SUMMARY AND CONCLUSIONS

6.1 SUMMARY

In chapter 1 the aim of the research is mentioned, trying to find an answer on the question: *Have the developments in amputation surgery and the developments in prostheseology influenced one another?* In this chapter the histories of both amputation surgery and prostheseology are discussed and the answer on the question is given through some conclusions.

In Ancient Times developments in amputation surgery take place. Amputations are at first done in the already dead tissue, through a joint and only with a knife. Later the severance is done on the border of healthy and diseased tissue or even in healthy tissue, through the shank and with knife and saw. Haemostasis is initially done by cauterization, later the surgeons of Ancient Times use ligatures, compression, torsion, vinegar bandages and caustics. Cauterization with a hot iron is then only used as last resort. With the decline of the Roman Empire amputation surgery deteriorates with it. Guillotine amputations are done on the border of healthy and diseased tissue again and only cauterization is used for haemostasis. This technique is written down by Paul of Aegina, an encyclopedist living in Alexandria, and taken over by the Arab surgeons, after they have conquered Alexandria. During the Middle Ages, due to a complete absence of scientific medicine and under the influence of Arabic medicine, developments in amputation surgery hardly occur in Western-Europe. Amputations are not performed by Salernian or university-trained doctores medicinae. These doctores are theoreticus, they listen to complaints, perform uroscopy, prescribe medicine and herbs and give advise about practical treatment including amputations. The actual amputations, performed for gangrene, warwounds, leprosy and ergotism, are done by barbers, surgeons and quacks. They mostly have a certain amount of practical experience, but hardly any scientific education and are undoubtedly not familiar with the writings on Ancient surgery, of men like Hippocrates, Celsus, Archigenes, Heliodorus etc. Only a few university-trained physicians, having found out that their education is useless on the battlefield, take the trouble to become physicians-surgeons. However, even these men remain true to the amputation technique described by Abul Quasim, an Arabic surgeon living in Cordoba around 1100 AD, who imitated the inferior technique of Paul of Aegina, except for some details. At the end of the Middle Ages a rise of amputations
follows the invention of the firearms, but initially no development in amputation technique occurs. The severances are, at the end of the Middle Ages, done again in the already dead tissue and haemostasis is done again only by cauterezation.

Medical and surgical books from Ancient Times and the Middle Ages do not mention the word prosthesis, but prostheses are mentioned in non-medical books and shown on pottery and pictures. According to these, amputees during Ancient Times and the Middle Ages use either crutches or a simple type of prosthesis, the peg leg. In the Middle Ages a special type of peg leg, the so-called kneewalker peg leg, is used. These peg legs are made of wood and sometimes reinforced with metal sheets. Archeologists even found a peg leg made of wood and reinforced by bronze sheets in a grave near Capua, probably used around 300 BC. The only development in prostheseology in this period is the refining of the peg leg to the kneewalker peg leg. There is no known design of a leg prosthesis in that period. It is not sure who makes these peg legs. In the Talmud is mentioned that in one occasion a non-trained craftsman made a prosthesis from a log of wood, but in the literature there is no further reference to a limb maker.

After the Middle Ages the scene changes. The invention of firearms gives a rise in amputations, because wounds made by bullets and shells are more severe than wounds made by swords and arrows. Besides in the sixteenth to the nineteenth century there is a succession of wars, fought out with huger and huger armies and with battles, which become more bloody every time. That raises the number of casualties and with it the number of amputations. Up to the First World War the biggest part of the amputations is done by army surgeons. Only a minority of the amputations is performed on civilians. So army surgeons become masters in amputation and for a civilian surgeon an amputation is a rarity, which he infrequently does. Therefore, this period of the history of amputation surgery can be called the era of the army surgeons.

Army surgeons in those days are mostly not the best in surgery. They enter the army for lack of money or education or both. They learn their trade on the job, by trial and error, without any tutor to give them advice or look over their shoulder. As they go along, they get a certain knowledge of first aid and traumatic surgery including amputations. Once they have learned their trade they want to go out of the army and start a civilian practice, which is more profitable and socially more accepted. There is probably always a shortage of these men for Ambroise Paré, who has not enough money to take the examination for master surgeon, can become an army surgeon just like that. Richelieu tries to keep the army surgeons posted by increasing their salary and making them members of the Collège de St. Côme, the famous French surgeons' corporation, in an exclamation of kind. The attempt was not all successful, their lack of knowledge is known to them. The surgeons are known as Feldscherer (barbers) for further education. Frederick the Great and the Prussian ones. The French Revolution and the new law of the state as a surgeon, cannot afford where his surgeon is. It is so high that no other responsibility becomes greater than that of the finest surgeon to them, like, among the soldiers. If out of it and have fewer would be the natural result. As an army surgeon he requires five years of thorough training only for his lack of operations and experience in amputation surgery. The first surgeon to that time a below the diseased part of the shank stump, the ankle joint, backwards. The site of the ankle joint is so high that a border of sound fingers will fit perfectly into the site of ligatures for him. Most likely he designs a bois pour les perdre, through which he designs a prosthesis. This leg prosthe...
development in amputation of the Middle Ages, done one again only by cauterization. The Middle Ages do not mention in non-medical sources to these, amputees duringitches or a simple type of artificial type of peg leg, the sockets are made of wood and even found a peg leg grave near Capua, probably prostheseology in this type of peg leg. There is no not sure who makes these occasions a non-trained surgeon, but in the literature there is mention of firearms gives a let's and shells are more besides in the sixteenth to fought out with huger and bloody every time. That number of amputations. Up to amputations is done by army surgeons on civilians. So for a civilian surgeon an army surgeon, this period of the army surgeons.

In surgery. They enter the in their trade on the job, advice or look over their knowledge of first aid and have learned their trade practice, which is more bly always a shortage of money to take the examination just like that. Richelieu their salary and making mous French surgeons' corporation, in an attempt to raise their standard of surgical knowledge. The exclamation of king Louis XIV, "For my soldiers the amputation knife of my surgeons is far more dangerous then the enemy's fire", proves that Richelieu's attempt was not always a successful one. This shortage of army surgeons and their lack of knowledge are not restricted to the French army. The same problems are known in the Prussian Army, where most surgeons are just Feldscherer (barbers). In 1716 five promising surgeons have to be sent to Paris for further education and on the eve of the Second Silesian War (1744), Frederic the Great has to bring in twelve French army surgeons for lack of Prussian ones. The shortage of army surgeons remains during the French Revolution and the Napoleonic wars. Larrey, who comes to Paris to be trained as a surgeon, cannot find a paid job in a civil hospital, but he can join the navy, where his surgeon's work is paid for. During the Napoleonic wars the shortage is so high that nineteen-years-old conscripted surgeons are saddled with a responsibility beyond their ability. Small wonder they transform their dressing stations into slaughterhouses. Of course there is wheat among the chaff. Some of the finest surgeons have started their career as an army surgeon and some of them, like, among others, Paré, Larrey, Percy and Guthrie even make a career out of it and have found a place in the history of amputation surgery.

As an army surgeon Paré can be counted among the better ones, for he has had five years of thorough training on the job in the Hôtel Dieu in Paris, and it is only for his lack of money that he joins the army. Besides he is not a man to perform in servile imitation of his tutors, but he acts upon his own observations and experiences. If necessary he does not shy from experiments. In amputation surgery Paré reintroduces amputation in healthy tissue and he is the first surgeon to choose a site of election for a below-knee severance. Up to that time a below-knee severance is done on the border of the sound and the diseased part of the shank, or even in the diseased part. Therefore the length of the shank stump can vary from very short below the knee joint to just above the ankle joint. The use of a kneewalker peg leg makes the stump protrude backwards. The longer the stump, the more obvious the result. Paré chooses the site of election five fingers below the knee joint, with no regard to the border of sound and diseased tissue, because a stump with a length of five fingers will fit properly into a kneewalker peg leg. He reintroduces also the use of ligatures for haemostasis, in favour of the more painful cauterization, and is, most likely the first surgeon to do a successful above-knee severance. Moreover he designs a new type of kneewalker peg leg (which he calls "Un jambe de bois pour les pauvres") and the first known leg prosthesis, an above-knee prosthesis. This iron prosthesis, weighting about seven kilograms, resembles the leg of an armour, has a knee joint with a locking device and an ankle joint. This leg prosthesis is manufactured by an armourer in Paris, who, for his
stature and his origin, is only known by his nickname "Le petit Lorrain". Besides, Paré's name for his kneewalker peg leg design is significant. It shows that only rich people in his days can afford to buy a leg prosthesis. There are not many rich in Paré's days and even less who need a prosthesis, therefore leg prosthetic designs are scarce. Unfortunately Paré is not able to hand on all his knowledge to his contemporaries, pupils and successors, although he is well known and writes several books on surgery. After his death it still takes several decades before hot irons and other cauteryization materials finally disappear from the scene, in favour of the ligatures. His site of election is not used commonly, though most surgeons operate in healthy tissue, and it takes more than a century before another surgeon designs a prosthesis.

Up to the end of the seventeenth century the guillotine amputation is the technique of choice, but from then on, owing to the use of a tourniquet and ligatures, new amputation techniques are introduced. These are the dorsal flap technique of Verduyn, the two and the three-cut technique and the double side flap technique of Ravaton. In 1696 Verduyn describes his technique in his book "Dissertatio epistolae de nova artuum decurdantorum ratione". In this new technique for a below-knee severance, a musculo-cutaneous flap of the dorsal part of the leg is created and raised anteriorly to cover the sectioned bones and close the wound. The stump, which Verduyn creates, makes the use of a kneewalker peg leg less suited, because the stump has too much length. Therefore Verduyn designs (and describes in the same book) a new type of below-knee leg prosthesis with a thigh corset, metal sidebars with hinges, a copper socket and a wooden foot. Here amputation surgery influences prosthesology. The same applies to the below-knee amputation technique of Ravaton. He makes a transverse circumferential incision, close to the ankle, up to the bones and then two perpendicular incisions one in the front and one at the back. The bones are sawn through at the top of the perpendicular incisions, leaving two side flaps to cover the wound. This stump is too long for a kneewalker peg leg too. In 1755 Ravaton therefore designs a boot like below-knee leg prosthesis with a leaf spring to imitate the ankle motion. This prosthesis is actually used by the dragon Pray. These designs are, with Paré's leg prosthesis, up to the time of the French Revolution, the only known examples of a prosthetic design made especially after a new amputation technique was described. The description of the other new techniques, the two and the three cut, is not followed by a special new prosthetic design.

Beside the improvement in amputation techniques the problem of the proper time to do a severance in case of a shot wound occupies the surgeons minds. There are three possibilities. Primary amputation, within twenty-four hours after receiving the wound. Intermediate amputation, after a couple of days, when the soldier has recovered from the shock. Secondary amputation, after
"Le petit Lorrain". It shows that there is no reason to be concerned about the possibility of the amputation being prolonged. It should be remembered that the length of time it takes for the wound to heal and the amount of material necessary for the amputation is not significant. It should be noted that although the material is well suited for the purpose, it still takes some time to prepare it for use. The choice of material finally depends on the surgeon's preference, and it is believed that the most suitable material for the purpose is the material used by Paré.

Amputation is the removal of a limb or a part of a limb. The technique used for amputation is called amputative techniques. In this period, it was common to use amputative techniques that involved the use of a tourniquet and the amputation was performed under local anesthesia. The technique used for amputation was called "amputatio ratione". In this technique, a flap of tissue was used to cover the sectioned end of the limb, which was then replaced by the flap and the amputation was performed under local anesthesia. The flap was then sutured to the flap of tissue that was covering the amputated end of the limb. This technique was used to reduce the amount of blood loss during the amputation.

A French army surgeon, Jean Faure, won the prize. He showed, by the results of the amputations after the battle of Fontenoy, that secondary amputation gives the most survivors. This is, incidentally, the first time in the history of surgery that some sort of statistic is used to prove the value of a treatment. Unfortunately Faure makes a mistake. He just counts the number of successfully secondary amputations versus the number of successfully primary amputations, but does not count the number of casualties that die of the inflammation of the wound before the secondary amputation can take place. Taking these in account too, the "outcome" of his statistic shows another picture. Although he has some opponents, Faure's idea is mostly accepted and for some decades secondary amputation becomes the treatment of choice.

Amputees in this period commonly use peg legs, because they are easy to make, mostly weight less than a leg prosthesis and are much cheaper. Only wealthy people can afford a leg prosthesis and there are not that many wealthy and even less who need a prosthesis. There are designs of leg prostheses known in this period though. They are made by limb makers, except the above-knee leg prosthesis, totally made of wood, designed by the French surgeon Pierre Dionis in 1707. Dionis' design was not made to meet the demands of a new amputation technique, but an attempt to make an above-knee prosthesis, which was not so heavy as Paré's design. The designs made by limb makers have no connection with a new amputation technique either. There are only a few designs known and most of them are unique pieces, probably made for a rich customer. Nevertheless, one of the important devices in prosthesology, the ischial seat, is designed in this period by the English limb maker Gavin Wilson. It is possible that this ischial seat, meant to shift body weight to the prosthesis, is designed under influence of the developments in amputation surgery. The amputation stumps that surgeons produce in that period are not end-bearing, so the limb maker has to find an anatomical convenient spot to shift body weight.

During the time of the French Revolution and the first half of the nineteenth century, amputation surgery reaches its pre-narcotic zenith. Army surgeons obtain a tremendous experience in amputation, owing to the enormous number of casualties they have to take care of. Their amputation speed is unsurpassed, a thigh or a leg severance is mostly done in about three minutes. Owing to this experience, sound indications for an amputation and right sites of election can be set up by some leading army surgeons, notably by Dominique Jean Larrey and George James Guthrie. They also prove that a primary amputation on the
battlefield gives better results, than a secondary amputation, performed after some weeks. Both prefer the three-cut technique, except in disarticulations and very high thigh severances, because a flap technique is used in those severances. They improve the amputation results, especially by better hygienic measures. Both are successful in amputating through the hip on the battlefield, Larrey is the first in 1803, Guthrie does his first successful hip disarticulation in 1815 on the fields of Mont St. Jean. Moreover both succeed in convincing their army commanders that first aid on the battlefield saves the lives of many soldiers. Larrey is the forerunner in this aspect too. Up to his days it is accustomed to leaving the casualties on the battlefield during the battle, without any aid, and collect them after the battle is over. Due to the bad deployment of the available conveyances it mostly takes more than twenty-four hours before the casualties are brought to the dressing stations. For most of them that is too late. In 1793 Larrey designs his Ambulance volante, a light, well-sprung carriage, for the removal of the casualties. With this carriage the casualties are collected, during the battle, at flying speed and if necessary live saving aid is given. The casualties are then brought to a dressing station, situated on the edge of the battlefield and further taken care of in order of their surgical need, regardless of rank or even nationality. Larrey tries to spread his ideas and techniques among the other surgeons in the French army. Initially he can do so while acting as a teacher at the new training school for army surgeons at Val-de-Grâce. Later, due to the enormous number of surgeons necessary for the French armies and the loss of the experienced surgeons, inexperienced conscripted surgeons are sent on the job right away. Occasionally they make a mess out of it and transform their dressing stations into slaughterhouses. Therefore the few experienced ones have to do most of the major operations and Larrey himself has to do 200 amputations in twenty-four hours during and after the battle of Borodino.

During this period the first partial foot amputations are described, namely the talo-tarsal amputation by Chopart and the tarso-metatarsal amputation by Hey and Lisfranc. The advantages of these type of amputations is that a patient can walk without a prosthesis, the disadvantage that the remainder of the foot does not rest in its normal position, but deforms into a rather painful stump. During the first half of the nineteenth century frequently amputations are done in civilian hospitals, but the death rate after these severances is rather high and that brings some surgeons to think about a cause and a proper solution. James Syme, chief surgeon of the Royal Infirmary of Edinburgh, has the idea that opening and thus inflaming the marrowhole of the long bones might have something to do with it and therefore recommends amputation through the spongy parts of the bone. According to this principle he describes in 1843 the disarticulation through the talo-crural joint. In this operation the shin and
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the splintbone are horizontally sawn through as low as possible. The anklebo-
ne is removed and the heelbone too, but subperiostally, leaving the heelcush-
on intact. This cushion is then brought forward to form the end-bearing
undersurface of the stump.
Leg prostheses are still quiet scarce in this period, most likely because the
death rate of a major operation like an amputation is high and to the fact that a
leg prosthesis is quite expensive. The above-knee leg prosthesis, designed by
the limb maker Peter Baliff of Berlin in 1816, costs ninety Taler and in 1839
an above-knee leg prosthesis, produced by the limb maker William Selpho, is
for sale in the USA for 150 US$. This amount of money is more than an
unskilled labourer or a common soldier earns in those years, the more so while
it is harder to earn a living after losing a leg. There is more proof about the
high cost of a leg prosthesis, for Dr Von Rühl, a physician from St. Petersburg
designs a below-knee leg prosthesis for his son in 1812. This son has lost his
leg during the battle of Borodino. Dr Von Rühl designs this new prosthesis
because he finds the existing prostheses, among other things, too expensive. In
1826 Dornblith, the court physician of Mecklenburg, designs new prostheses
for the musketeer Drefal, who lost both legs during the fighting around Lille
in 1814. In 1830 these prosthetic designs are praised during a meeting of natura-
lists in Hamburg, among other things because of their low costprice. Neverthe-
less, developments in prostheseology take place. For the below-knee amputee
the kneewalker peg leg is still the prosthesis of choice, but for the above-knee
amputee new designs for peg legs are made and leg prostheses are designed for
both below and above-knee severed. Up to 1816 the above-knee leg prosthesis
has a knee joint, which is locked during walking, giving the user a distinct
walking pattern. In that year above-knee leg prostheses are designed with a
knee joint, which is movable during walking, giving a more natural walking
pattern. This novelty is designed by Peter Baliff and by the limb maker James
Potts of Chelsea. Baliff designs an ingenious device that locks the knee joint
with heel-strike and unlocks it with toe-off, giving the leg enough stability
during the stance phase and the possibility to flex during swingphase. Potts'
design has no lock, so the knee joint is not as stable as Baliff's, but gets its
stability during stancephase from some elastic straps and possibly from the
natural friction between the wooden parts the knee joint is made of. Potts'
above-knee prosthesis becomes quiet famously, because a client he makes this
prosthesis for, is Henry Bayly, Marquess of Anglesey. At the end of the battle
of Mont St. Jean, Anglesey is struck by a grape shot, which shatters his right
knee joint to pieces. He is amputated the same evening. Back in London he
obtains a prosthesis from Potts. He is so satisfied with it that he gives Potts
permission to use his name in advertising. Therefore the prosthesis becomes
known as the Potts-Anglesey prosthesis or simply as the Anglesey prosthesis.
The history of amputation surgery takes a drastic turning during the second part of the nineteenth century. Owing to the introduction of anaesthetics amputation technique can change from swiftness to thoroughness. Surgeons have ample time to perform more elaborate operations and can try out new techniques, now their patient is temporarily unconscious and feels no pain. The introduction of antiseptic measures lowers the mortality rate, so ever more patients survive and need prosthetic supply. Amputation techniques become more designed to meet the demands of prostheseology. This change in attitude of the surgeons is not caused by a sudden interest in their patients, but the result of a turning in the history of prostheseology, which is as drastic and takes place in the same period. Up to 1860 the amputee is accustomed to pay for his own prosthesis. Most amputees cannot produce the costprice of a leg prosthesis and have to be content with a peg leg. With the start of the American Civil War (1861 - 1865) this changes for the better. In both the "North" and the "South" committees are founded, which devote themselves to raising money for the financing of leg prostheses for the soldiers, who have lost a leg serving their country. As soon as the hostilities suspend, the American government makes an official regulation about this item and about 28,000 soldiers get a leg prosthesis paid for by the government. In the same time the Prussian government sets rules about financing leg prostheses for amputated soldiers and some years later Her Majesties government does the same for the British amputated military men. Considering the fact that most amputations still take place in wartime, this means that the bulk of the amputees can afford to "buy" and use a leg prosthesis. The fitting of a leg prosthesis requires more of a stump than the fitting of a peg leg and so the surgeon has to meet these demands.

Having the time to do more elaborate operations gives the surgeons the opportunity to find solutions for some of these demands. One of them is the transfer of bodyweight to the prosthesis. The easiest way to do this is by creating an end-bearing stump. If the amputee can put his total bodyweight on the end of his stump and lean on it, the substitute of the lost part of the leg can be a simple peg leg, attached under the end of the stump. If the amputee cannot put his total bodyweight on the end of the stump, or even any weight at all, anatomical convenient spots must be found to transfer bodyweight. This makes the prosthetic appliance more complicated. It is found out that bones with an intact periostial or cartilagenous lower surface can bear weight, but sawn through bones, of which the lower surface consists of a marrow hole, surrounded by a bony ring, cannot. Therefore operation techniques are devised to make the weight bearing surface of the bone consist of either periost or cartilage. So, for example, Pirogoff, a Russian surgeon, uses the intact dorsal surface of the heelbone as weight-bearing surface for his amputation technique.
during the second injection of anaesthetics roughness. Surgeons can try out new ideas and feel no pain. The mortality rate, so ever more techniques become the change in attitude to their patients, but the which is as drastic and is accustomed to pay the costprice of a leg start of the Ameri- In both the "North" themselves to raising hemispheres, who have lost a leg re American govern- about 28,000 soldiers get time the Prussian r amputated soldiers same for the British mputations still take i can afford to "buy" requires more of a e has to meet these surges the surgeons the One of them is the way to do this is by total bodyweight on the amputee cannot any weight at all, t weight. This makes that bones with an weight, but sawn narrow hole, surround- es devised to of either periost or uses the intact dorsal amputation technique through the ankle, which he describes in 1854. In 1857 the Italian surgeon Gritti describes an above-knee severance in which he uses the knee cap as weight-bearing bone. Both the Russian surgeons Sabanejeff and Abrashanoff describe a modification on the Gritti technique, in which they use either the anterior or the posterior surface of the upper part of the shinbone as weight-bearing surface. Even at places where normally no osteoplasty is possible, like in the middle of the shank, surgeons try to make an end-bearing stump by closing the opened marrow hole somehow. The French surgeons Laborie and Duvolle use the Achilles tendon for this purpose in 1869. In 1882 the German surgeon Levy creates a bony bridge between shin and splintbone as weight-bearing end of the stump. Another German surgeon, August Bier, uses the dorsal surface of the shinbone as weight-bearing end in his so-called "window" technique, described in 1892. He makes an oval hole in the soft tissue of a long shank stump (the window), removes a conical piece of the two bones and turns the lower part of the two bones ninety degrees to the front, thus creating something like a small foot. The skin of the back of the shank becomes the "sole" of this small foot and the dorsal, periostal, surface of the bones makes the amputation end-bearing. In the first half of the twentieth century osteoplasty is still used in Germany, even for midthigh severances. M. Kirschner closes the marrow hole with pieces of bone and Loeffler does the same in the thirties. Other surgeons, like Blencke and zur Verth do not believe in end-bearing midthigh stumps, though they believe in the end-bearing capacity of the Gritti operation and even try to find a solution for the greatest problem of this technique. This problem is the slipping away of the kneecap from under the thighbone. To avoid this zur Verth scoops the kneecap and shoves it, as a lid, on the thighbone end. For the same problem Oehlecker, another German surgeon, remodels the kneecap into a press stud and pushes it into the marrow hole.

The form of the midthigh stump changes in this period due to prosthetic influences. According to Larrey and Guthrie a midthigh severance is done with the three-cut technique, which produces a rather cylindrical stump. But the limb makers prefer a more conical stump, which will slide more easily into a plug-fit socket. Therefore the muscles in the three-cut technique are cut away or allowed to retract as much as possible. In 1913 the American surgeon Jackson uses another technique. He sutures the opponent thigh muscles over the bone end, so that part of the muscle strength remains and the stump can act as a good lever for the prosthesis. Although the imbedded bone stump is less vulnerable, it takes more time before the stump is ready for prosthetic supply and the shape of the stump is rather cylindrical. This technique becomes afterwards known as the myoplastic technique. Of course there are opponents to this technique, who, influenced by the prosthetists, remain true to the old
technique and a conical stump and only after the Second World War the myoplastic technique is generally accepted.

The limitations of prostheseology are responsible for two other developments in amputation surgery, the cineplasty and the turnover operations. Cineplasty is created by Vanghetti and Ceci, two Italian surgeons. It is a plastic operation on the thigh stump, performed to use the contraction power of the remaining muscles, to control a movable part of the prosthesis. Muscle tunnels are made in the stump. Through these tunnels a metal axis is placed and a tow-line is connected with the axis. Muscle contraction moves the axis and the tow-line with it and by connecting the tow-line to the knee or ankle joint the movement of this joint can be controlled. Rotation operations are designed in cases where a hip disarticulation is due for a tumour or trauma high on the thigh, although shank and foot are uninvolved. Walking with a hip disarticulation prosthesis is less obtrusive and costs more energy than walking with an above-knee prosthesis. Therefore special techniques are designed, in which the shank bones are used as a substitute for the thighbone. The use of the remaining muscle power in an above-knee stump is furthermore preserved in the tendoplastic amputation technique, which is quite popular in the thirties of the twentieth century, but it takes till well after the Second World War before the importance of the muscles in an above-knee stump is fully understood and used in techniques like myoplasty and myodesis.

During the first half of the twentieth century the amputation level is determined with the so-called amputation schemes. These schemes are set up, in Germany by zur Verth, Kreuz, Lange and Watermann, in England by Aldredge and in the USA by Thomas & Haddan. In this schemes the leg bones are divided in parts, which are classified as valuable, less valuable, unimportant and annoying. By using these schemes, according to their makers, the surgeon can always choose the right level to amputate, being sure that the stump will have the proper length for a prosthesis. By strict obedience of these schemes more trans-femoral than trans-tibial amputations are performed because the trans-femoral stump shows a better healing tendency. Therefore, many knee joints will unfortunately have been sacrificed without necessity. The knee disarticulation is almost totally neglected, for the knee and its surroundings are in the schemes classified as unimportant or annoying. This is probably because it is not easy to fit the knee disarticulation stump, though end-bearing, in those days with a proper prosthesis, for lack of a good prosthetic knee joint. The schemes remain in vogue till the Second World War.

After the Second World War the indication for an amputation changes drastically, from accident and infection towards vascular diseases. Initially this brings no change in the amputation level, for still more trans-femoral than trans-tibial severances are performed, due to the fact that the trans-tibial
technique shows a bad tendency to wound healing and reamputations have to be done often. During the fifties the surgeons become ever more aware of the importance of the knee joint and in the early sixties Burgess describes his new trans-tibial technique, the dorsal flap technique. With this technique the saturation of the trans-tibial stump is sufficient and the amputation wound heals nicely. Actually this technique of Burgess is a refinement of Verduyn's technique of 1696. The length of the trans-tibial stump in Burgess' technique is initially about 15 cm., but becomes less and less over the years, because prosthetists can fit a shorter stump by using the "total contact" socket. Other amputation techniques described and used after the Second World War are the osteomyoplasty and the myodesis. In osteomyoplasty a bony bridge is made between shin and splintbone and the opponent muscle-groups are stitched together across the bridge. In myodesis holes are drilled through the bones and the muscles are attached to the bones by threads led through the holes. These techniques are designed to improve the usefulness of the stump and to make prosthetic supply easier and more meaningful. The knee disarticulation remains unpopular among the surgeons until the seventies. The eldest amputation technique ever described, by Hippocrates in his book Ἰπτ ἀποτοκών, has never been very popular, though easy to do, not even a saw is needed. In the amputation schemes the knee joint is even called annoying, while it is not easy to fit this end-bearing stump with a decent prosthesis. Due to the length of the stump a prosthetic knee joint placed under it always leads to a very long thigh and a rather short shank, which is cosmetically unacceptable and unpleasant when sitting, for the short shank mostly does not reach till the floor. The knee disarticulation stump is normally fitted with a leather thigh corset and the prosthetic shank is connected to it with metal bars with side-hinges, which is not a decent fitting from a cosmetic point of view. In 1973, Eric Lyquist of Copenhagen designs a special four-bar linkage knee joint. While bending, the pivot of this knee joint shifts to the back of the thigh, making the difference in length between the two thighs more acceptable. With this better prosthetic supply the knee disarticulation becomes more popular among the surgeons. The drastic turning that the history of prosthesology takes in the second half of the nineteenth century, means a change for the limb maker. His shop or factory is flourishing. Instead of a few wealthy customers he has to provide prostheses for many military amputees and mostly against a fixed price. That means that every prosthetic design can no longer be a unique piece but is multiple produced. On the other hand it means that limb making becomes a profitable business and with it competition sets in. The limb maker can do two things to fight his competition, one is to protect his products by patents, the other to simply deliver better products. The last thing is possible by gaining more knowledge about the way a prosthesis functions and about the materials
he is using. So limb making becomes a real profession and the limb maker is no longer the local carpenter or blacksmith, but a trained craftsman. Gradually he becomes better trained for the job and develops into a prosthetist. The technical development of prosthesology in this period is above all a matter of inventions in the shops and factories with hardly any influence by amputation surgery, though the limitations in this development have their influence on amputation surgery. Up to the First World War mostly small factories can come up to the demands of prosthetic supply, but during that war the number of amputees, which have to be provided with prostheses, grows enormously. Therefore special hospitals, with limb factories attached to it, are set up in various countries. In the factories mass production of prostheses is done. For example in Budapest where General Stabarzt (brigadier-surgeon) Dollinger commands a hospital of 600 beds and a factory with 230 employees. There his design, the "Arbeitsprothese", a rather crude temporary prosthesis, consisting of two metal sidebars with in between a leather thigh and shank corset and ending in a wooden or iron foot without ankle joint, is made. This prosthesis is available at short notice and fitted by the prosthetist under supervision of a surgeon or physician. If the fitting is proper, the amputee is sent to a walking school, also attached to the hospital. The same set up is made in England in Roehampton, where Queen Mary's hospital for the limbless is founded in 1915, with limb factories attached to it, and in some places in Germany. In these hospitals and factories surgeons and prosthetists meet and gradually become aware of each others possibilities and problems. That does not mean that all surgeons and prosthetists come and remain on speaking terms once and for all, for it takes until well after the Second World War before mutual contacts become normal.

Between the First and the Second World War the technical development of prosthesology goes on. New materials are introduced, like cast iron, aluminium alloys and the first synthetics. The prosthesis is divided in three components, the socket, the knee joint-with-shank and the foot-with-ankle joint. These components can be aligned and a certain standardization is initiated. Factories start a mass production of components, which lowers the costs. Further research makes the components more sophisticated over the years. The suction socket, originally designed in 1863, but with a low success, is produced again and tried out, on an experimental base in England and on a commercial base in Germany.

The Second World War gives a new impulse for prosthetic research. A new socket design, the quadrilateral socket, is introduced, both as normal and as suction socket. New materials, plastics, are used to produce sockets and components. Further technical research brings innovations, like new hip, knee and ankle joints, onto the market. Knee joints are provided with a stancephase control and for below knee amputees a proximal tibial prosthesis (PTB) producing a functional prosthesis. At the end of the war the knee joint with a suction socket as the component (CBS) is the end result of the artificial limb development. Plastic components, the complications and the complications are the main factor of the development of prostheses. There is a lack of evidence, both clinical and experimental, that would identify the real cause of these complications. The second period is characterised by a more systematic approach, with a better understanding of the problems of limb making and an improvement in the technique of limb making. The second period is characterised by a more systematic approach, with a better understanding of the problems of limb making and an improvement in the technique of limb making.
control and a hydraulic or pneumatic swingphase control. Totally new designs for below-knee prostheses are made, resulting in the Patella Tendon Bearing (PTB) prosthesis. Later this design is modified in Europe into the Prothèse Tibiale à emboîtage Supracondylén (PTS) and the Kondyle Bettung Münster (KBM) prostheses. Another novelty, which enters the market in the seventies, is the endoskeletal or modular prosthesis, with its tubular frame and soft plastic cover. In the eighties new materials like Carbon Fibre Reinforced Plastics (CFRP’s) and titanium make their way into prostheseology and finally the computer enters the world of prostheseology, both as aid in designing and manufacturing and as device in a new generation of modular knee joints.

6.2 CONCLUSIONS

To begin with, there is no trace any mutual influence between amputation surgery and prostheseology in Ancient Times and the Middle Ages. There is no indication that prostheseology or limb makers have any influence on the developments in amputation surgery or on the deterioration of these developments. It is doubtful that the limb maker as a profession even exists, because except for the citation in the Talmud, about one occasion when a non-trained craftsman makes a prosthesis from a log of wood, no limb maker is ever mentioned. There is also no indication that amputation surgery or any surgeon have any influence on the developments in prostheseology. There is no evidence about any surgeon who cares whether his patients can walk again after the amputation, except the mythical twins Cosmas and Damian. But even they do not provide their patient with a prosthesis.

In the Renaissance there is a change for the better. Paré chooses an amputation level, his site of election, which is influenced by prostheseology, for he decides to make the length of a trans-tibial stump five fingers below the knee joint. That gives the stump the ideal length for the prosthesis that is most used during his times, the kneewalker peg leg. His leg prosthetic design is influenced by amputation surgery, for the design of an above-knee prosthesis is only necessary if there is a patient who needs such a prosthesis, i.e. a patient who survived an above-knee severance. So Paré can be considered as the mutual influence incarnate. Moreover he is the first known surgeon who has contact with a limb maker, Le petit Lorrain. It is almost certain that they have discussed the manufacturing of Paré’s design, but it is not to our knowledge if the limb maker has any influence on the final product, though the fact that he is an armourer and the prosthesis resembles the leg of an armour, might indicate some influence. Unfortunately Paré is far ahead of his time, for there is no evidence of any further influence from either side for more than a century and
the only influence that can be found before the French Revolution is in the
designs of Verduyn's and Ravaton's prostheses, who are influenced by their
own new amputation techniques. No other amputation technique has any
influence on developments in prostheseology and no development in prostheseology has any influence on amputation surgery.

During the French Revolution and the first half of the nineteenth century the picture is essentially the same. Some surgeons choose a site of election, influenced by the then used prostheses. It is possible that a prosthesis has been made for a hip disarticulation amputee, for that is the new amputation level, which is successfully explored, but no evidence of such a prosthesis still exists.

From the second half of the nineteenth century on the scene changes. Owing to the introduction of anaesthetics and antisepsis surgeons have ample time to do elaborate operations and the mortality rate is lowered. On the other hand the number of potential amputees rises, due to the increasingly huger armies, which are brought into the field during the almost continuous wars. So the number of surviving amputees rises and with it the demand of prosthetic supply. In the same period the possession of a leg prosthesis comes within reach of the common soldier, the bulk of the amputees, because their prosthetic supply is paid for by a third party. So the production of leg prostheses changes from a singularity into a profitable business, and from the manufacturing of a unique device into mass production of prostheses and later of prosthetic components. The use of a leg prosthesis requires more of an amputation stump, in the field of fitting, than the use of a peg leg, so surgeons are obliged to improve their amputation technique and reckon more with the possibilities and limitations of prostheseology. That generates the new amputation techniques like osteoplasty, myoplasty, cineplasty and turnover operations. On the other hand it is also responsible for the strict use of amputation schemes, the way a midthigh severance is usually handled and the aversion to the knee disarticulation. The surgeon's knowledge of possibilities and limitations of prostheseology supposes a certain contact between surgeons and prosthetists.

This contact originates from the military (amputation) hospitals annex limb fitting centres who are set up during the First World War in Austria, Germany and the United Kingdom. In these hospitals surgeons and prosthetists meet and gradually become aware of each others possibilities and problems. Before the Second World War these contacts are not generally established, but some contacts remain, like in Queen Mary's hospital for the limbless in Roehampton and in Germany between Schede and Habermann and between Görlich and Franke. After the Second World War the research in human physiology and kinesiology benefits both amputation surgery and prostheseology. In amputation surgery new techniques as osteomyoplasty and myodesis are developed and in prostheseology new physiological material is investigated. Amputations develop a level of precision that was unattainable before. In prostheses too no development is made. Thus in both respects the contact between surgeons and prosthetists is also completed.

So it can be seen that the revolution in prostheseology on the one hand, as well as the development of a new amputation technique on the other, has influenced the development of the prostheseology, as can be seen from the different amputation schemes where the stump is handled. These changes are not the only reason for the change in prostheseology, as can be seen from the fact that the prosthetists demand a change in amputation behaviour. The surgeon's knowledge of possibilities and limitations of prostheseology supposes a certain contact between surgeons and prosthetists.

From the military (amputation) hospitals, the major improvement in prosthetic devices as well as the change in amputation technique is propagated;

6.3 Contacts Between Surgeons and Prosthetists

The hospitals in which amputees are treated, have finished their operation and have to be fitted with a prosthesis. That is usually done in a hospital with a limb fitting centre. In this hospital the surgeon meets the prosthetist and has the opportunity to tell him the details of the operation, in order to get a prosthesis that fits the patient's stump. The surgeon is then also aware of the possibilities and limitations of prostheseology, and the prosthetist of the consequences of a certain amputation technique. This contact is essential, as it can be seen from the fact that the prosthetists demand a change in amputation behaviour. If a surgeon successfully performs an amputation, he will have no difficulty in getting a prosthesis that fits the stump, and vice versa. The prosthetist is then also aware of the possibilities and limitations of prostheseology, and the surgeon of the consequences of a certain amputation technique. This contact is essential, as it can be seen from the fact that the prosthetists demand a change in amputation behaviour. If a surgeon successfully performs an amputation, he will have no difficulty in getting a prosthesis that fits the stump, and vice versa. The prosthetist is then also aware of the possibilities and limitations of prostheseology, and the surgeon of the consequences of a certain amputation technique.
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6.3 CLOSING REMARKS

The history of amputation surgery and prostheseology of the lower extremity has finished in this thesis, but it is not the end of the history. In both fields not everything has been investigated yet and many improvements can still be made. In amputation surgery the research for the proper test to determine the amputation level and for a better way to heal amputation wounds continues.
In prostheseology there is still much research left, on the best socket design and on the working and usefulness of components. The connection between functional and technical characteristics of components is hardly known, even by the manufacturer. Most statements on the working of prosthetic components are not scientifically proven. The prescribing physician must know more about the connection between functional and technical characteristics to be able to serve his patient the best way possible.

Moreover it is time to combine the knowledge of amputation surgeons and physicians for rehabilitation medicine more than is done today.

In the Netherlands amputations are performed in almost every hospital by almost every surgeon. In view of the number of amputations performed yearly and the number of surgeons available, it means that most surgeons do only a few amputations per year. Too few to know and use the refined technique an amputation requires. Therefore physicians for rehabilitation medicine see many unfavourable amputation stumps, of which the prosthetic supply is extremely difficult. It is about time that a few specialized amputation clinics are founded in the Netherlands, where all the amputations of a certain region can be performed by a few highly specialized surgeons, in close cooperation with physicians for rehabilitation medicine and their rehabilitation team, who take care of the prosthetic management. **Only this way the amputee will have the assurance that the very traumatic operation of the severance of a part of his leg and the rehabilitation are done in an optimal way.**