to hoof required some consideration. In the real world, hoofed animals are all quadrupeds, and since their weight is distributed across four legs rather than two, their lower legs have relatively less muscle mass than humans. Since the daemon has only two legs, I decided to leave his lower legs with the original human muscles. I defined the peroneus longus and tibialis anterior mucles, which are visible running down the outside front of the lower legs, and in retrospect I think it may be worth taking these out, as their purpose is to aid mobility in the foot, which would not be needed.

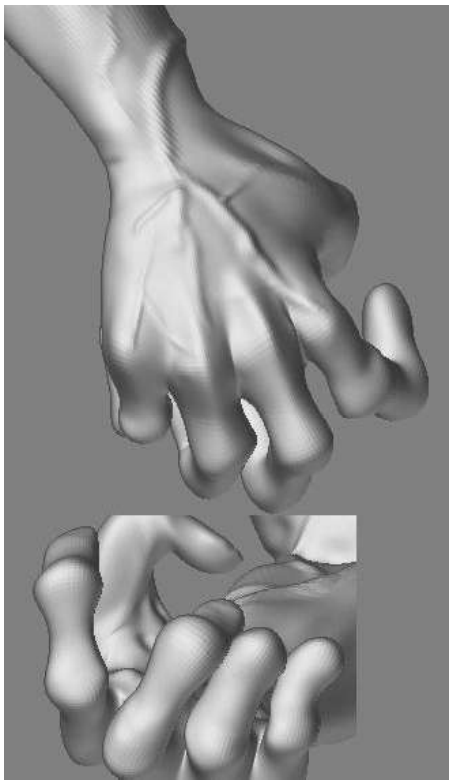


Fig 3.4 (Daemon hands)

Hands

As with most of the daemon, the hands (fig 3.4) are quite human. However, since he his head is based on a skeletal shape, I wanted to reflect this in his hands - so although they are very big and muscular, the shapes of the bones are quite visible in the fingers. Something not seen here are his claws, which, like the teeth, were made as separate objects in Maya. They are huge and sharp, as the daemon uses them in catching prey.

Reference

As might be expected, the bulk of reference for the daemon came from bodybuilders, especially as showing off their bodies is their job. As always, the internet is a good source of reference, and also any books made to instruct would-be bodybuilders. Most of my photographic reference came from a DVD

entitled “Pumping Iron”, which follows a young Arnold Schwarzenegger as he competes for his 6th Mr.Olympia title. It has great reference of Schwarzenegger and many others training and competing. For in-depth anatomical reference, “Strength Training Anatomy” is an excellent book filled with illustrations of the positions of people’s muscles (male and female) as they weight train. This is also a useful book for any anatomy study.

Gruncher Swamp Troll

Age - 47
Body type - Obese with strong underlying musculature
Example of body type in reality –
(source: phototravels.net, see reference page)

The troll was firstly a study of the overweight/obese body type, and how we can use it to define a certain type of character. Secondly, I wanted to show that subtle changes to the anatomy, borrowed from elsewhere in nature, can help make a character slightly less human, and reflect the environment it’s grown up

in, and what it's evolved from.

Although he is substantially larger than the average human, the overall proportions of the troll are fairly dumpy - he is a long way from the ideal eight heads in height. This is because I wanted him to look clumsy and lumbering.

Whilst the troll was a study into the overweight/obese physique, as a character he is a fighter, and so his body has a fair degree of underlying muscle - making it more akin to a sumo wrestler than a couch potato.

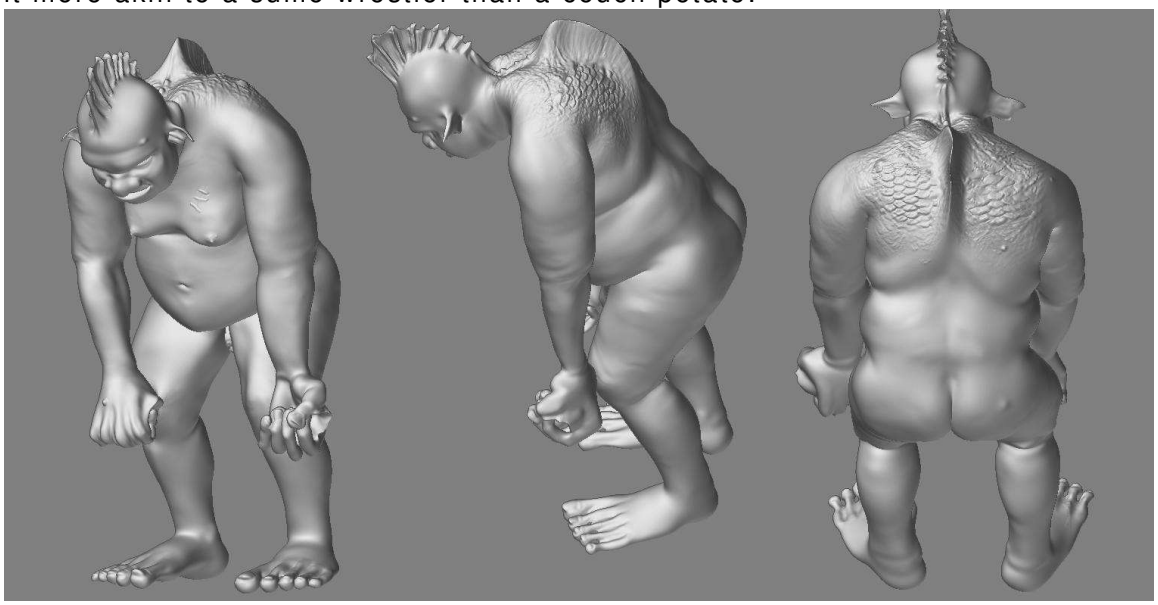


Fig 4 (Troll front, side and back views)

Front

From the front, we can see that the forms his body creates are mostly dictated by his large fatty deposits. His belly is large and smooth - in a less overweight person, we would see "rolls" of fat, especially in this hunched pose, but with a certain amount of fat the stomach gets pushed out to create a big smooth belly. The fat in his pectoral region is substantial, and creates breasts which droop over the stomach.

There is enough muscle in his arms and legs to define a recognisable shape there - the bulges created by the deltoids (shoulder muscles), biceps, and forearm muscles can be seen, but are well rounded off by the general body fat.

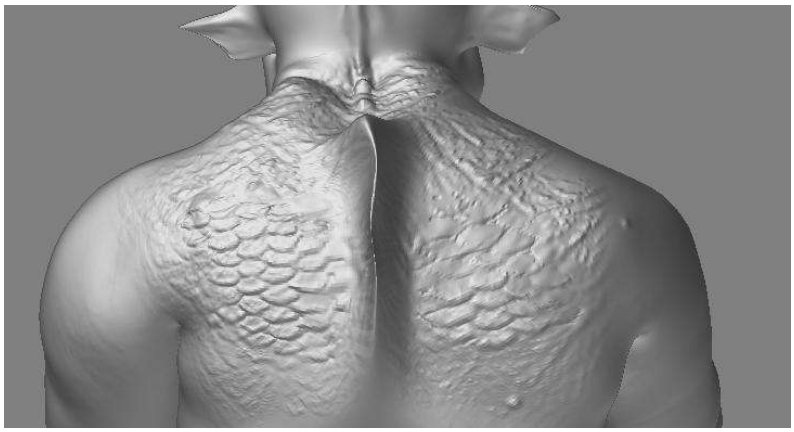


Fig 4.1 (Back with scale detail)

Back

The roll of fat created by the troll's breasts continues round and up the back. A point of interest in creating fat people is that the skin folds curve upwards from the side as they get closer to the centre of the back. General bumps and indentations follow this curve as well. The upper back is covered by scales – a small detail left over from his ancestors. Cellulite is visible along the bum and legs.

Fig 4.2 (Troll face and chest)

Face

As always, the face (fig 4.2) was a good opportunity to bring out the personality of the character. Out of the six characters, I made the troll the most asymmetrical – I wanted it to show the toll of years of getting smashed around

and general bad treatment. The features of the face were designed to give him an air of stupidity, so I played on the cliché and based them on an exaggerated Neanderthal man - heavy set brow, protruding under biting jaw and a wide nose. To integrate it into the rest of his body, I added a few fish like qualities, the most notable of which is his eyes are set wide apart and point slightly to the side of his head. His ears are floppy and fin-like, and he has a fin which runs down the middle of his head. Like on many fish for example the Porgy, the fin closest to the head has thick and well defined fins, whereas the ones along the back are
finer.

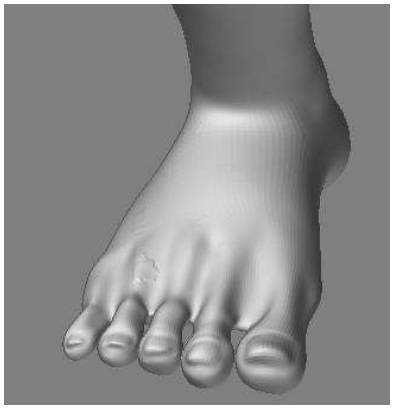


Fig 4.4 (Troll foot)

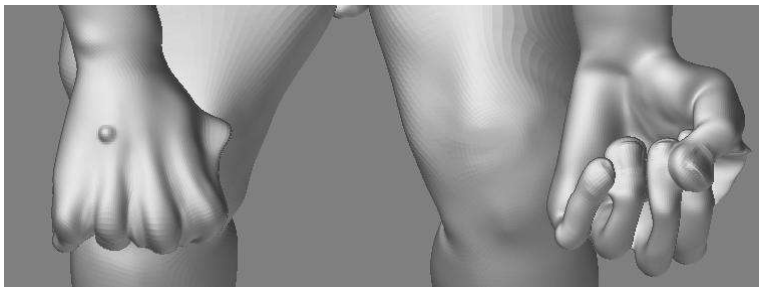


Fig 4.5 (Troll hands)

Hands and Feet

His hands and feet (fig 4.4 and fig 4.5) were more influenced by his amphibious ancestry than his fat.
They are abnormally large relative to his limbs and torso, which is to make them
more useful for movement through water. The webbing between the fingers and toes also aids in this.

As in other amphibians, there is very little fat stored in the hands and feet
and so the bones are quite noticeable beneath the skin.

Wizard

Age - 93
Body type - Old, thin, and frail
Example of body type in reality –
(sources: Waking Ned, DVD, and www.agavemedia.no. See reference page)


The wizard was a study of an old and quite frail body structure. Out of all the characters, I felt that the wizard was the one least defined by his anatomy, as we are accustomed to seeing wizards well covered up in robes. However, I thought it was necessary to include an old body type in order to fully investigate as many different ones as possible - and the human body changes a lot with age.

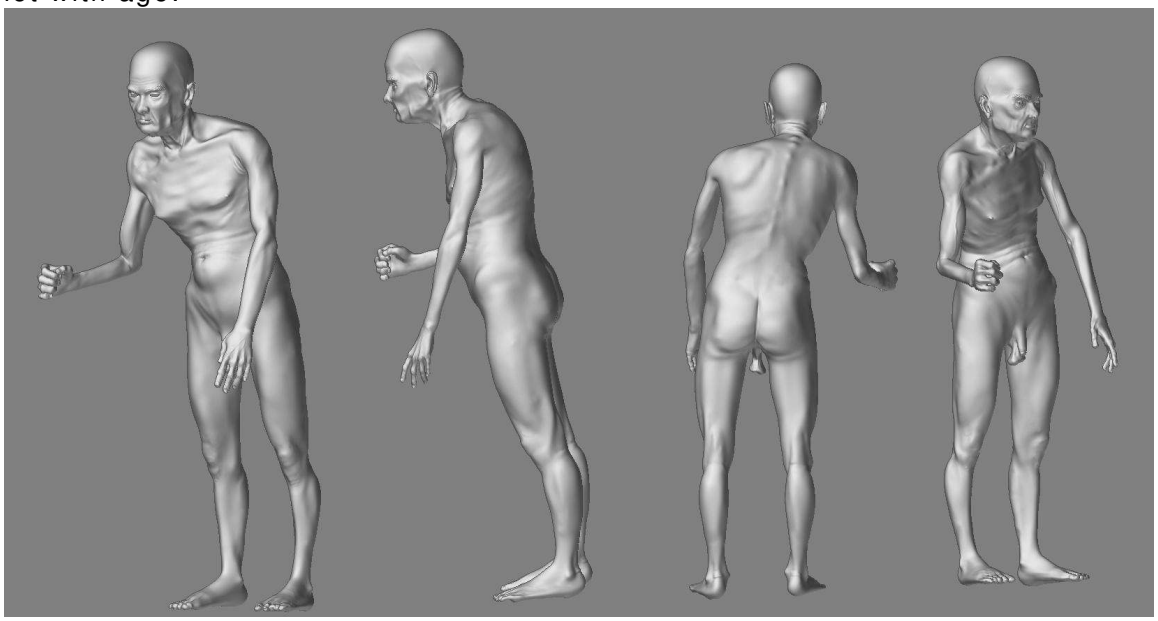


Fig 5 (Wizard from front, size, back)

Body

The main changes in appearance in an old person are driven by a number of things - much smaller amounts of muscle, smaller amounts of fat and looser skin. This means that the skeleton plays a larger part in defining the shape of an old person compared to a younger person.

For example, from the front (fig 5), the wizard's hip bones jut out, creating a clearly defined shape there. The ribcage is visible, and the ribs are visible along the side and back. The arms and legs look thin and frail - this is just due to the reduction of muscle and fat.

The muscles are small but often clearly defined, we can see the muscle groupings of the pectorial muscles creating indentations along the chest, and his bicep and forearm muscles are quite distinct.

As a rule of thumb, skin will wrinkle and sag wherever it has the chance - we can see that the position of the wizard's head causes wrinkles in his neck, the skin around his pectorials has sagged, creating small drooping breasts, and similarly the skin around his buttocks has sagged and creates wrinkles easily.

Also note that the body loses a lot of its natural curves, far example the outward curve created by the deposits of fat in the buttocks has declined significantly with the reduction of fat there. Overall, the body is more angular, as it's shape is defined more by bone than muscle or fat.

The pot belly is often seen in old people, but not always. It would depend on the type of lifestyle that the character was living or had lived in the past. I found that if my old character did not have a little bit of a belly, he came across a lot more frail. As with the rest of the body, the skin wrinkles here, but if the belly was larger, we would see less wrinkles as the skin got pushed out. If it was not there, we could expect to see many more wrinkles.

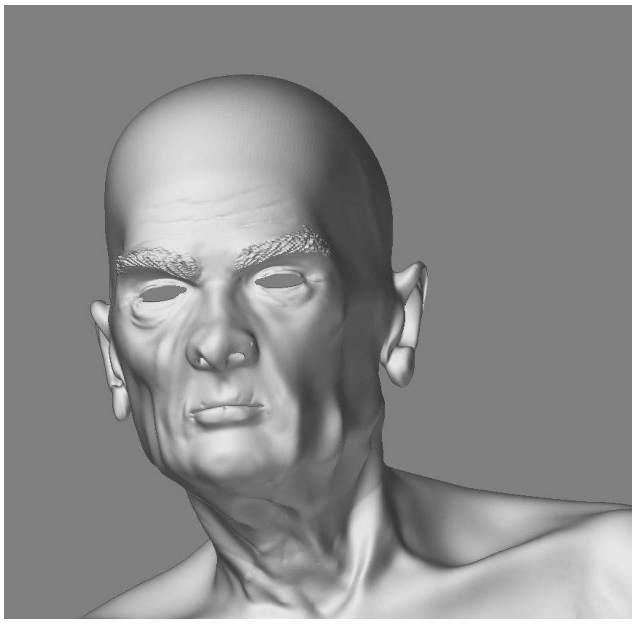


Fig 5.1 (Wizard head, without beard)

Head

As with the rest of the body, the bone, so in this case the skull, has a large impact on the look of the head. The temples appear to dip in, whereas in a younger character the temporalis muscle there would have given it a little bit of bulk, the cheekbones are clearly visible, and the skull creates a raised line from the eye to the ear. The jaw is less visible, as the loose skin hangs off it. The loose skin also causes wrinkles around the eyes, forehead, and mouth. The upper lip has lost volume, and is barely visible. The ears and nose appear larger. The skin sags a great amount around the neck.

The face was an opportunity to give the wizard some character, I wanted him to come across as mentally tough and driven, despite his fragile body. This was partly achieved through his expression, but I also based gave him a skull that would, in earlier years, have shown through as a very male one, with a chiselled jaw. His bushy eyebrows are fairly typical of an old man, but add to his slightly stern look.

Trevor the Zombie

Age - 30, plus 4 months dead.
Body type - Rotting

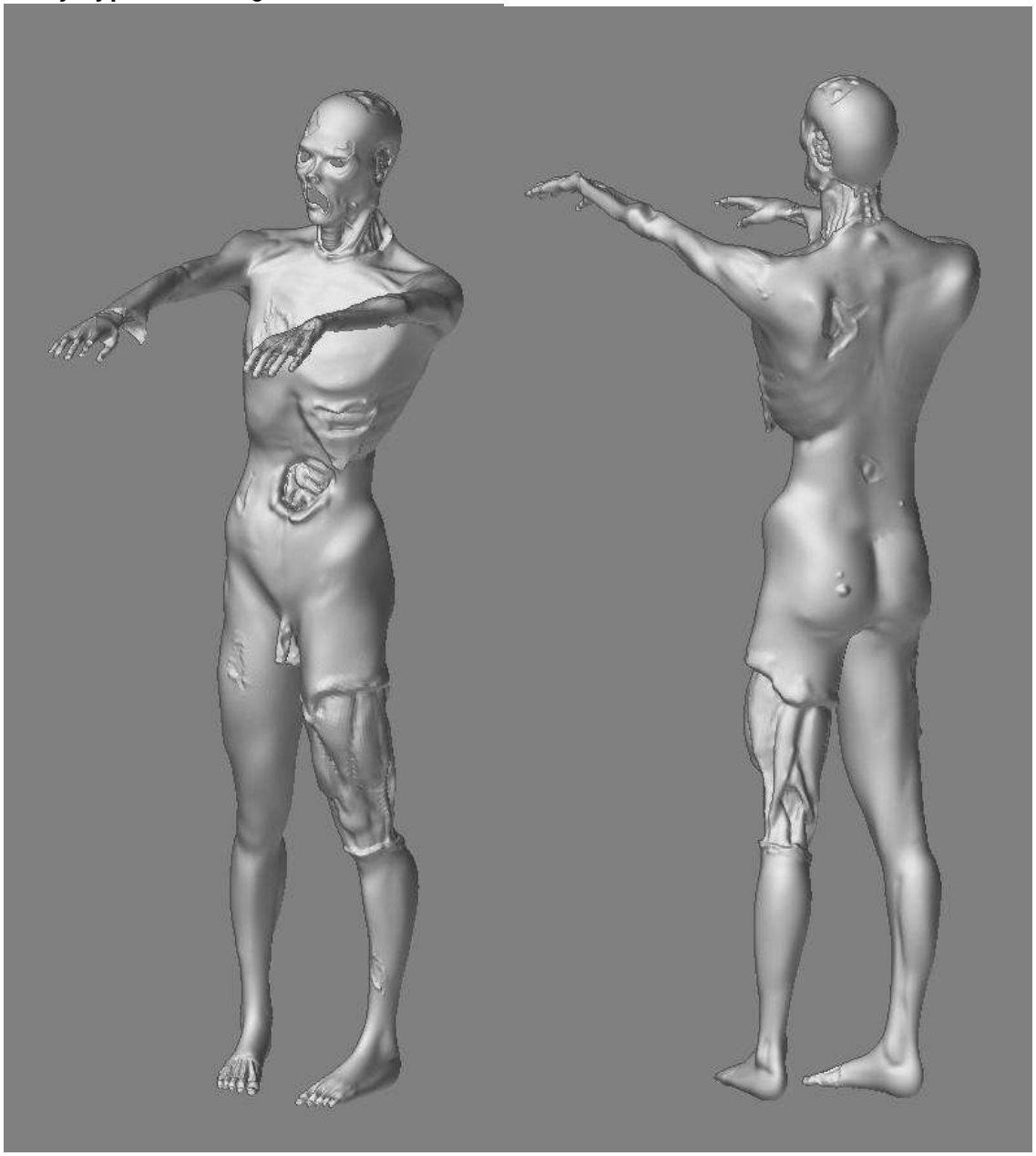


Fig 6 (Zombie front, left, and zombie back, right)

The zombie character was made to explore how we can take an ordinary human figure, and by revealing some of the underlying anatomy, make it a horror character. This relies on most peoples' aversion to death and gore, so by creating a character that displays both, we should be able to create something that most people will find unpleasant or horrific to look at.

The base proportions of the zombie are the same as the normal man, and the adjustments were just made on the basis of what decided might happen to our man if he had died, been buried for a while, and come back from the dead.

In film, there are two types of zombie - those that have come back from the dead after rotting for a while, and those who have just recently died and been zombified. For a more interesting character, this zombie has been dead and buried for four months.

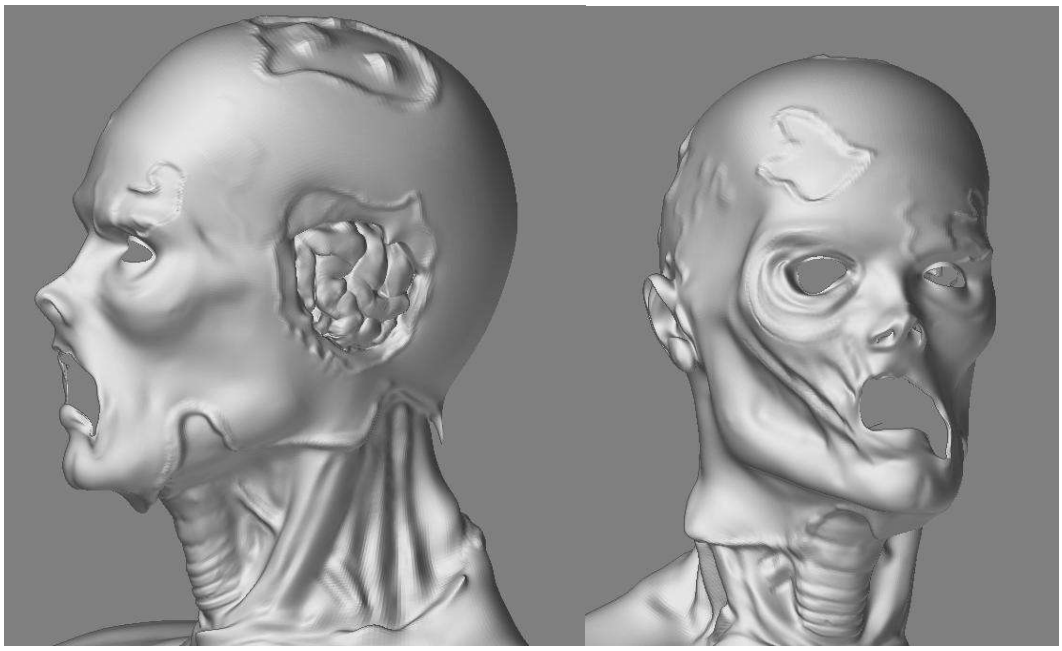


Fig 6.1 (Zombie head right side, and zombie head front)

With a character like a zombie, there is a huge amount of scope for adding things to the character just because people find them unpleasant. So for example, the most notable thing when we view the head from one side (fig 6.1, left) is the brain there. Why his brain is are visible is not important, it could be in the incident that killed the man in the first place, or perhaps it was something that happened to him in his zombified state. Regardless, as long as it reads as a brain, it should have the desired effect as people are generally uncomfortable seeing the insides of a human body. One thing to bear in mind with brains is that even though there is a lot of intricate detail created by it, the surface is generally fairly smooth, and if we silhouetted it, we would see that it is less bumpy than we might believe. The effect is similar to packing a lot of sausages tightly into a small compartment - we see a lot of detail, but the shape is roughly that of the compartment. Again, I was trying to imagine how it would look if this was an injury in reality, and so we see that the skull is visible all around the brain, and around that we see skin, which has come away from the very edges of the skull. On the other side of the head we can see the skin has rotted, leaving the shapes of the underlying muscles around the eyes and

running along the cheek to the mouth.

One idea that is repeated in several places around the zombie is the idea that his skin been torn off completely from certain areas of his body to reveal the muscles underneath, and the neck (fig 6.1, 6.2) is a nice area since we have quite a few little muscles there to detail in, and the sternocleidomastoid muscle cuts across it diagonally, creating an aesthetically interesting effect. One important thing to notice here, however, is I chose not to show the muscles exactly how they would appear if we took the skin off. In reality there is a sheet muscle covering the entire surface of the neck (the platysma), which if it was left in would in all likelihood confuse people, since most are not familiar with its presence. Also, the muscles on the front of the neck were removed to reveal the trachea (windpipe). Again, this was because I felt it would be something more recognizable to most, and also more aesthetically interesting. Essentially the point is that we should feel free to play with anatomy to make it serve the purpose we want - after all, this is about creating characters, not replicating ourselves.

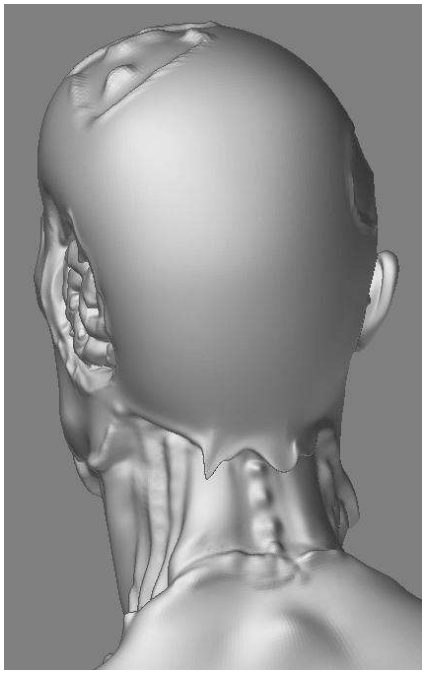


Fig 6.2

Figure 6.2 shows us the back of the neck, where we can see the skin is missing, revealing the underlying trapezius muscle, as well as the top of the spine, since the muscle doesn't completely cover the spine.

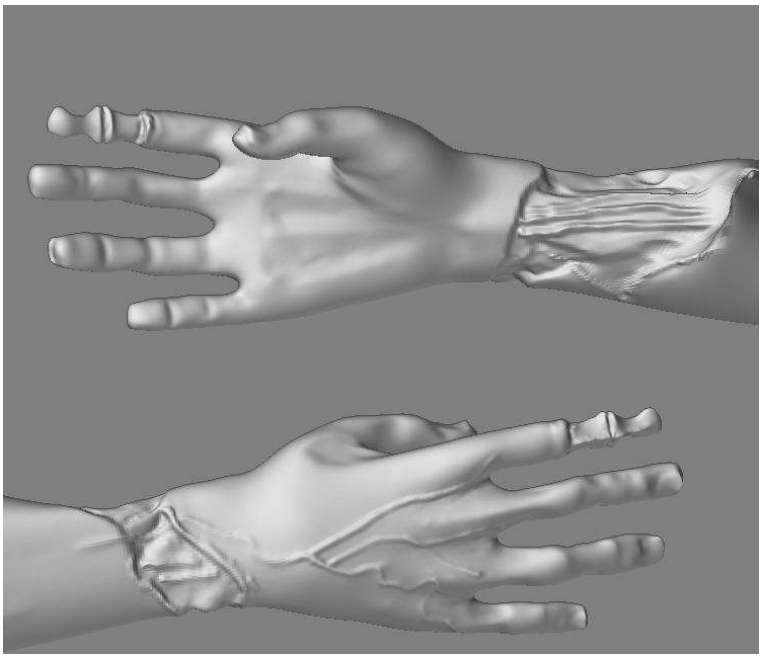


Fig 6.3 (Zombie right hand, showing missing skin around wrist and finger)

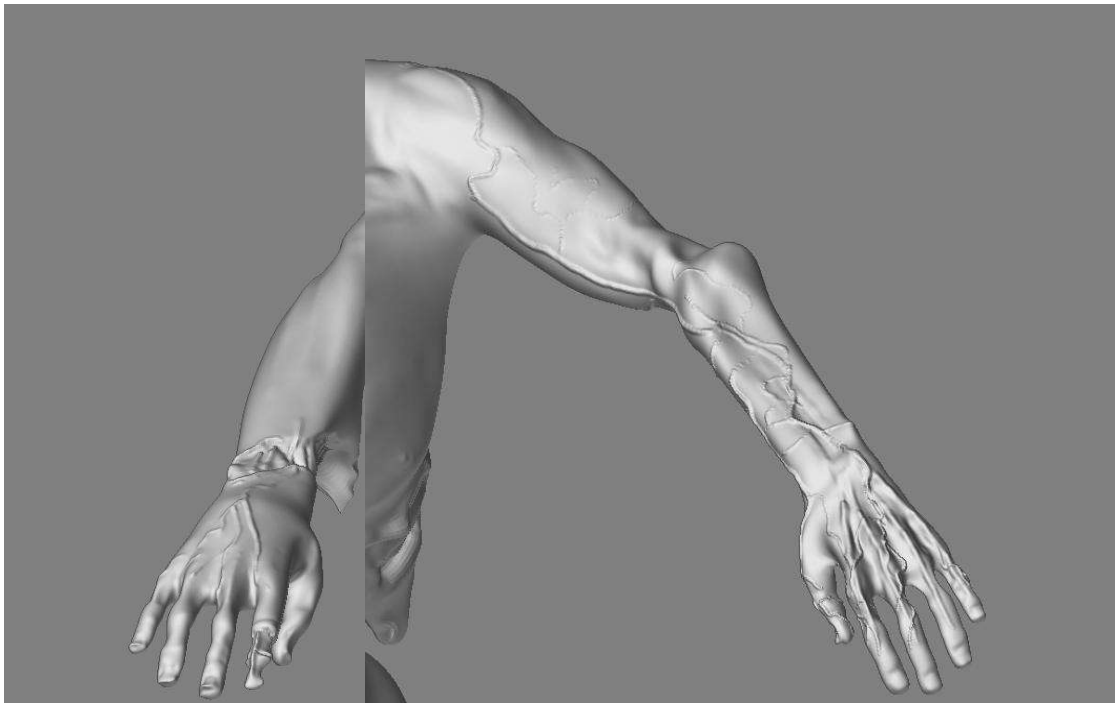


Fig 6.4 (Zombie right arm, on left, and zombie left arm, on right)

I chose to go in completely different directions on the arms (and hands) (fig 6.3, 6.4), exploring two different possibilities that may occur to an undead

being. With his left arm (fig 6.4, right side), I decided that the muscles had almost completely wasted away, leaving only bone definition on the forearm and hand. To add to the unpleasantness, I decided that the veins may still have blood pumping through them, and coupled with the now very wasted away skin, these would be very visible across the whole area. As with most of the veins on these characters, the main ones are anatomically correct, and the smaller ones are educated guesses based on reference.

With his right arm (fig 6.3, 6.4 right side), I decided that the muscles have not completely wasted away. Why they would waste on one side and not the other is anybodies guess (maybe he was lying strangely in his coffin), in fact it may add too much asymmetry to this character. I gave him fairly strong muscle and bone definition however, since the skin would also be quite thin and reveal the underlying structure more. This was also an area that I chose to remove some skin. Underneath we can see the tendons of the forearms muscles inserting into the hand (the forearm muscles turn to tendons roughly half way down the forearm. The tip of the index finger also has the skin removed, just as a little ghoulish detail. The tendon can be seen on top of the bone (and slightly explains why the bones haven't just fallen off).

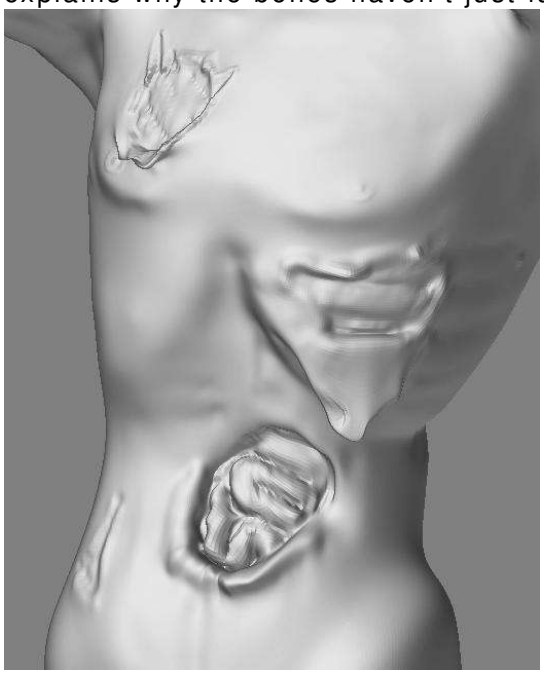


Fig 6.5 (Zombie torso front)

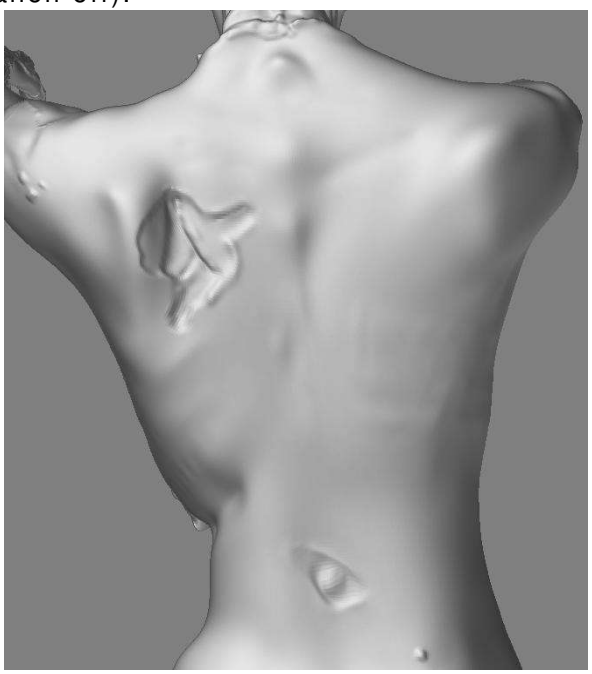


Fig 6.6 (Zombie torso back)

From the front (fig 6 left side, 6.5) we can see that his intestines are clearly visible. One thing that is missing from this picture (because it was added as a separate object in Maya) is some of his intestines are hanging out. The left side of his body (his left) is considerably thinner than his right, because this is where the hole is, and so this is where most of his organs have already

dropped out. Missing skin reveals his ribs (on his left), and the diagonal muscle fibers of the pectoral muscle (on his right).

From the back (fig 6 right side, 6.6)we can see a slight indication of his ribcage. This is not normal for a male (unless they are underweight), but I put it in because his skin is so thin and his muscles are so wasted that it is likely that the ribs would show through. His scapula (shoulder bones) are prominent because of the position of his arms, and also because of the thin skin and muscle covering them. The missing skin on his lower back reveals a mound where his spine is (in retrospect I feel it would have been nice to have his actual spine showing through - currently it is just a bump caused by the spine being covered by muscle and fascia). The missing skin around his left scapula reveals the muscles there (the trapezius, and underneath the infraspinatus and teres major). His buttocks are devoid of fat and thus shows the shape of the underlying gluteus maximus muscle. The sores on his bottom were added because he probably carries an untold number of diseases, and these were a way of showing them that would hopefully make the audience uncomfortable.

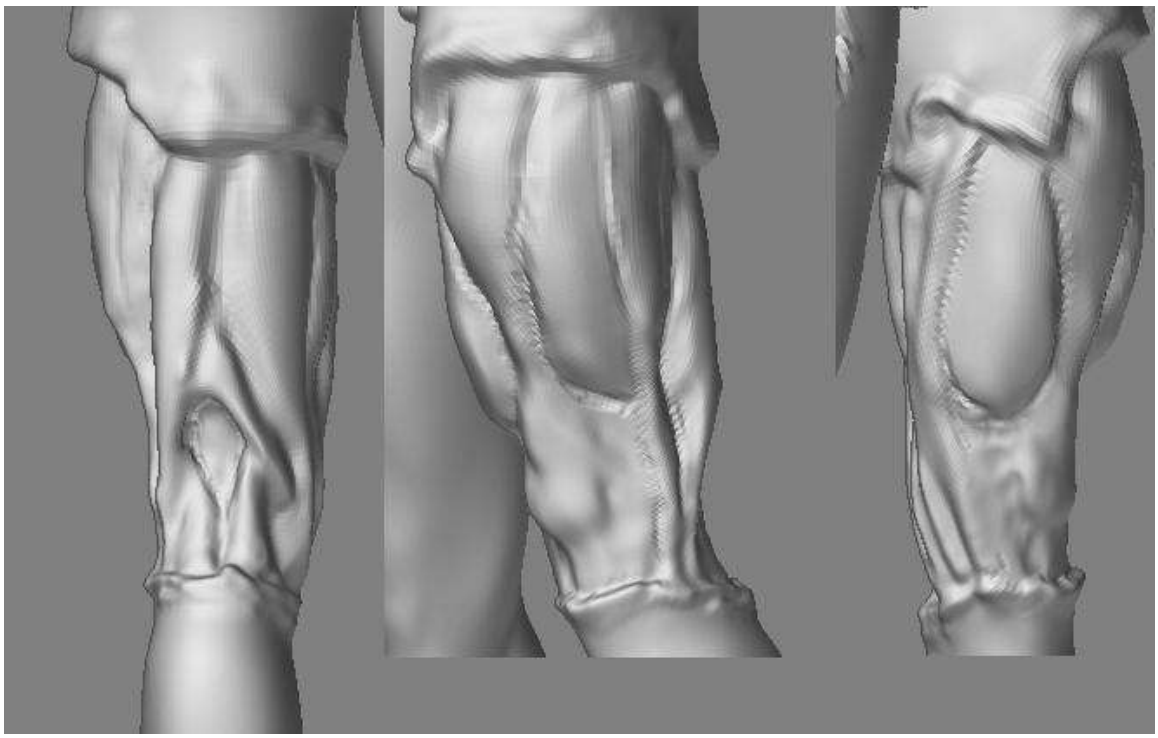


Fig 6.7 (Left – back view, middle – three quarters outside view, right – three quarters inside view)

His legs were made fairly thin and frail. The inside of the thigh carries a large amount of fat, and since I did not want the zombie to carry any fat, this was mostly taken away which thinned out the leg considerably. His left leg (fig 6.7) had a large amount of skin missing. I chose this area as the largest area with

missing skin because I find the muscle so interesting around there. From the front, we can see his quadriceps, held together by his sartorius muscle (the long ribbon-like one that wraps around the inside of the thigh. Looking to the inside of his thigh, we see the muscles there, such as the gracilis, inserting by the knee, and from the back we see his hamstrings (biceps femoris and semi-tendinosus), and just the top of the two heads of his calf muscle (gastrocnemius). On the back and front of his knee we would expect to see some fat, but this is long gone. The important lesson here is that not only is anatomy important if we want an audience to believe our characters, it also makes our job a lot easier. Designing such a fascinating and interesting pattern of muscles as can be found in the leg would be a very difficult process, but fortunately nature has already created this design for us.

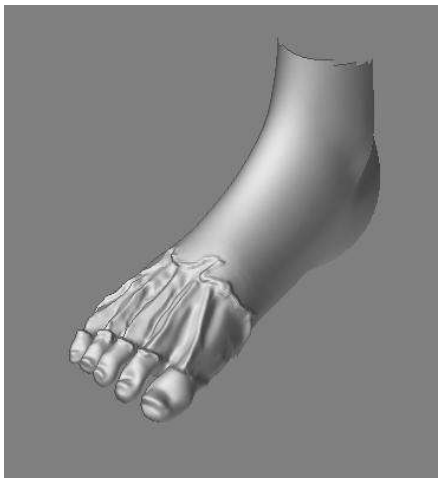


Fig 6.7 (Zombie foot, showing tendons)

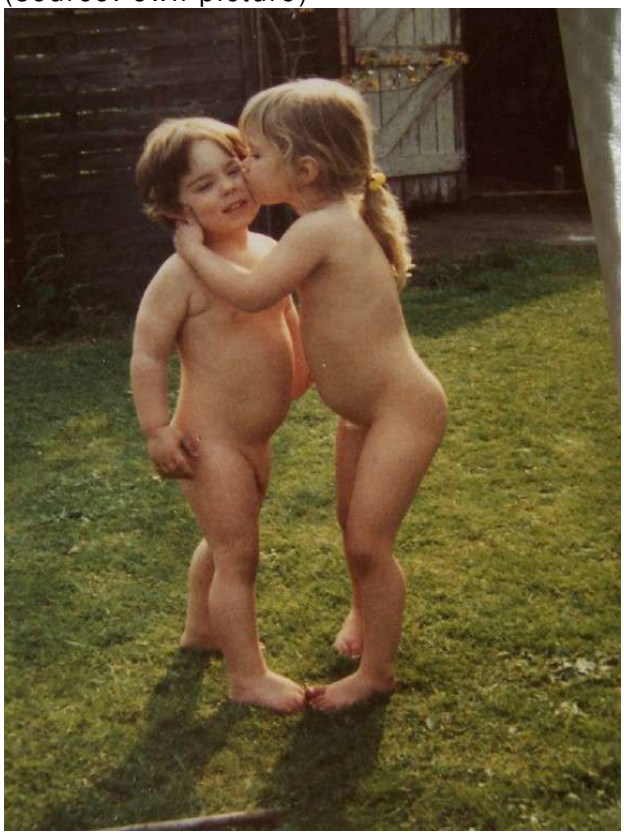
His feet were, like the rest of him, wasted away and thus visibly more skeletal than the rest of him. His right foot has some skin missing, revealing the tendons that insert into each toe.

Reference

Zombie films are useful of course (anything by George Romero), but are not necessary, since when you understand the anatomy you can freely create your own zombie without ever needing to see someone else's creation. If you can stomach it, corpses are an obvious, if unpleasant, source of reference. Gunther Von Hagen's live anatomy studies are very useful, as he uses fairly recently deceased bodies, and also cuts them open to reveal the organs, all the time describing the various parts of the body, making it useful for body and organ reference. His book "Bodyworlds" (based on the exhibition) also contains organ reference and descriptions.

Marco the Cherub

Age - 18 months
Body type - Child
Example of body type in reality (slightly older than 18 months) –
(source: own picture)



A good looking baby can be guaranteed to make most people smile and coo. Understanding what it is that provokes this reaction is very important when creating any young character, fictional or real. It can also help with creating more attractive adults. As a rule of thumb, the closer a person's facial features are to baby features, the more attractive they are. I've found this more applicable to woman and "pretty" males (i.e. males with more feminine features).

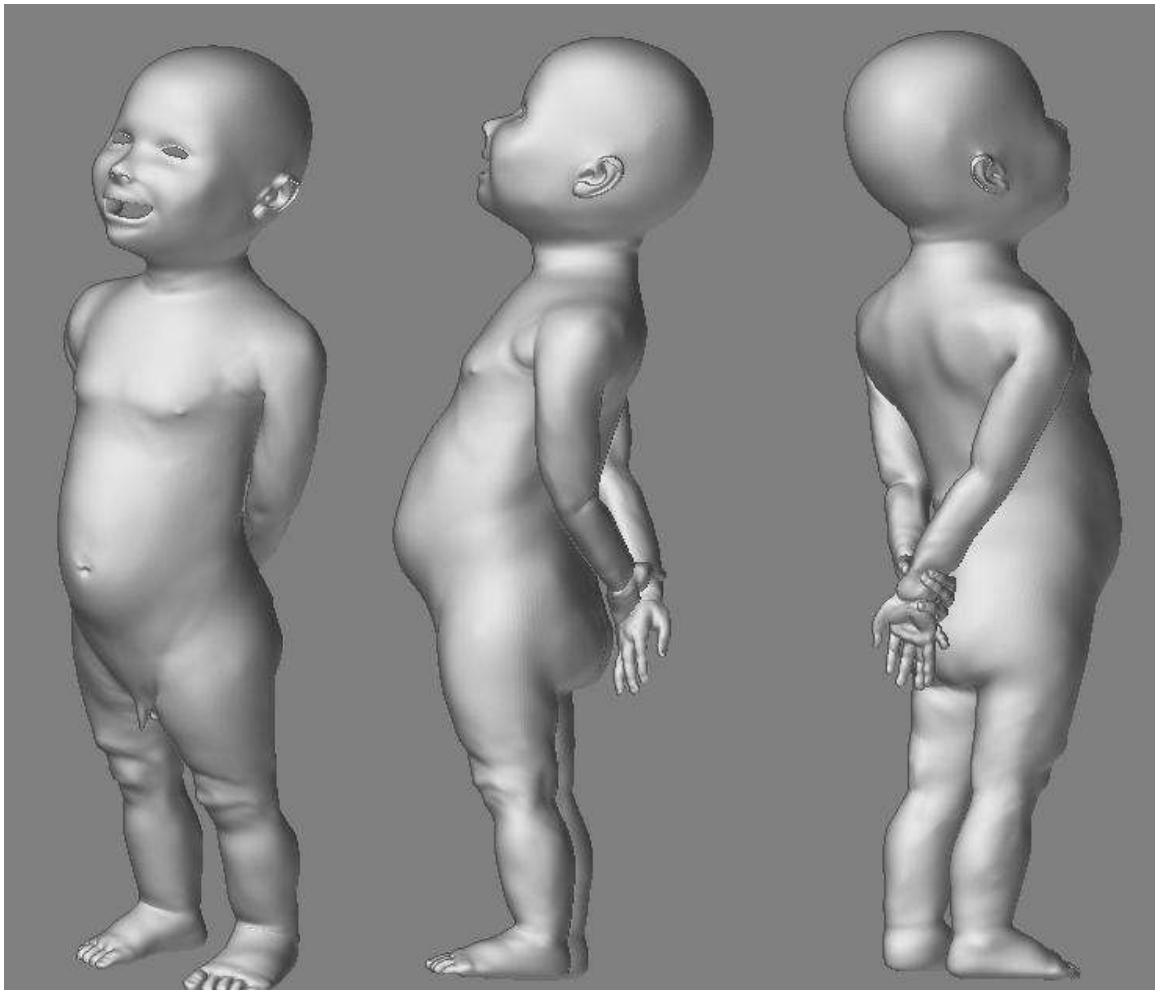


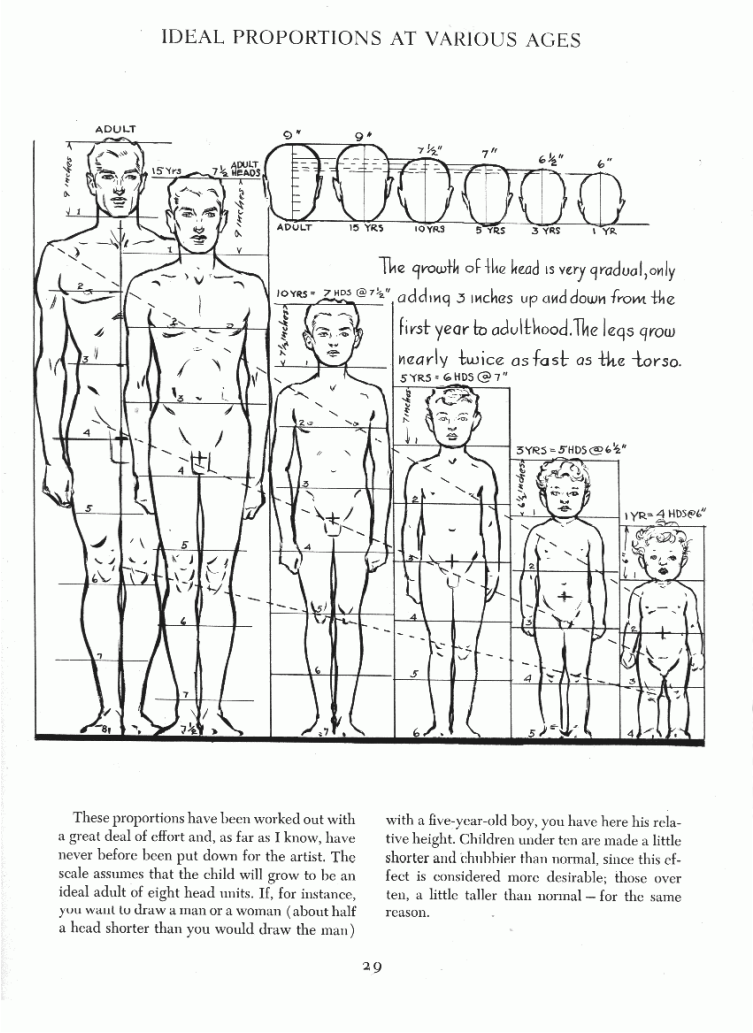
Fig 7 (Cherub without wings. 3 quarter front view, side view, and 3 quarter back view)

Head

The first thing to notice is the head size in relation to the rest of the body. If we measure the proportions by ideal human proportions (eight heads in height), we can only ever end up with something that looks adult, no matter how small we make the character. Figure 7.2 shows us Andrew Loomis's researched ideal baby proportions, and we can see that by his reckoning, a one year old baby will only be around four heads high, and the size of the head is only around three inches shorter than an adult head. This is very important, because it is this comparatively large head in comparison to the body that allows us to instinctively read it as a baby at a glance. To highlight this, figure 7.3 shows a silhouetted baby and a scaled down silhouetted male. Hopefully it will be immediately apparent which is which.

Also note the relative size of the facial features of a baby's head – relatively

large ears, large eyes (since the eyeballs do grow, but only slightly), and small nose and mouth. These are things that should be noted when trying to create an attractive adult character.



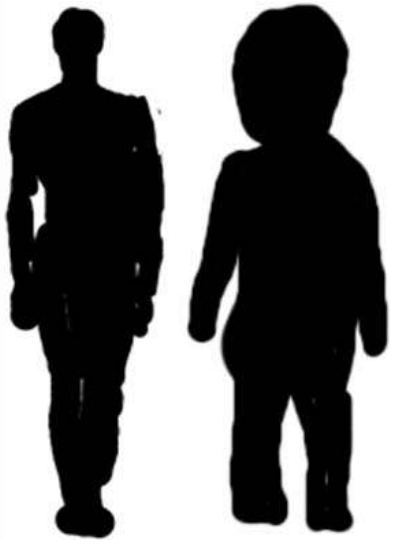


Fig 7.2 (Loomis proportions diagram) **Fig 7.3 (silhouette of baby and adult)**

Torso and limbs

The torso and arms bear a closer correlation to an adult body than the head - the arms are relatively slightly shorter, and rest slightly higher up relative to the thigh than in an adult, and the relaxed elbows can be marked slightly higher above the belly button than on an adult.

The legs, however, are considerably shorter relative to the rest of the body. In a full grown adult, we can expect the legs to be roughly half the length of the body (four adult heads in length). In a baby, the legs are generally under four

(baby sized) heads in length, and this is what lends them their “dumpy” look. One thing that should be worth bearing in mind is the fact that babies (and generally young people’s) bodies change drastically over a short period of time, and Loomis notes that the legs grow nearly twice as fast as the torso. This largely accounts for the large difference in the proportions of children depending on their age (for example, a one year old baby, an eighteen month old baby, and a three year old are all quite different), so remember that an older child is not just a “scaled up” baby, but that the torso and head will only grow slightly, and the majority of change is to be found in the legs. Coupled with the head, the size of the legs are one of the most important things for your character to instantly “read” as a baby.

In young children, chubbiness is regarded as an attractive thing, the sign of a healthy baby. If your baby character does not have an ample amount of baby fat, it’s going to look ill or starving, rather than cute. Of course, this may be desirable for your character, but in the case of this cherub I wanted a character that would make people instinctively smile when they saw it, and for this, baby fat is a must.

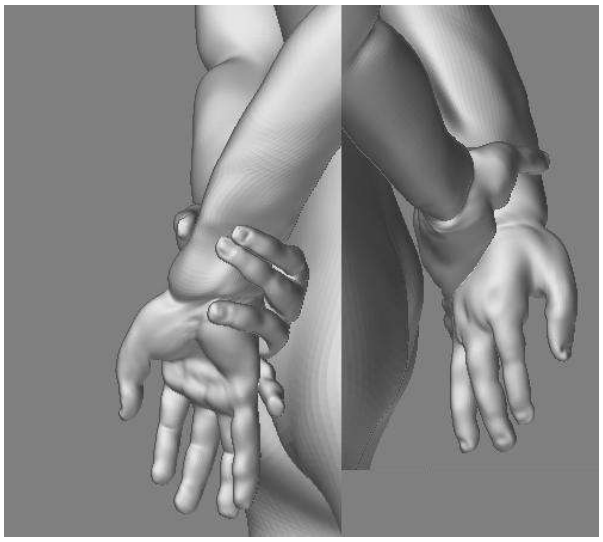


Fig 7.4 (Cherub hands)

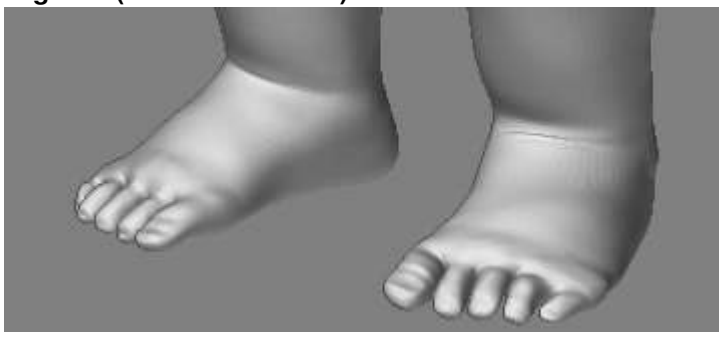


Fig 7.5 (Cherub feet)

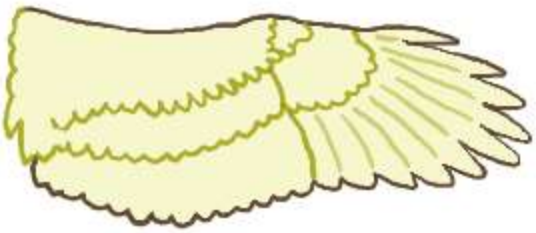
Hands and feet

The hands and feet of a baby (fig 7.4, 7.5) are also slightly smaller compared to the rest of their body. For example, by my measurements, a human hand will only fit around one and a half times into the forearm, whereas a baby's will fit around two and a half times. As with the limbs and torso, the appearance of the hands and feet are largely dictated by baby fat – note the lack of bone definition in the fingers and toes, they are more "sausage-like" than most adults. Also there is often a visible crease around the wrists and ankles where the fat overlaps.

Wings

Whilst of course human's don't have wings, to create a believable character I felt that the wings needed to grounded in a degree of anatomical correctness, but also be able to carry a human. A little research into bird anatomy reveals that there are four types of wing (source: http://orion.animaltracks.net/winga.html) -

From there, we see that one type in particle fits the description for the Cherub: (taken from source)

> **"The slotted high-lift wing**.
>
> 
>
> Birds that soar over the land, such as owls, vultures, eagles, and hawks have long, wide wings with many slots. The design combines manoeuvrability with efficient gliding, enabling the birds to circle in **thermals** (small updrafts of warm air that occur over land.) This wing shape, in an area with good thermals, can allow a flying creature to be, by design, far bigger and heavier than they could be in other environments. It's the same shape imitated by hang-gliders."

(end of source)

Provided we can assume that our audience will not have a great knowledge of

these different wing types, it would be overtly pedantic to insist that if our characters have wings that would best suit their environment, especially if our characters are humanoid in nature (if we were creating a bird-like character, however, it would be wise to give it a wing type that we can expect it have). When designing the wings for the cherub, I wanted something that would suit his body structure, which was the shorter wing types, and the “slotted high-lift wing” would seem best suited to carrying a whole human, and also have the look that I was going for. Overall, though, it was more important to observe the recognisable characteristics of a wing – these being the general shape, the different types/sizes of feather depending on the location of the feather on the wing, and the overlap on the feathers (from the front the upper feathers overlap the lower ones, and from the back this is reversed). These characteristics can be seen in figures 7.6 and 7.8. One change I made from a normal bird wing was the definition of the large bones in the wings. The actual skeletal structure of a wing is very similar to that of an arm, so I based the shape of the main bones in the wings on the humerus bone (that of the upper arm), and the size is roughly the same as the humerus bone in the Cherub’s arms. This was to make it look like they could feasibly lift a human. Since they require a lot of detail, they could not morph from the main body with the morphing method I used, so they were a separate object. It would be an interesting exercise to work out how wings would attach to a human, and what the muscular layout would be to make it possible.

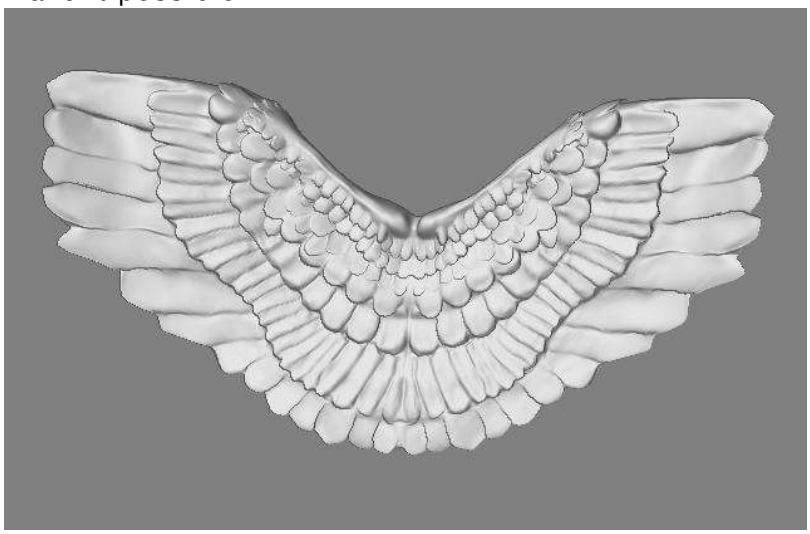


Fig 7.6 (Wings from the front)

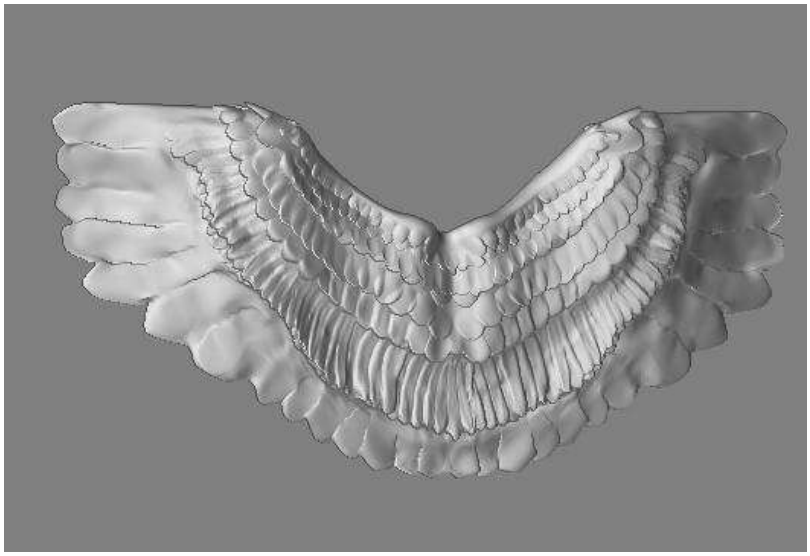


Fig 7.7 (Wings from the back)

Technical Issues

The cherub was the hardest of the six characters to model, because it had to be created out of a mesh that was designed for an adult body. This meant that a large amount of detail had to be forced into a small space, and that topology designed for defining muscles had to be smoothed out because of the cherub's low muscle definition. The wings were also very hard - a decision had to be made whether to make them out of duplicating lots of feathers, or modelling them out of a single piece. I chose to model them out of a single piece as it was a more enjoyable and artistic process, but for real, animatable wings, I would recommend having lots of single feathers.

Getting reference

I found that getting reference for babies was fairly easy, as often people will dedicate whole pages on the internet to photos of their young children, but often there is no easy way of telling how old a child is in a picture, and since children grow so fast, it is quite often difficult to tell what size the character you're making would be. This is why it's helpful to understand how children grow, and what parts grow fastest, so that you can make an educated guess at the proportions of your character. Other useful sources of reference were pictures of myself and siblings a child, baby care magazines, and statues/paintings of cherubs (although here you are relying on another artists work to be correct, so care should be taken). Wing reference is easy to get on the internet (for example google.com).

A note on props

For the final animation, each character had a “prop”, which was an object that helped flesh them out and give them character, but couldn’t be created out of the base mesh. However, bar the Cherub’s wings, these were not really relevant to include here as it is an anatomy project. For the sake of completeness, I include a list of props, which can be seen in the final animation:

Human – Head hair
Daemon – Large claws
Troll – Hammer
Wizard – Beard, staff
Zombie – Intestine hanging from stomach
Cherub - Wings

Creating the morphs

Whilst this project is at heart an anatomy study, to realize it a lot of research and time had to be spent in finding out how best to achieve a morph in 3d, and I feel that this is worth documenting here.

In a previous project I had researched into morphing, and managed to achieve it with a single blendshape alone. This was done by effectively modelling one shape out of the original, so that the vertices can just linearly interpolate between positions. Whilst this worked, it made animation difficult, as the whole morph was controlled by a single blendshape, and so any secondary animation became difficult, as there was no rig. To achieve some sort of realistic and believable movement during the morph, a rig would be needed that could handle the animation whilst the blendshape moved the vertices on top of this, effectively creating a two-layered morph.

A rig needed to be created that could handle the extreme changes in size of the morphing character, so be able to squash and stretch. I did this by using utility nodes (expressions would also work, but would be less efficient) which found the overall distance of a given set of bones (e.g. spine or legs), and would scale each bone along its x axis so that it would be equivalent in length to the average length of each bone, given the total length of that set of bones. This is a method outlined in “The Art of Rigging: Volume 1” (see bibliography).

Of course, this rig only creates a squashed or stretched human, there is no way to, for example, push out the stomach for a fat character or create hooves for the daemon. An ideal rig would be able to handle as much of the morph as possible, to keep it animatable, but since this is not a rigging or a morphing project such a rig was unnecessary.

The character was skinned, and the rig was animated going from pose to pose, and at each pose (which would of course be a new character), the mesh was duplicated and taken into ZBrush where it could be sculpted into the appropriate shape.

Zbrush was necessary for this project was it allows us to change the shape of a character much more quickly than in maya, and often the blendshapes that would be taken off the rig (especially in areas where the rig has squashed) would be a crumpled mess of polygons, which would have taken a long time to smooth out using Maya’s modelling tools alone.

The mesh created was fairly light in terms of polygonal density (around 6000 polygons), which was necessary to be able to create new shapes with relative

ease (any detail that was character specific would have made the other characters harder to model). However, such a light mesh did mean that there is no way it could hold the higher levels of detail for the characters (veins, brains and intestines for example), and so this is where displacement maps needed to be generated for each character. Again, ZBrush was used for this process as it allows the user to “sculpt” displacement maps and export them as greyscale images, rather than having to paint them as greyscale images and estimate the effect they will have when translated into 3d space.

The idea was to have a layered texture plugged into the displacement for the shader with each displacement map plugged into it and layered. As the morph progressed, the textures would become more transparent to reveal the underlying ones, thus creating a transition between maps, and a morphing effect. One major problem with this was the issue of UVs. For the displacement maps to render accurately, the character’s UVs had to be laid out well. However, the polygons change shape so much in the process of the morph, that a single UV set will simply distort too much and not be usable for more than one character. Therefore, it is necessary to create a separate UV set per character. Given that there were six characters, it would be ideal to use Maya’s automatic mapping to prevent the need to UV all the characters by hand. Unfortunately, when taking displacement maps out of Zbrush, there are sometimes slightly noticeable seams that need to be touched up in Photoshop. With an automatic mapping, there would be hundreds of seams, potentially creating an undesirable effect. This meant that all six characters needed to be UVed by hand, which was costly in terms of the large amount of time that it took, but necessary to be able to render out the details of the characters.

However, this then leads to another large stumbling block. At the time of writing, Maya (version 6.5) is unable to handle UV sets sufficiently well to blend between displacement maps. It is incapable of rendering any UV set that is not the default one. The way around this was a custom mental ray shader (see appendices), written by Jimmi Gravesen specifically for this project. It essentially blends between textures, and links these to the appropriate UV maps. The shader can be found in the appendices.

To summarise, the morph was achieved through three separate techniques - a rig for animation, blendshapes for accurate body shapes, and displacement maps for details.

Critical Evaluation

To evaluate the success of the overall project, it would seem appropriate to break it down into two parts - firstly how well it worked as an educational piece, i.e. whether by watching the animation and reading the report someone would be in a better position to design/model a humanoid character, and secondly how believable the characters created for the final animation were, because if these were badly modelled then the whole project lacks credibility. Reading the report retrospectively, I do feel that it would be a useful resource if I were to create the characters again not having the understanding that I do now, having done the project. Certain aspects were very challenging - for example, why does a character based on an old man look the way he does? Everyone has their own idea in their head about how he should look, but to actually create this in three dimensions, where precision is everything (assuming one wishes to make a "real" character), is a very different story. How can you know what his legs or buttocks look like? Pictures of 70+ year olds showing any amount of naked skin are very hard to find. It is these types of problems that I encountered initially, and endeavored to answer in my report.

In this regard, I feel that the project succeeds. The large amount of time I spent finding out what the nuances and landmarks of a certain body type are would be cut down substantially if I were to have read the report before starting the project. Having said that, there are very few short cuts in creating realistic characters, and getting a firm grasp of anatomy and learning how to apply this understanding in 3d is a time consuming process, and there is only so much a project like this can do to speed that up.

The actual models were created to the best of my ability given the amount of them and the time constraints. Whilst I cannot claim that they do not have a great number of inaccuracies, great care was taken to make them fundamentally accurate, and they were cross-referenced with a number of other artists to check for noticeable errors. Each model in their own right I feel was modelled well and is believable.

However, one issue that affected the quality was that I was unable to get the detail that I had created in ZBrush into my final renders in Maya. Generally this is an issue when taking displacement maps out of ZBrush, as it lets you model at a very high detail (over two million polygons), and getting these results in Mental Ray takes time tweaking and refining, which unfortunately I didn't have. This also resulted in a slightly different appearance to some of the characters, which was most notable in the cherub, as he lost some of his "cuteness" in the final render. Currently it is not known where along the line the detail was lost, most likely in the resolution of the displacement maps (which were either 4096

by 4096 or 8192 by 8192), which were not high enough to carry the detail across. A solution to this would have been to have separate UV spaces for various parts of the body, so that multiple maps could be exported for a single model. However, with the issues that cropped up regarding UVs, this would simply have created too many problems and was not viable within the scope of the project. Instead, this report uses screenshots from within ZBrush rather than the renders from Mental Ray so that the detail is much more readable, and thus still serves a purpose somewhere.

How much the final piece without the report aids in understanding the importance of anatomy in character design is debatable. Clearly, people will not immediately understand that the project is a study in anatomy just by watching a character morph into other characters. However, since the starting character is clearly human, seeing how this can be a basis for other characters will, it is hoped, educate the viewer more than just looking at six seemingly unrelated characters, and hopefully inspire those with an interest in character creation.

Was the morph necessary for this project? Choosing to have the character morph into his different types of anatomy was a decision that hugely affected this project. The time spent researching morphing and the time spent making it a reality (rigging, skinning, uving, and general problem solving) was considerable, and this could have been spent further exploring the potential of anatomy in character design, looking at the female form, or quadrupeds, or birds, or insects - there is an infinite range of characters we can create inspired by the world around us, and perhaps this project would have benefited from delving further into this potential.

As previously mentioned, though, I wanted an animation that would give the viewer just an inkling of what can be done by using anatomy as a base for characters, and although creating a broader range of non-morphing characters would have demonstrated more examples of this, there would have been no incentive to make the connection that they are based on reality. Ultimately, it is not for me to demonstrate all the ways in which different types of anatomy could be used in character design. If this project serves its purpose and is the slightest bit of inspiration to other artists, then it is up to them to explore it for themselves.

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Appendix

The following is the mental ray shader written by Jimmi Gravesen to blend between UV sets in this project

```
#include <shader.h>
#include <stdio.h>

struct result {
        miColor color;
        miScalar alpha;
};

struct UVsetBlend {
                miScalar debug;
    miTag color1;
                miScalar blend1;
    miTag color2;
                miScalar blend2;
                miTag color3;
                miScalar blend3;
                miTag color4;
                miScalar blend4;
                miTag color5;
    miScalar blend5;
                miTag color6;
    miScalar blend6;
                miTag color7;
    miScalar blend7;
                miTag color8;
    miScalar blend8;
                miTag color9;
    miScalar blend9;
                miTag color10;
    miScalar blend10;
};

DLLEXPORT int UVsetBlend_version(void) {return(1);}


DLLEXPORT miBoolean UVsetBlend(
    struct result       *result,
    miState         *state,
```

```
        struct UVsetBlend       *paras)
{
miScalar debugs = *mi_eval_scalar(&paras->debug);
miScalar blend1 = *mi_eval_scalar(&paras->blend1);
miScalar blend2 = *mi_eval_scalar(&paras->blend2);
miScalar blend3 = *mi_eval_scalar(&paras->blend3);
miScalar blend4 = *mi_eval_scalar(&paras->blend4);
miScalar blend5 = *mi_eval_scalar(&paras->blend5);
miScalar blend6 = *mi_eval_scalar(&paras->blend6);
miScalar blend7 = *mi_eval_scalar(&paras->blend7);
miScalar blend8 = *mi_eval_scalar(&paras->blend8);
miScalar blend9 = *mi_eval_scalar(&paras->blend9);
miScalar blend10 = *mi_eval_scalar(&paras->blend10);

            miColor outPut;
            miColor current;
            outPut.r =0;
            outPut.g =0;
            outPut.b =0;
            outPut.a =0;

            int n;
            if( ! mi_query( miQ_NUM_TEXTURES, state, miNULLTAG, &n ) )
            {
                        printf("SHIT!!!\n");
            };

int i;
if(debugs)
{
            for(i = 0; i < n; i++)
            {
                        printf("UV set %d: %f , %f \n", i+1, state->tex_list[i].x, state->tex_list[i].y);
            }
}

if(blend1 > 0)
{
            miTag texTag = *mi_eval_tag(&paras->color1);
            mi_lookup_color_texture(&current,state,texTag,&state->tex_list[0]);
                        outPut.r += current.r * blend1;
                        outPut.g += current.g * blend1;
                        outPut.b += current.b * blend1;
```

```
                outPut.a += current.a * blend1;
}

if(n > 1 && blend2 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color2);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[1]);
                outPut.r += current.r * blend2;
                outPut.g += current.g * blend2;
                outPut.b += current.b * blend2;
                outPut.a += current.a * blend2;

}
if(n > 2 && blend3 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color3);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[2]);
                outPut.r += current.r * blend3;
                outPut.g += current.g * blend3;
                outPut.b += current.b * blend3;
                outPut.a += current.a * blend3;
}
if(n > 3 && blend4 > 0)
{

        miTag texTag = *mi_eval_tag(&paras->color4);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[3]);
                outPut.r += current.r * blend4;
                outPut.g += current.g * blend4;
                outPut.b += current.b * blend4;
                outPut.a += current.r * blend4;
}

if(n > 4 && blend5 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color5);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[4]);
                outPut.r += current.r * blend5;
                outPut.g += current.g * blend5;
```

```
                outPut.b += current.b * blend5;
                outPut.a += current.a * blend5;
}
if(n > 5 && blend6 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color6);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[5]);
                outPut.r += current.r * blend6;
                outPut.g += current.g * blend6;
                outPut.b += current.b * blend6;
                outPut.a += current.a * blend6;
}
if(n > 6 && blend7 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color7);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[6]);
                outPut.r += current.r * blend7;
                outPut.g += current.g * blend7;
                outPut.b += current.b * blend7;
                outPut.a += current.a * blend7;
}
if(n > 7 && blend8 > 0)
{

        miTag texTag = *mi_eval_tag(&paras->color8);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[7]);
                outPut.r += current.r * blend8;
                outPut.g += current.g * blend8;
                outPut.b += current.b * blend8;
                outPut.a += current.a * blend8;
}
if(n > 8 && blend9 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color9);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[8]);
                outPut.r += current.r * blend9;
                outPut.g += current.g * blend9;
                outPut.b += current.b * blend9;
                outPut.a += current.a * blend9;
```

```
}
if(n > 9 && blend10 > 0)
{
        miTag texTag = *mi_eval_tag(&paras->color10);

        mi_lookup_color_texture(&current,state,texTag,&state->tex_list[9]);
                outPut.r += current.r * blend10;
                outPut.g += current.g * blend10;
                outPut.b += current.b * blend10;
                outPut.a += current.a * blend10;
}

result->color.r = outPut.r;
result->color.g = outPut.g;
result->color.b = outPut.b;
result->alpha = outPut.a;

        return(miTRUE);
}
```