National College of Art and Design

Faculty of Design

Department of Industrial Design

A Contextual Account of the Artificial leg 1806-1940

by

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But when it came to fitting the stump
With a proxy limb - then flatly and plump
She spoke in the spirit olden;
She couldn’t - she wouldn’t - she wouldn’t have wood
Nor a leg of cork, if she never stood,
And she swore an oath, or something as good,
The proxy limb should be golden.

(From Thomas Hood’s ‘Miss Kilmansegg and her Precious Leg’,1840 in Gordon Philip’s Best Foot Forward (1990), p.xiii).

1.0 INTRODUCTION

The meaning of the word prosthesis depends on that of the root of thesis from the Greek for "placing," a "position," "laid down," to be maintained against attack, "to make a stand." When applied to prosthetic limbs , in this case legs, " it is a foreign element that reconstructs that which cannot stand on its own, at once propping up and extending its host," (Wigley, Mark, 'Prosthetic Theory,' Assemblage, vol. No. 15, Aug. 1991, pp 7-9).

This thesis will deal with the area of prosthetics- the design and manufacture of devices that replicate and, as far as is technologically possible, substitute various parts of the human anatomy, such as, arms, hands, legs, feet, eyes, teeth etc. I have a personal interest in artificial limbs (my family is involved in the orthopaedic and orthotics industry) I shall concentrate on them as opposed to the other areas of prosthetics mentioned.

To begin with, I shall give a general overview of the development of artificial limbs from their origins in history. This section will lead up to the 19th Century. The core of this thesis will be set between the years 1805 and 1940 because:

a.) In 1805 a limbmaker by the name of James Potts in London, designed and produced an artificial limb that was to be the cornerstone in the design of artificial limbs right up to the present day.

b.) The 19th Century was the most important era in the development of the artificial leg as the result of a combination of developments within the medical industry, technological advancements in weaponry and the advancements made by limb makers.

c.) The early 20th Century (pre 1940) was a time of many more improvements and development in the progress of the artificial limb. The most significant event of that time was the First World War (1914-1918), after which the artificial limb industry in Europe was established as a result of the large numbers of war casualties. Once again, improvements in the medical and weaponry industries had an influential effect on the artificial limbs industry.

d.) 1940 saw the invention and development of myoelectrically controlled prosthetics. This thesis will not cover this new era in prosthetics because it was a dramatic change from what had existed before - manually operated artificial limbs. I feel that this new development would have to be taken as a study in itself because it changed the face of prosthetics on a scale previously unseen.

In the final chapter I shall look at the social and psychological effects of amputees and the wearing of artificial limbs. This chapter will not cover any particular time span because I feel that the problems of artificial limb wearers, be they psychological, social or both, have always existed and will continue to do so in the future. This chapter will be followed by a conclusion in which I shall sum up the factors involved in the development of the prosthetic leg throughout the outlined time period of 1805 -1940.

THE EARLY DAYS

The loss of limbs affects every living thing on this planet. The reasons are innumerable, the problem of limb loss probably unavoidable. War immediately comes to mind as the main reason for limb loss due to the numbers concentrated in being maimed at a particular time. This is perhaps true but the problem of the loss of limbs lies inherently within the area of medicine or the lack of it, as the case mainly is. Disease and infection cause a threat to life, a threat which through amputation can be eliminated. This solution must have been realised well over three and a half thousand years ago as the earliest mention of the use of a prosthesis seems to be in Indian literature, in the Rig-Veda, the oldest book of the Veda period (1500-800 BC), when the use of artificial eyes and artificial teeth, as well as artificial legs, was recorded[1]. Along with this is the story by Herodotus (485-425 BC) which refers to the mystical seer Hegesistratus of Elias who was imprisoned by the Spartans and held by one foot in stocks. This he hacked off at the instep, through the Chopart joint, so that he would still be mobile after escape (Philips, 1990, p. 28).

The history of artificial limbs probably dates from the emergence of intelligent man himself, which makes them as old as humanity. Whatever the motivation for the earliest amputations- ritual sacrifice, cure of disease, magic or punishment,- no one knows for certain where and when the first maimed person sought a remedy for their imperfection.

One could assume that since man first survived the loss of a lower limb, his immediate search was for a prop to support his body weight and enable him to stand up. He fashioned crude devices for himself such as 'peg legs' (or pylons as they were also called because of their tapered pole shape), wooden props or splints which could be bound to the stump for support (fig. 1).The earliest known representation of an artificial limb is said to be on a vase in the Louvre, from the fourth century BC , it depicts a crippled satyr with a peg leg at the knee (Philips, 1990, p.27).

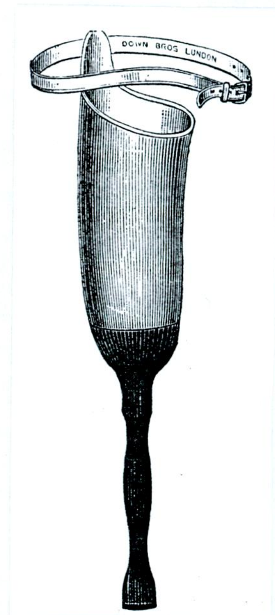


Fig. 1. An example of a 'Peg Leg' from a Down Bros. Catalogue of 1900.

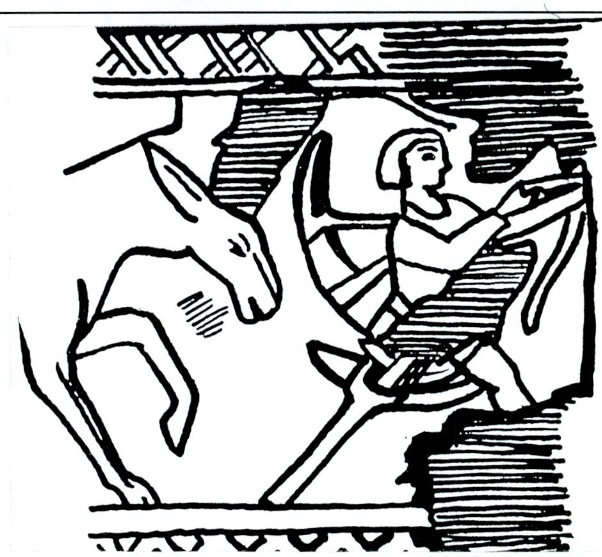


Fig. 2. Shows a pen drawing of a section of mosaic from the Cathedral of Lescar, France, depicting an amputee supported at the knee by a wooden pylon.

There is also an Inca pottery remnant (date unknown) which shows a figure of a man with a leg amputated at the tibiotarsal junction, and holding in his right hand a pointed cap to be adjusted to the stump of his leg. Another pictorial example comes from the cathedral in Lascar, France, from a mosaic which dates back to the Gallo-Roman era and shows an amputee supported at the knee by a wooden pylon (Fig. 2). Viking sagas sing of a hero called Trefote - 'wooden foot', (Philips, 1990, p.28)A Roman artificial leg excavated near Capua, Italy is the oldest artificial leg found so far. This limb was made of bronze plates and fashioned to a wooden core, (Fig. 3). It was on display in the Royal College of Surgeons, London up until 1941 when the college suffered badly during an air raid attack which destroyed the leg. It is said to have been made around 300 B.C.

Considering the nature of society in the early days of the artificial limb, we realise that those who withstood the loss of a limb depende upon the restoration of

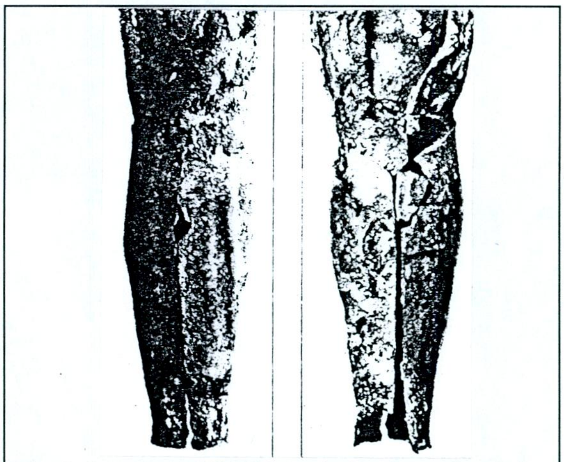


Fig. 3. Roman artificial leg, dating from the early Christian era, excavated near Capua, Italy.

their mobility for survival. No attempts were made at enhancing or disguising the appearance of these crude devices whose function was so essential that the patient tolerated considerable pain and effort to use them. Carved wooden pylons were the norm, similar to the one the infamous Long John Silver fashioned. But the question here is, why did it take so long for people to realise that through the hands of any half decent craftsperson these pylons or 'peg legs' could have been made more attractive (by adding feet or carving a more leg- shaped form), and less stigmatising ? Of course finances usually dictate the quality of living, as we can see from the reams of self congratulatory verbiage in Frederick Gray's book <u>Automatic Mechanism</u> (1855). In this account of his personal success as a limb maker, Gray brags about having been commissioned to make limbs for military captains, generals, majors, reverands, the Marquess of Anglesey and many more, and states towards the end of the book

- “Before I proceed to transcribe some of the cases in which my mode of supplying artificial substitutes has been eminently successful I will state my regret that, from the expense entailed by their elaborate construction, they are not within the reach of the poorer class of sufferers” and that “when a poor man becomes crippled he is reduced to a state of almost perfect destitution and misery ;” also, “it may be that the shorter stump would be more convenient for the poor man because it would fit better the supporting ledge of the common pin with which he is obliged to be content afterwards”,(Gray,1855 ,p. 50).

The peg leg worked …and worked right up through the centuries, through the Dark Ages, where very little is known about the progress made ,if any, in the line of prosthesis. The limbless were left to defend for themselves, if they survived. In the early days of amputations i.e. pre 1600’s (before any major improvements in medicine such as Pares findings) few patients survived above-knee amputations and the peg leg that existed then did not generally include adequate knee functions. It wasn’t until the invention of the tourniquet by the French in the sixteenth century and other advancements like the production of anaesthesia through alcohol and the use of cauterisation by red hot iron instead of boiling oil in medicine, that amputation patients began to survive their operations on a greater scale.

War is, of course the great forcing ground for spectacular innovation an the saying -‘necessity is the mother of invention’- couldn’t be more true. Newer more deadly weapons meant more death and injury. The “criteria of effectiveness for weapons are related to their ability to penetrate the body, a breastplate, or a wall; or to the radius over which they act, either through dispersal

of blast or shrapnel from grenades and high explosive shells ; or more simply to the weight of weapon necessary to kill one man, which has in some cases exceeded a ton," (Corvisier, 1988, p. 860). As the criteria for weapons became more demanding so too did the need for medical services on the battlefield.

The main points of reference in the advance of medical science are the practice of amputation- "curtailed for a while on account of a religious interdit in regard to operations that caused an effusion of blood" (Corvisier, 1988, p. 493), the invention of the tourniquet for stopping haemorrhages, the increasing skill of surgeons such as Pare in France and the slow steps in the struggle against the infection of wounds which lasted from the sixteenth to the nineteenth century from the use of the red- hot iron to Pasteurs employment of antibiotics.

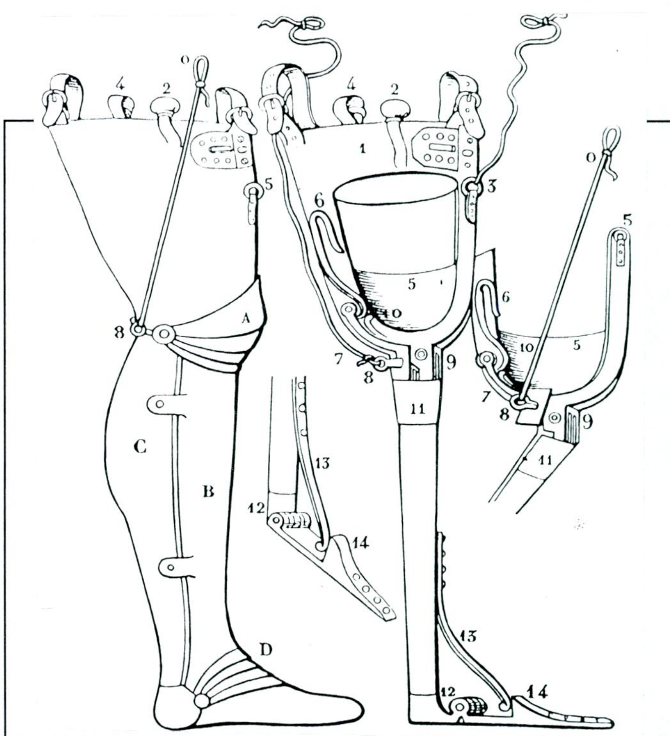


Fig. 4. Designed by Ambroise Pare, this is the first known jointed leg prosthesis from 16th Century.

Doctors in several countries devoted themselves entirely to treating soldiers , the best known being Ambroise Pare (born 1509 France, died 1590).

Pare began his medical career as an apprentice to a barber-surgeon, ('formerly the barber was also a surgeon and a dentist (The Shorter

Oxford English Dictionary on Historical Principles, Vol. 1), but in 1536 he started work as a military surgeon and it was in this field that he made many of his most important contributions. He established his reputation in 1545, when he reported his discovery that gunshot wounds contained no mysterious 'poison', as had been thought previously. He urged doctors to stop treating them with boiling oil (used because of it's soothing qualities when cool and because it didn't evaporate off the wound as water did) and to use a soothing dressing instead. Likewise, he discovered that ligature, (the operation of tying up a bleeding artery), was a more effective and more humane method of stopping bleeding after an amputation than a hot cautery.

But it was in replacing amputated limbs with man made substitutes that Pare made his most decisive contribution to human welfare. Pare was unique in the ingenuity he used in trying to simulate natural functions with mechanical gadgetry, (Fig. 4). Pare also recommended preferred sites for amputations and designed prosthesis with moveable joints and was the first surgeon to work in close collaboration with artificers, fore-runners of the modern day prosthesist. Pare devoted a considerable amount of time to the means of repairing or making good natural or accidental deficiencies in the human body, and " his whole approach is marked by an unusual compassion for the problems of handicap" (Philips, 1990, p.30). Because of this unusual compassion and the accuracy with which he carried out his science he has been called the "founder of modern principles of amputations" (de Bono, 1974, p.54). One could say that by the mid 1600' at this stage that Pare had set the ball rolling for both medical and prosthetics advancement.

At the end of the seventeenth century all European armies had surgeons on their strength and as conditions improved for the soldiers, (such as the invention of instruments ,e,g tubes for the extraction of musket balls and the application of soothing dressing onto wounds), the weapons they used in combat became equally as efficient.

However it wasn't until the turn of the eighteenth century that any major developments in weaponry technology really took place. Up until then the main causes of death on and off the battlefield , were from missiles in the form of lead shot from musket fire, cannons using solid lead balls though probably the most threatening of all was disease, infection and starvation. Gangrene set into untreated wounds and was the cause for many thousand amputations.

3.0 THE NINETEENTH CENTURY

At the turn of the nineteenth century an artisan mechanic by the name of Gavin Wilson of Edinburgh attempted a solution to above-knee prosthesis. His limb creation was fashioned from hardened leather with a knee joint which could be flexed in sitting and it was designed so that the knee stiffened while walking. This was the first attempt since Pares at overcoming an above-knee amputation. He also made the first use of what is now known as an 'ischial seat', (Fig. 5).

The nineteenth century brought the most significant changes in the construction and manufacture of prosthesis since Ambroise Pare's work in the six

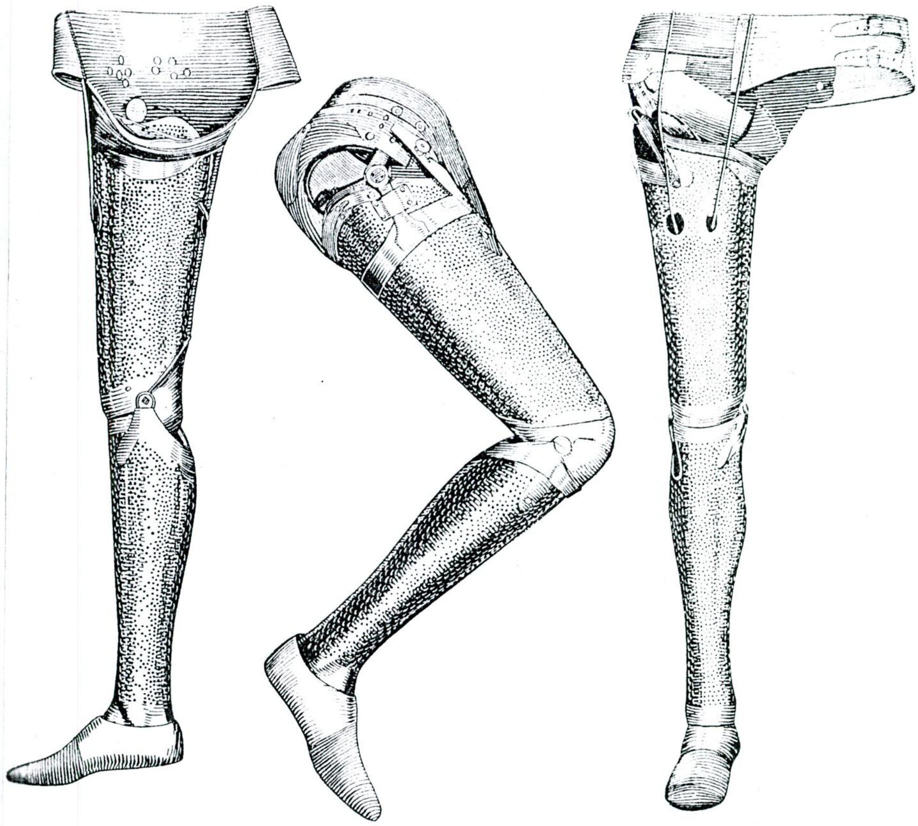


Fig.5. This example of an artificial limb shows the ischial seat in three views - from Maws catalogue of 1925.

teenth century. New materials such as aluminium were applied in the construction of limbs and their appearance began to become as important as their function. People now wanted artificial limbs that worked better and looked better, or more like the real thing, as opposed to the old fashioned peg leg which made no attempt at cosmesis. In saying this one cannot ignore the demands of the Italian Marquis Francis Riarrio who in 1616 commissioned a limb maker by the name of Zucchini to make for him both a functional <u>and</u> aesthetic limb.

Another landmark in the design of artificial legs was made by a Dutch surgeon by the name of Verduin at the turn of the nineteenth century. Verduin constructed a below- knee prosthesis with a wooden foot and a copper socket and

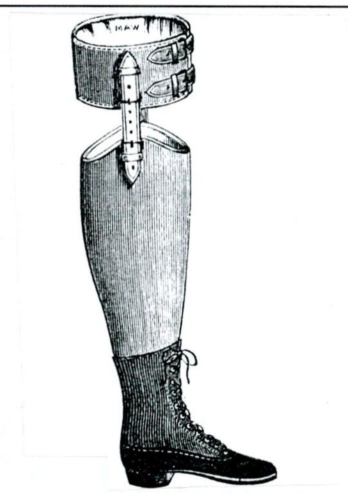


Fig. 6. Example of the metal hinged artificial limb- from Maws catalogue 1925.

used metal hinges on either side of the knee area (Fig. 6),which , after sundry modifications served as the pattern for modern prosthesis until the 1960s.

In 1805, a limb maker named James Potts of Chelsea in London put through a patent for an artificial leg articulated at the knee, ankle and toe joints. Potts continued to improve on what had already been achieved by earlier limbmakers and soon became one of the most famous limbmakers of that time. The main reason he is remembered in the prosthetics industry is for his famous 'Clapper Leg', thus called this because of the noise it made when fully extended, which he made for the Marquis of Anglesey (1768-1854) in 1816 after the battle of Waterloo (18 June 1815). " By God, sir, I've lost my leg!", is what Lord Uxbridge (soon to be created Marquis of Anglesey) is supposed to have exclaimed when, by almost the last shot fired in the Battle of Waterloo, a grape shot shattered his right leg. He

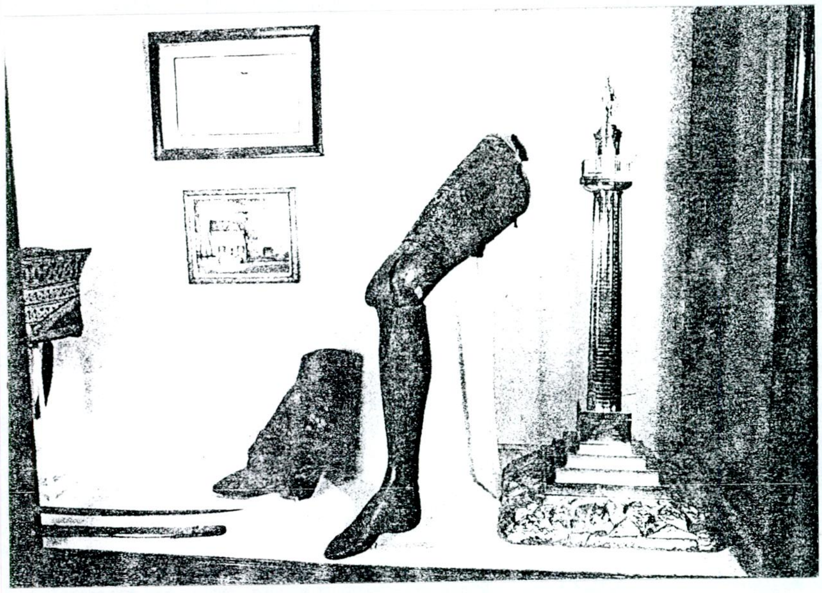
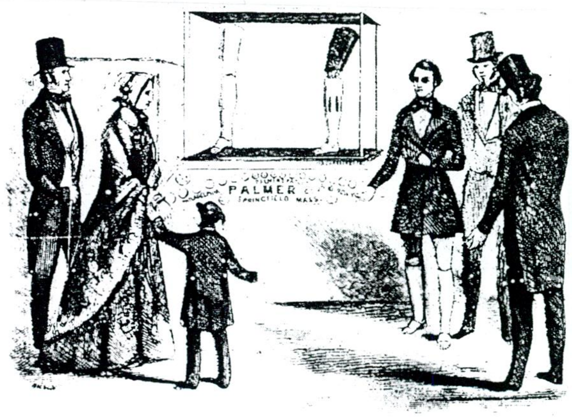


Fig. 7. Regalia of the 1st Marquess of Anglesey as General of Hussars, and the famous wooden leg named after him- from Philips, Gordon, Best Foot Forward, 1990.

was riding beside the Duke of Wellington at the time, who, on considering the mangled limb replied, "By God, sir so you have!" (Fig. 7). The Marquis of Anglesey was later treated by the rather pompus author and limbmaker, Frederick Gray, who describes the Marquis' case in a chapter from Automatic Mechanism, (1855), on - 'CASES'-in which relief has been afforded by my inventions'- and illustrates the current state of affairs with regard to amputations in the field as "the amputation not being satisfactory, a second amputation was performed...," Gray then goes on to describe over a hundred more cases many of them as criticising bad amputation operations, e.g. General Koupreanoff, whose amputation was badly performed ", similarly in the case of Mr. R...B..., who had a particularly "bad case"; the amputation had been badly performed, and the flaps had torn away from the front leaving no protection for the bone"(Gray, 1855, p.137).

In 1839 the 'Anglesey leg' was brought to America by a Doctor Palmer, him-self an amputee, and it was the only wooden leg to receive an honourable mention at the Crystal Palace Exhibition of 1851. The improved Palmer 'American leg'(Fig. 8) was a novel combination of artificial tendons within the



PALMER'S PATENT LEG.

Fig. 8. Illustration from Siegfiied Gideons' Mechanisation Takes Command, 1948.

limb which simulated muscle action. "In the 1850s they were used by 1200 people in the UK, and permutations on the original remained in use in Britain and France until the First World War"(Philips, 1990, p.30).

The Battle of Waterloo sparked off a chain reaction in the progress of military development, or as Asa Briggs has put it -"The face of war changed more radically in the sixty years after Waterloo than it had done in the previous six hundred",(Briggs, 1970, p.170).

These following years of military technological development brought with them machines that had the power to cut through entire armies like a great

scythe, leaving thousands of soldiers dead or injured at a much quicker rate than ever before.

The first major reform in weaponry development in the 19th Century was the improvement of the method of igniting the charge in rifles (the charge being gun powder). And in 1839 the British Ordanance Department replaced flint-lock with a percussion cap. This reduced misfires and lessened the handicaps of firing in wet weather. The second significant innovation in weaponry development was the substitution of a cylindro-conoidal bullet for a round ball; the new elongated bullet had a hollow base which expanded when fired. This development was rejected by the Ordinance Department but taken up by Minie a French armaments expert, in France and adopted by the French army in 1849. The 'Minies' effect on range and accuracy was quickly put to use by British troops who were able to open fire against the Kaffirs at 1300 yards. The Minie musket ball had a shattering, splintering effect on bone and because of this effect many an amputation had to be performed on the field.

Machine guns, in the sense of repeating fire arms, had a long history in terms of their evolution from the single shot rifle, but only in the mid nineteenth century did they become really effective weapons of war. Their three vital advantages were that they fired more shots than a rifle, they could raise a 'curtain of fire' through which it was suicidal for infantry or cavalry to advance, and they made fewer demands on the steadiness and marksmanship of the firer.

Between 1851 and 1869 under Napoleon III, patronage a much more impressive instrument was being developed-the mitrailleuse (Fig. 9). This gun possessed 37 barrels, weighed a ton and had a rate of fire of approximately 370 rounds per minute. One of the most lethal developments in weaponry of the nineteenth century was the introduction of high explosives. The use of explosives in war is the main reasons for amputations to take place. Mines are the worlds greatest limb destroyers. Mines and mining as weapons of war have been in existence for centuries, however, with advancements in explosives technology in the nineteenth century, they became much more effective.

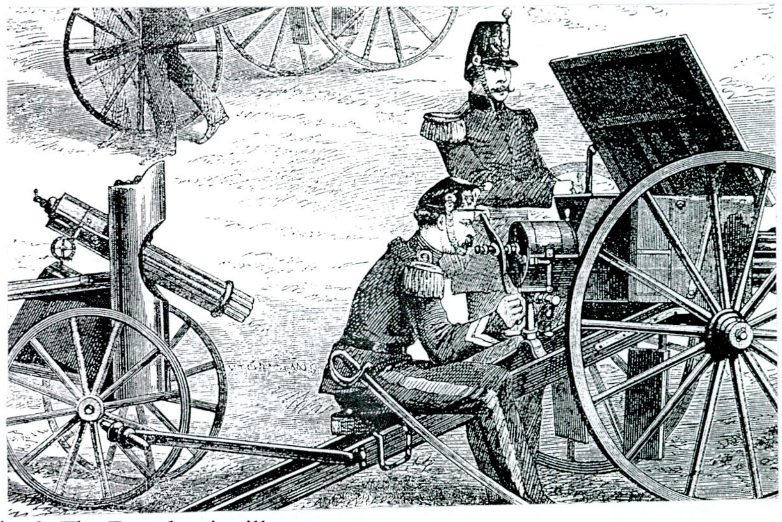


Fig. 9. The French mitrailleuse.

In 1846, the Italian chemist Ascanio Sobrero (1812-1888) discovered the explosive properties of liquid nitro-glycerine (NG) but before this, in 1838, T.J. Pelouze had developed nitro-cellulose (guncotton). By treating ordinary cotton with nitric acid and sulphuric acid, nitro-cellulose was formed. This was later purified and made less violent in it's raw state by Sir Frederick Abel, (1827-1902) in 1865, and in 1868 E.A. Brown discovered that guncotton, dry and

compressed, could be detonated by a fulminate detonator and this led to its adoption as a filling for shells.

3.1 MEDICAL SERVICES

Medical services within the army have a vital role in the well being of soldiers and civilians. It has the task of keeping in good health a considerable mass of people brought together by "adventitious circumstances and at great cost, and who frequently had to endure hard living conditions" (Corvisier, 1988, p.493). Many changes took place in the nineteenth century within military medicine, most notably the founding of the Red Cross by Henri Dunant in 1864. The necessity for medical aid on the battlefield was realised initially by the Romans when rulers began to assume responsibility for the maintenance of their armies. Later on, the Byzantine armies , which were small in size but highly developed, had men acting as medical orderlies on a scale of 8-10 per *tagma* (1500-4000),to collect the wounded in order to allow soldiers to continue fighting and to avoid breaking up the battle formation.

In 1806 ambulance battalions were brought into being under Napoleon These had six companies, each with sixteen ambulance vehicles for the collection and transport of the wounded. In 1824 teaching hospitals were opened in France and a corps of administrators of military hospitals in Europe was created. This was followed in 1856 by the setting up of the Ecole Imperiale de Service de Sante in association with the Faculty of Medicine at Strasburg University. During the nineteenth century it was the French who made the most ground with regard to improving medical services for soldiers. From 1863 onwards, the French applied a code of hygiene when dealing with medi-

cal issues such as operations, which was to prove extremely successful. This entailed: good organisation, the absence of alcoholic beverages, care over cleanliness and the wearing of flannel shirts. The introduction of ambulances onto the battlefield proved to be a prime necessity and the surest way of combating gangrene.

Taking these examples of military medical progress into account, one wonders why Gordon Philips, in his book Best Foot Forward, says what he does about the stage of progress in medicine in the nineteenth century, namely that - "doctors and apothecaries of the 1850s and 1860s scarcely more than did the physicians and priests of ancient times. They were strong on laxatives, leeches and purges, but apart from quinine and morphia were quite happy to try anything that had a medicinal smell or an interesting taste." (Philips, 1990, p.31). Surely the successes of the French medical services with their understanding of hygiene and the successful experimentation's of both Louis Pasteur and Joseph Lister cannot have escaped recognition from Mr. Philips?


Fig. 10 shows a modern day example of a 'flap job'.

Amputation techniques seem to have been left out of all these medical progressions. The methods pioneered by Ambroise Pare in the sixteenth century were still being ap-

plied in the 1800s. There were two options the surgeon used then :the first was called the 'guillotine' operation which was performed by slicing the soft tissue to the bone just above the damaged area and finishing the job in two or three minutes. The second technique was called a 'flap job', whereby the surgeon shortened the bone and brought flaps of soft tissue down over the end producing a better looking stump, albeit one very vulnerable to infection and slower to heal (Fig. 10). At least the improved stump from the flap job meant that amputees could wear their prosthesis with more comfort than before, (some amputees used to suffer severely if the amputation operation was poorly executed, whereby the cut bone would split due to pressure applied onto the artificial limb). Because of this, it was necessary for the surgeon and limbmaker to work in tandem, one advising the other so that the limbmaker could make a limb for the stump left by the surgeon.

3.2 AMPUTATIONS and THE CRIMEAN WAR (1854-1856)

The Crimean war ended forty years of peace in Europe. The Generals were old and out of practice and neither England nor France had any experience of large scale operations so far from home. As a result the horrors the horrors off the battlefield eclipsed those on it," (Briggs, 1970, p.166), and it fostered the first dim awareness of the futility of tearing the body rather than mending it. This war has been called, with justice, 'one of the most ill managed campaigns in modern history.' (Briggs, 1970, p.178). The conditions in field hospitals were appalling and disease and hunger were rampant. The fatality rate for amputations in the Crimea was never experienced before. The conditions

(disease, malnutrition, e.t.c.)made it extremely difficult to carry out successful amputations and for those that did, to survive afterwards. The mortality rate was about 55% for both primary and secondary amputations.(Philips, 1990, p.31).

3.3 THE PROFESSIONAL PROSTHESIST

In the United States, amputation was a much commoner operation than in Europe during the 19th Century, and the reason for this was that increased mechanisation had made accidents in and out of the workplace a more frequent occurrence.

Gradually limb making became less of a trade and more of a science and the specially skilled carpenter or blacksmith evolved into a trained prosthesist who set up or worked in shops that specialised in limbmaking. One such person responsible for setting up a limbmaking firm was Colonel J.E Hanger, who had lost a limb at the battle of Bull Run and proceeded to make for himself an artificial leg so that he could return to the field. Gradually his fellow soldiers with similar inflictions came to him for their own artificial legs. His son went on to set up the firm of J.E Hanger and Co. in England. In 1842 the firm Sheldrake,Bigg and Co. London, invented, by means of India Rubber tendons, an artificial limb in which the action of the knee and ankle joints were said to be 'as perfect as those of the natural limb'.

William Robert Grossmith picked up medals for his products at the Great crystal Palace Exhibition of 1851, and his patent leg in the 1860s was much lighter and cheaper than the old style of cork leg. It also lasted a lifetime and

was the only limb yet designed that women and children could wear with safety"(Philips, 1990, p.35)

In the U.S.A, The Marks Co. built a rubber foot which increased the safety and stability of the wearer as well as absorbing a considerable degree more of the impact shock. This was also the first industrialised use of rubber in the manufacture of prosthetic limbs. However, the Marks rubber foot did not allow lateral motion. This was achieved in 1858 by Douglas Bly of Rochester, New York, USA, who designed a limb with a ball and socket ankle mechanism which was useful for slopes and uneven surfaces. Another important step in the history of prosthesis was made by Dudois Parmalee in 1860 in America. He developed a suction socket and roller knee which was intended to reduce friction of the knee joint and by dispensing with body straps gave the user more freedom and ease of wearing and removal. 1860 also saw the introduction of aluminium in the manufacture of prosthesis as a replacement for steel parts.

The International Exhibition of 1862 was the second time artificial limbs were put on show, revealing their development since the peg leg. Old established companies like Bigg and Grossmith were well received. Bigg won praise for the lateral rotative motion of the ankle joint by means of the ball and socket which had been previously invented and patented by Bly of Rochester, New York, USA, and Grossmith for a novel spring principle which connected the action of the knee and ankle joints. Another firm whose patent work was noticed was that of Moses Master's, who was commended on the finish of his

artificial limbs. Also he had designed a knee spring which allowed the lower leg to recoil to a natural angle and a flexible toe mechanism which eliminated the need for a wooden joint and steel bolt. Masters concave hinge at the knee joint was immensely welcomed by below knee amputees; it was lighter and stronger than any other hinge and at the same time almost frictionless making it more durable, while the concavity allowed it to lie closer to the leg.

4.0 THE 20th Century

When war broke out in Europe on August 1914 (after Germany refused to withdraw from neutral Belgium) the artificial limb industry was almost unheard of in the UK. Makers were few and demand was minimal, bar the odd industrial or domestic accident, a common cause for leg injury was from accidents with fire arms. Overall, the industry was one that seems to have been kept out of the public gaze.

However, as it has and will always do, war, World War 1 in this case, acted as a stimulus, provoking the invention, improvement and production of artificial limbs. Like J.E Hanger in the Battle of Bull Run, injured soldiers often made makeshift limbs for themselves utilising old crutches, wood and leather waste. On a global level World War 1 yielded an experience in the creation and fitting of scientific prosthesis that was to be unique in history. The main problem of course was that the rage of war made it impossible for amputations to be made along set lines if as much of the limb was to be saved as possible. On a

general level, the condition of a soldier in war was taken to be one of poor health and because of this the scars and flaps covering the stump of a recently amputated limb were going to be more tender than for an ordinary amputation. So the fitting of prosthesis was more difficult in military life than in civilian life, where the patient had the continuity of treatment, hygienic surroundings, prolonged observation and some degree of counselling to keep alight the patients' spirit and resilience.

It was not until the first of the wounded began to arrive home that special amputee centres were established such as at Roehampton, Queen Marys Hospital London, where both surgical and prosthetic care could be given to the wounded. It was in these centres where the surgeon and limbmaker met literally at the bedside of the patient before the amputation, in order to discuss the optimum sites and discuss how the patient would be managed after the operation.

America didn't enter the war until 1917 and the fact that their prosthetics industry was considerably advanced and prolific at that time meant that they could supply artificial limbs in significant quantities to those countries who required them. The French Red Cross was the first to react positively to the crisis effect of scything machine gun fire and shrapnel, which left demand for limbs far outstripping capacity and appreciated that sophisticated limbs were available from the United States.

The introduction of American legs was not as much of an innovation in Britain as it was in France , as British limbmakers had been used to making a

stump socket out of a single piece of willow for years. What American innovation provided was

a.)The use of a sling which passed over the shoulders and attached to the leg below the knee, so as to act as a mechanism for extending the knee.
b. The manufacture of the leg portion out of a single piece of wood.
c. abolition of the old tendon action for the ankle joint and its replacement by the ankle with movement limited by Indian rubber buffers
d. One wooden part of the limb covered with a layer of raw hide or parchment so adding to its strength.

The stimulus of war led to swift advances in the design of mechanical knee joints, ankle joints and other innovations bearing on the skill of walking, and were the subject of constant research especially by the limb making firm of Blatchford Co. in England.

On the 9th of November 1917 Chas. Blatchford offered for approval a simple and inexpensive Central Knee Control (CKC) device whereby the lower leg or calf member of an artificial leg could be returned to a supporting position after it had been moved backwards when walking, or when the wearer had been sitting, this ensured a safe and almost silent mechanism. The day after the CKC was devised, the staff at Blatchfords came up with a simple and inexpensive ankle joint designed to minimise shocks when the wearer was walking up and down hill.[2]

In July of 1915 the Roehampton Hospital in London held an important international exhibition of artificial limbs. Around twenty four firms, many of

which were American and one or two Scandinavian, participated. The judging panel consisted of the Directors General of the Navy and Army medical services, together with the president of the Royal College of Surgeons of England and a committee of English, Scottish, and Irish surgeons. What they were looking for were appliances that could be adapted as standard patterns. The gold medal went to the Chicago firm of J.F. Rowley whose General Manager in the UK had only recently undergone amputation after a railway accident. He demonstrated the adaptability of his company's leg by running the length of the hall, moving freely up and down the stairs and by dancing and jumping.(Philips, 1990, p.55).

The carnage after the outbreak of war in 1914 was immense and the number of amputations many and there was still a long trail of wounded men expected to arrive back in Britain yet. By November 1916 there were 2400 cases on the hospital register at Queen Mary's, Roehampton, and 1250 patients ready to be admitted. Because of these kinds of backlogs in patient numbers waiting for limb fittings, muscles and strength tended to waste away.

Roehampton had workshops and a research department. These workshops gradually grew in size and importance and soon became a centre for design, fitting and post graduate training (rated as being one of the best of its kind in the world back then). Among its innovations was the development of Certalmid, which was like a laminated plastic material used primarily in artificial arms manufacture but also as a feature of leg prosthesis. This material remained in use until the end of the Second World War and the advent of true plastics. By 1918, there still had to be perfected a satisfactory knee mecha-

nism which would lock in any degree of flexion so that users could feel stable when their weight came upon the flexed knee. Also at this time there was still not a definite chosen standard or pattern of how the artificial limb should be made or what it should be made of. So far, of all the limbs developed none showed such an advantage over any other as to warrant it becoming the standard.

4.1 WEIGHT PROBLEMS

The weight of artificial legs caused much controversy. Overall distribution of weight is even more important than the total weight, a point clearly put by one patient :"When the socket fits me properly the limb feels no weight at all but when it's too loose it seems to weigh a ton" (Philips, 1990, p.57) After much time, limbmakers decided as a result of patient feedback, that no leg prosthesis could be too light provided they are strong enough, and light metal limbs made of duralumin arrived on the scene;(this was an aluminium alloy containing 4% copper, 0.5% magnesium and 0.5% manganese favoured for its high strength and extreme strength-(Schlenker, 1974, p. 79). Unfortunately Mr. Gray, who seems to know all there is to be known about prosthesis, doesn't cover the problem of weight in his book Automatic Mechanism. The nearest he comes to this point is when he describes the importance of the form of the limb -" It is of more importance than would at first be supposed, to make it a perfect match with the natural leg, of which it is to be the fellow,"(Gray, 1855, p. 90). Surely then Mr. Gray, if this is the case, with your limbs beings made of willow, that they would cause undue distress to the wearer due to this mass?

An engineer by the name of Charles Desoutter, created a metal limb for his amputee brother, a former test pilot in WW1 and won widespread approval for its lightness and mechanical ingenuity. The materials he used were aluminium and leather. Demand for similar limbs poured in and, in 1913, the Desoutter Bros. was formed. Their artificial limbs were reckoned to be immeasurably superior to the wooden legs which were then the main source of supply. Their only problem was that they were expensive and in 1917 not many ex-servicemen could afford £100 plus for a high tech limb. It was not until the 1920s that the British Ministry of Pensions decided that a Desoutter type limb was worth the expense and so they commissioned from Desoutters a light metal limb with a wooden socket at a cheaper price for ex- servicemen. By the end of the 1914-1918 war, limb manufacturers were glutted with work and could virtually dictate the pace of output.

4.2 THE TECHNOLOGY OF WEAPONRY IN WORLD WAR 1

Around 1900 most armies possessed field guns of 75 or 77mm, firing shrapnel shells against troops in the open and howitzers of 100mm, which fired high explosive shells on a steep trajectory to attack fortifications and dug-in positions.

The first World War witnessed the return of the mortar as a weapon for trench fighting because of the fact that the shells were shot at a high angle from the ground and then dropped into the desired target namely trenches Fig. In 1914

the British imitated the Germans in adopting TNT as their shell filling but demand rapidly outstripped supply. As a compromise, they mixed TNT with ammonium nitrate to produce Amatol, which became the standard British shell filling throughout the first and second World Wars.

The advent of the tank in World War 1 restored mobility to armies. Anti- tank mines and guns were introduced, bringing naval-style mine warfare onto a land environment. Anti-personnel mines were developed to make mine-lifting hazardous, particularly at night when covering fire was less effective. The Germans had used a primitive form of anti-tank mine in 1918, consisting of an artillery shell fitted with a pressure fuse, and all armies developed their own versions in the interwar years. However, the British did not produce an anti-personnell mine, preferring to depend upon covering their mine fields with machine gun fire. Also because mines were defensive weapons, they were not politically acceptable and were thought to be weapons of the 'weak' (The Oxford Companion to the Second World War, 1995, p. 341).

Anti-personnel mines became the world leader at maiming soldiers on the battlefield by the end of the 1914-1918 war. They posed many problems for surgeons and prosthetics experts. Firstly, when exploded the mine shatters the bone and sends hundreds of tiny fragments into the surrounding flesh. This usually caused infection to set in straight away and by the time the injured soldier was rescued from where he'd fallen, gangrene was almost certain to have attacked the shredded and fragment infested flesh. Because of this the surgeon would have to remove much more of the limb then would initially

have seemed necessary. This type of injury differed hugely from that of an infected musket shot wound (Fig. 11).

Fig. 11. A landmine victim.

4.3 WHEN THE GUNS FELL SILENT

As a result of the 1915 exhibition at Roehampton Hospital, the Rowley limb with its knee control mechanism was adopted by the British Government as

the 'standard limb' or pattern limb. And in 1920 the Advisory Council to the Military approved the specifications of this limb. Over the following few months, all artificial legs of wood or leather supplied to war pensioners would comply with the new patterns. From the ankle joint up to the thigh, the components were standard pieces and could be mass-produced easily. It was up to the limbmaker what components would suite his clients and it was also up to him to assemble the limb in accordance with his own technique.

The standardisation of the artificial limb did not, however, hamper progress as individual limbmaker's applied their own knowledge to the set pieces and there was a large amount of similar components with various limbmakers additions available, e.g.: ankle joints tailored to give the specific amount of movement acceptable to the wearer.

In 1921 the Chas. Blatchford Co. began work on their revolutionary 'New

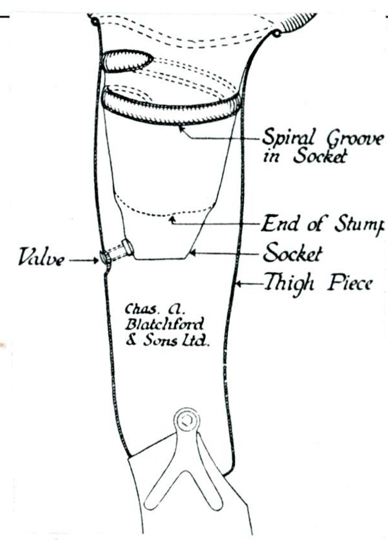


Fig. 12. The Premier Leg.

Blatchford' leg. Claimed to weigh 4.5 lbs, the 'premier' leg, with weight-adjustable, hygienic, stump socket and 'patent' ball-bearings throughout, was the latest development in the industry. It was patented "in all leading" coun-

tries in the world (Philips,1990, p.67). This most revolutionary of artificial limbs was fitted by enclosing the stump in a suction socket(Fig. 13) and it rendered obsolete

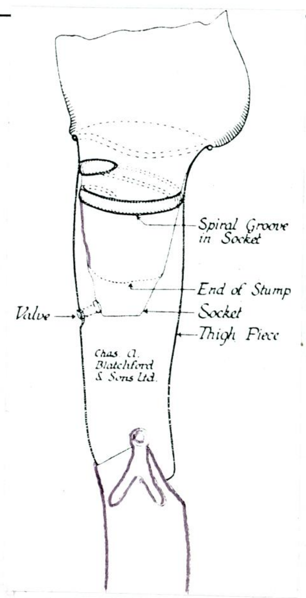


Fig. 13. Drawing of the suction socket incorporated into an artificial limb.

the rather awkward and uncomfortable shoulder straps or suspenders passing over the shoulder, and in the case of short stumps, the additional belt around the pelvis made of steel , leather or woven fabrics. The prosthesis moved with the stump as if it were a permanent extension of the stump and, without straps, it was boundlessly more suitable for women.

Often, amputees would take the designing of their artificial limb into their own hands in order to find the most suitable one possible. This is exactly what Ernest Underwood, a former weight lifter of championship rank, did (Fig. 14). He was one of the many ex-servicemen requiring an artificial limb and probably ended up with a limb from the Ministry of Pensions that, due to its

standardisation, was unsuitable for his needs. And so he decided to get his creative side to work on

Fig. 14. Blatchfords patient, Ernest Underwood, with the company's refinement of his own invention.

a personalised limb. In 1924 Chas. Blatchford & Co. began to refine his rather crude design which was turned on a lathe with 3-4 inch grooves on the inside, filling the stump as tightly as possible, and in 1925 the Blatchford Co. applied for a patent for an "Open- ended socket with projections" (Philips, 1990, p.68). The nature of this socket design eliminated as much discomfort as possible. The socket was made of duralumin and it fitted so closely that a partial vacuum was created, and a spring valve fitted into the socket , allowing air in when the limb was being removed. The close contact made by the metal socket and the spiral groove held the limb tight, and because this eliminated

friction, there were hardly any sores at all.. Finally it permitted healthy muscle growth thus increasing the circumference of the stump.

By March 1926 Moses Masters released their new metal leg with internal tendon attached, using their patented 'Surhold' hip joint and pelvic band enabling for the omission of shoulder braces. At this time too, Grossmiths improved on the Anglesey leg and the outcome was unsurpassed for lightness.

By the 1930s limb design had stabilised and there were no more miracle breakthroughs on any front. In fact, manufacturers of metal limbs began to receive complaints from pensioners and many wished to exchange their duralumin limbs for wooden ones (Fig. 15). The reason for this was because the wooden limb had

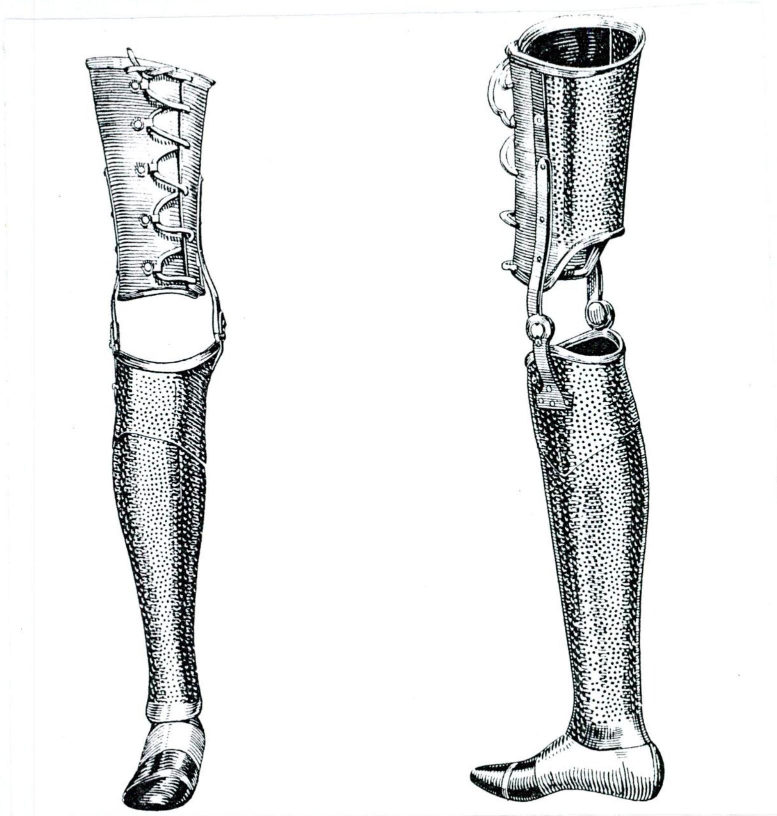


Fig. 15. An example of a duralumin leg from Maws catalogue 1925.

been so improved that it was actually lighter than the metal one , and was more suitable for certain cases of below-knee amputations. Limbs for above-knee amputations made of wood were as light as the prototypes in duralumin. No lighter limb existed in the 1930's than the British 'Anglesey' type, constructed in willow wood with only a small part of the knee and ankle bolt being made of metal. This design was copied by many, e.g. Fig. 16. Nevertheless, duralumin limbs still had their supporters and for "lady patients, several of whom are delicate, the change from the old limb to the duralumin limb has been of the greatest benefit" (Ernst,F.G, Branch of Associated Surgical Appliance Makers Ltd, letter to the British Medical Journal, 15 January 1921).

Fig. 16 shows an example of an artificial limb with an 'Anglesey' type joint.

Desoutter, another manufacturer of duralumin limbs was obviously in support of the metal limb and claimed that the light metal limbs could fit long stumps perfectly adequately and still be symmetrical with its fellow, leaving the limb for the long stump no heavier than one for a short stump. Desoutter's limbs were expensive but held in high regard, weighing on average 3.75lbs for above-knee amputations . By 1927 they had gradually ousted the 'Anglesey' among limb wearers.

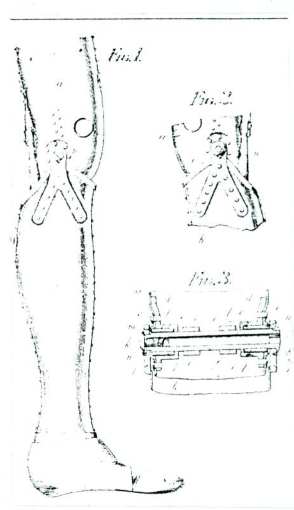


Fig. 17 showing Blatchfords roller bearing knee.

In 1925 Blatchfords patented the roller bearing knee (Fig. 17) for a metal leg. This reduced friction and any noise that friction created. Here the base of the shin and artificial shin bone in the metal limb was forged and machined from the solid and the ankle bolt was an integral part of the base. According to Chas. Blatchford & Sons, "It was the only limb made without loose pieces of sheet metal and rivets liable to become detached"(Philips, 1990, p.78). The knee-bearing surfaces were exactly the same as those used in the willow leg. The forward thigh motion was arrested by a sophisticated blend of check chord, wheel and spindle, so that by a simple screw adjustment the direction of movement of the thigh was self operated.

One of the last major developments before the Second World War was the safety knee lock (Fig. 18), in which articulated artificial legs locked by pressure without losing their lightweight element by the addition of extra components.

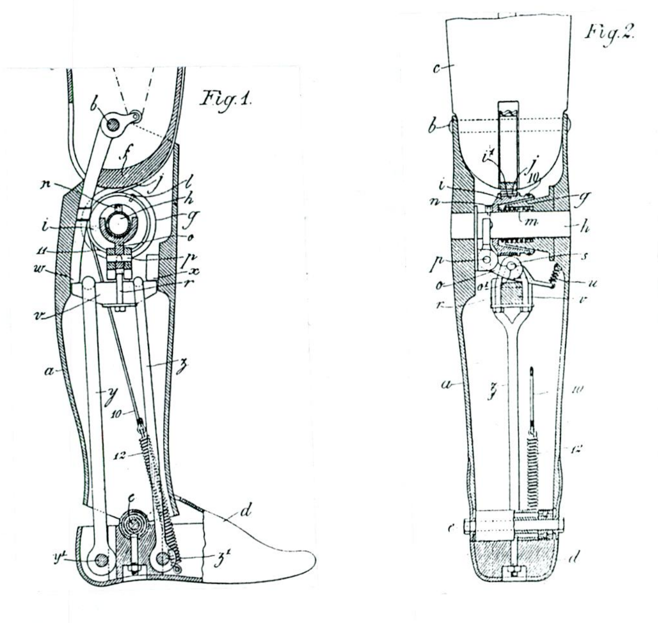


Fig. 18 shows a drawing of the safety knee brake from Blatchfords.

After the First World War most armies realised that, in the event of another war, their weaponry would have to be more accurate and more effective. One weapon closely related to

the loss of human limbs, as mentioned previously, is the anti-personnel mine. In the years leading up to the Second World War this explosive weapon became lighter and more difficult to detect. Mine-fields were laid according to precise plans, with roads through them to allow for counter attack and to allow them to be lifted when no longer required. So long as mines had metal casings , detection by magnetic detectors was a relatively easy task. More sophisticated mines were encased in wood, glass or plastic casings and were less easy to detect. In fact, the only sure method of detection meant a soldier or team of soldiers lying on their stomachs with bayonettes prodding the ground (Fig. 19).

Fig. 19 shows a de-miner prodding the ground for landmines.

4.4 MINE INJURIES

Survivors of mine blasts are usually inflicted with ravaging wounds resulting in traumatic surgical amputations. They require antibiotics, large amounts of blood, and extended hospital stays followed by physical therapy and prosthetic devices in order to lead any sort of normal productive lives. Some end up being horribly disfigured and may need therapy to cope with their trauma.

Mines damage the body either by blast or by dirt, bacteria, clothing, and metal and plastic fragments forced into the tissue and bone. Victim's legs are most commonly affected. However, damage is rarely confined to one leg, the other usually suffers lesser, but still severe, damage. "The shock wave from an exploding mine can destroy blood vessels well up the leg, forcing surgeons to amputate much higher than the site of the primary wound." (The Oxford Companion to the Second World War, 1995, p121).

5.0 PROSTHETICS AND SOCIETY - THE RETURN TO DIGNITY- A PSYCHO AND SOCIOLOGICAL CONSIDERATION OF THE EFFECTS OF PROSTHESIS .

What happens when amputees leave the prosthetics fitting rooms? Reintegration into society for some can be as painful as the blast that maimed them in the first place. In some countries, amputee soldiers often band to-

gether to protect one another. An example of this is in America where veterans from the First World War set up the Veterans Administration in Washington in 1930 with their motto of "To care for him who shall have borne the battle," (Motto is printed on the cover of each issue of the Bulletin of Prosthetics and Orthotics). The Administration set up research centres dealing in all the areas involved in prosthetics, treatment centres, orthopaedic shops, medical departments; in short they built a whole industry stemming from injured soldiers and camaraderie. However not every country has such an organisation and amputee soldiers are not generally looked after as well as in America. This, combined with the fact that they are maimed for life can breed hatred and anger amongst the bands of veterans. They may hold protest vigils in front of government buildings, demanding food and shelter. And "although they may eventually receive artificial limbs, they are rarely given government - sponsored training in new job skills applicable to civilian life. Abandoned by the government and society they fought to protect, many will grow resentful and turn to alcohol or drugs or become petty criminals" (Davies, 1995, p. 120). The legless beggar on the street, stripped of the glory and honour of war, becomes an eyesore in any society. (Fig. 20)

Fig. 20 shows the silhouette of an amputee begging in the streets.

Prosthetic replacement following amputation poses problems of function, cosmesis, self esteem, economics and social integration of the individual concerned, to which must be added the wider implications for the community or even the national economy.

In agrarian or pastoral societies, where muscle power means survival, an amputee may often be viewed as unproductive and simply another mouth to feed. Marked differences have been observed between the social position of amputees in rural and urban settings (Davies, 1995, p. 123). In part these differences are attributable to economic factors - it is easier for a rural amputee to contribute, albeit at a reduced level, to the family economy in village life than for an amputee to find work in the city. Not only does the ability to contribute economically make a difference to personal confidence and self image, but the ability not to be a burden to one's family seems to be the key in determining the ease with which the amputee is reintegrated into social life.

"No one thanks a surgeon for cutting off an arm or a leg" (Nicholas, John, J, 1993, p.16). However , once amputation has saved a patient's life, their feeling about the procedure and their situation will influence the subsequent course of life, rehabilitation, personal relationships, income, health and spirit (current practice in Cambodia is that no man who is an amputee may become a monk - Davies, 1995, p.114).

The attitude towards an amputee in the developing world relates to the culture and social structure of each country. There may even be differences within different regions in a single country. In Ethiopia, the concept of "alms for the

poor" is part of the country's culture and tradition. Giving money to disabled people is considered "lending money to God". In other countries, such as India, losing a limb is considered Karma and is neither a good nor a bad thing, rather fate. However , the rural amputee may be poor and, after considering the cost of a prosthesis, which may represent a year's earnings, may decide to do without. To feed the family or own a cow may be more important than owning a prosthesis.

In short, the psychological and social effects of amputation and the subsequent wearing of prosthetic limbs, are immense. The majority of them are a result of man's inhumanity to man, when prejudice and selfishness are ultimately to blame especially for the psychological trauma that amputees must endure.

Unfortunately, the loss of limbs amongst human kind will probably be with us for eternity, whether through the horrors of war or through simple accidents in the home. The only hope we have in aiding those who loose limbs is through the science of prosthetics and through understanding the difficulties they have in dealing with their losses.

6.0 CONCLUSION:

There has been a long and somewhat unsteady progression since the first mention of artificial limbs in the 'Rig Veda', the earliest book of the Veda period which dates from 1500-800 BC. This progression, to this day, has still not finished running its course. Modern man, whose superior intellect has invented machines that can do the workload of a thousand humans, has the ability to determine the fate of every living thing on this planet, even to walk on the moon. But to this day (1997), he has yet to devise a way in which human beings can regenerate lost parts of their anatomy. The possibilities for such a breakthrough may lie centuries into the future, or just around the corner, " but one thing for certain is that no matter what method we use to replace lost body parts it will never totally replace the original", (Murphy, Eugene,Spring 1965, p.4). One still wonders if physiological organs may someday be voluntarily replaced by artificial ones which are better.

The specific area of leg prosthetics has been an extremely interesting journey of discovery for me as a design student, and although there are many blank spots in the history of artificial limbs, such as during the Dark Ages, when hardly anything is known about their development, I have managed to find a considerable amount of information necessary to write about the history of artificial limbs and the weaponry most likely to have caused the need for artificial limbs, up until the outbreak of the 2nd World War.

To conclude this essay I feel it is necessary to illustrate how three predominant factors contributed to the artificial limbs industry just before the outbreak

of the 2nd World War in 1938: the development of artificial limbs , the development of the medical industry and finally the technological developments within the armaments industry.

It seems to me that the first person who should be credited with a mention in the long history of the artificial limbs industry is Hippocrates (460-370 BC). The reason for this is because he gives what is probably the earliest clear account of formal amputation by cutting through gangrenous tissue- to avoid pain, "those parts of the body which are below the boundaries of the blackening are to be removed at the joint, as soon as they are dead and have lost their sensibility; care being taken not to wound any living part" (Earl, P.F, 1977, p.19). It is clear that an understanding of amputative surgery had thus been established. This significant acknowledgement of the presence of gangrene was not matched in importance in amputative surgery advancement until the arrival of the French surgeon, Ambroise Pare (1510-1590), who introduced artery foreceps and ligatures for use in amputations, to control bleeding. Pares' surgical improvements (including his recommendations of preferred sites for amputation and the elimination of the use of boiling oil as a hot cautery), plus his attempts in trying to simulate natural functions with mechanical gadgetry (see Fig. 4), was in my opinion one of the most important landmarks in the progress of the artificial limb industry. Pare linked both professions providing future surgeons and prosthesists with the knowledge that resulted in an almost exponential development rate in the field of prosthesis.

The next important stage in prosthesis was the Battle of Waterloo (1815-1816), which resulted in the invention of the 'Clapper leg', made by James

Potts in 1816 for the Marquis of Anglesey. This leg proved to be the most successful device of its kind and permutations of it remained in use up until the First World War (1914-1918). 1846 saw the first surgical operation under ether anaesthesia, by Liston, an English biologist. Anaesthesia allowed longer and more complex operations than ever before, but there remained appalling risks of wound infection. Pasteur (1822-1895) proved beyond doubt that germs in the air are the *cause* of infection. In 1867 Joseph Lister (1827-1912), began to use ' antisepsis' in operations. Since heat cannot be used on the skin, he developed a carbolic spray which was directed at the wound , instruments and surgeons' hands. Lister's use of antiseptics reduced the mortality rate of his patients by two-thirds (Early, P, F, October, !977, p.19)

Unfortunately, although the 19th Century unveiled to the world some of the most significant findings in medical science, so too did it spawn monsters in the form of explosives and multi - barrelled machine guns, cannon shells and mines.

In 1838, T.J. Pelouze developed nitro - cellulose (guncotton), followed by the discovery of the explosive properties of liquid nitro - glycerine. In 1865 Sir Frederick Abel (1827-1902) purified nitro - cellulose and made it less violent in its raw state. Then in 1868 E.A. Brown discovered that nitro - cellulose, dry and compressed, could be detonated by a fulminate detonator leading to its adoption as a filling for shells. Between 1851 and 1869, under Napoleon iii's rule the French army developed the 'Mitrailleuse',- a machine gun boasting 37 barrels, weighing a ton and with a rate of fire of approximately 370 rounds per minute.

Technological advancements in the three area I am considering (weaponry, prosthesis and medicine) continued into the 20th Century. The First World War (1914-1918) saw the introduction of TNT by the British Forces on the battlefield. The application of high explosive shells in WW1 and anti - tank mines by the Germans resulted in the most unprecedented amount of limb loss ever seen in war .

In 1915 Queen Mary's Hospital in London established a special amputee centre to deal with the first of the casualties returning home from the front; it was here that the limb maker met the surgeon, literally at the bedside of the patient, to discuss optimum sites for amputation. By November 1917 Chas. Blatchford and Co., Limb Makers, had developed their Central Knee Control device which they applied to their artificial limbs. After this date the artificial limb industry took off. Newer, more advanced limbs made their way onto the market,gradually improving amputee's lifestyles. This progression continued until the next major breakthrough in 1940, the development of myoelectrically controlled prosthetics. This new area in prosthetics was so revolutionary that I have decided to end my study here.

The relationship between prosthetics, medical science and weaponry is inter-linked. To remove one of these would upset the rate of progression of the other two in an enormous way.

After researching these related subjects, I have become even more aware of the futility of war, but am still fascinated by its destructive powers and by man's attempts at resolving the devastation left by it.

7.0 IMPORTANT DATES IN RELATION TO THE DEVELOPMENT OF THE ARTIFICIAL LIMB INDUSTRY AND RELATED SUBJECTS

1500-800 BC - Earliest known mention of the use of artificial limbs, found in the Rig Veda, the oldest book of the Veda period.

400-300 BC - Earliest known representation of an artificial limb is said to be on a vase in the Louvre -Fig,

460-370 BC - Hippocrates describes gangrene following injury to limbs, he also describes amputation procedure.

300 BC - Earliest known artificial leg found in Capua, Italy, made of made of wood with bronze side- steels (plates).

1545 - Ambroise Pare (1509-1590), urges surgeons to treat wounds with soothing dressing instead of hot cautery, such as boiling oil.

1616 - Marquis Francis Riarrio of Italy commissions the limb maker Zucchini to make for him both a functional and an aesthetic limb.

1805 - James Potts of Chelsea, London puts through patent for artificial limb articulated at the knee, ankle and toe joints.

!806 - Napoleon introduces ambulance battalions onto the battle field.

1815 - Battle of Waterloo, (1815-1816).

1824 - Teaching hospitals opened in France to establish teams of medical officers for field hospitals.

- Sir Astley Cooper , English surgeon, performs first successful amputation through the hip.

1838 - T.J. Pelouze develops nitro-cellulose.

1839 - Anglesey leg brought to U.S.A. by Dr. Palmer.

- British Ordnance replaces flintlock with percussion cap.

1842 - Sheldrake, Bigg and Co. of England invent rubber tendons and achieve almost natural leg action.

1846 - Ascanio Sobrero (1812-1888), Italian chemist, discovered explosive properties of liquid nitro-glycerine.

- Liston of England carries out first operation under ether anaesthesia in England - a mid-thigh amputation.

1851 - 1869 - Development of the 'Mitrailleuse' machine gun in France.

1854 - 1856 - Crimean War.

1855 - Frederick Gray publishes 'Automatic Mechanism as applied in the construction of Artificial Limbs in cases of amputation'.

1858 - Douglas Bly of Rochester, U.S.A. designs artificial limb with a ball and socket ankle mechanism.

1860 - Introduction of aluminium as a material for use in construction of artificial limbs.

- Dudois Parmalee of America, develops a suction socket and roller knee mechanism.

1864 - Founding of the Red Cross by Henri Dunant of Italy.

1867 - Joseph Lister (1827-1912), begins to use 'antisepsis' in operations.

1868 - E.A. Brown discovers that dried and compressed nitro-cellulose could be detonated by a fulminate detonator.

1914 - 1918 - World War 1.

- British use TNT for use as shell filling.

1915 - Queen Marys Hospital in London holds international exhibition of artificial limbs .

1917 - Chas. Blatchford and Co. of London, patent CKC device.

1918 - German armies use primitive anti-tank mine.

1925 - Chas. Blatchford and Co. patent roller bearing knee for metal artificial limbs.

1926 - Moses Masters & Co. of London release their new metal artificial limb with internal tendons.

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