"We're seeing the first glimpses of the development of prosthetic devices," says Dr Jacky Finch, who has analysed this Egyptian prosthetic toe. It dates to between 950-710BC and was found on a female mummy in a tomb near Luxor. There are earlier references to prostheses - Indian texts from 1,400BC talk about an iron leg, but this is the "earliest tangible piece of archaeological evidence".

A model of "the Capua leg", part of the Brought to Life exhibit at the Science Museum in London. Found in Italy, it was the oldest artificial leg excavated and dated to 300BC. The original was destroyed in an air raid during World War II.

This heavy oak leg was made for a British merchant seaman after his ship was sunk during World War I. He was captured by a German ship, whose carpenter made the leg.

A prosthetic foot which laces around the lower leg - known as the Jaipur Foot. It was developed in India and can be made cheaply in under an hour. [Note: There is also the Jaipur Limb that goes to the knee.]
A Brief Review of the History of Prostheses by EARL E. VANDERWERKER, JR., M.D.

The history of man has been accompanied by trauma, war, and congenital anomalies. Consequently, amputations and deformity have been dealt with, one way or another, throughout the ages. Those with severe injuries either succumbed to their wounds or were disposed of on the battlefield, in the face of the inevitable. Only those with peripheral amputations might have survived.

Congenital anomalies were considered to be an act of retribution by the gods upon the offending parent. Consequently, most societies, disposed of the infant to hide the evidence.

It is believed that amputations were performed in the Neolithic times, from evidence of saws of stone and bone and what appears to be amputated bone stumps in skeletons of the period.

The first recorded instance of amputations and prosthetic replacement appears in the book of the Vedas, written in Sanskrit in India. The oldest of the Vedas is the Rig-Veda, which is believed to have been compiled between 3,500 and 1,800 B.C. It records that the leg of Queen Vishpla was amputated in battle. After healing of the repaired wound, an iron leg was fitted to enable Queen Vishpla to walk and to return to the battlefield...

... An Italian vase of the Fourth century B.C. shows a lower-limb amputee supporting himself with a wooden pylon. An artificial leg dating to about 300 B.C. was unearthed at Capua, Italy, in 1858. It was made of bronze and iron, with a wooden core, apparently for a below-knee amputee. The prosthesis was destroyed during an air raid on London in 1941.

Marcus Sergius, who lost his right hand in the Second Punic War (218 202 B.C.), was fitted with an iron hand, which he apparently used effectively.

The knights of the medieval days were anxious to replace limb loss with a prosthesis, not only to improve function but also to conceal their deformity and thus their weakness. It is only natural that prosthetic fabrication became a function of the armorers of the day, who were skilled in the use of metal and wood.

In 1550 Ambroise Pare designed an artificial hand called "le petit Lorrain" that had a fixed thumb but spring-loaded movable fingers. He also devised an above-knee prosthesis with a knee joint that could be released by a thong running to the hip. An upper-limb prosthesis using the trunk and shoulder-girdle muscles as a source of power for flexion and extension of the fingers was designed in 1818 by a German dentist, Peter Ballif. An above-elbow arm, using Ballif's principle to flex the elbow, was proposed by a Dutch sculptor in 1844.

The Civil War, with a resultant multitude of amputees, stimulated the development of more functional lower-limb prostheses by Marks and Hanger. In 1912 Dorrance invented the first split hook which has continued in standard use, with few modifications, to the present day. A suction socket for both arms and legs was invented in 1863 by Dubois Parmelee, 90 years before it received general acceptance.

Although instances of prosthetic replacement are mentioned throughout history, it is doubtful that more than a few per cent of amputees were fitted until after the Civil War period. With improved materials and miniaturized components available, we are progressing closer to the "ideal prosthesis" that has been sought for centuries.
The History of Prosthetic Devices

Prosthetic devices have existed for centuries. Originally prosthetics were simply replacements for missing limbs, but now they help people have extremely active lives. Such improvements have been made possible because of new surgical techniques, the advancement of components for making prosthetics, and creative engineering ideas.

Here is a timeline recounting the significant dates and developments for prosthetics.

**In Mythology:**

- Aia Paec (Ai Apec), a Peruvian god, was missing one of his arms below his elbows.
- **Tezcatlipoca, the Aztec god of creation and revenge, did not have a right foot.**
- New Hah, an Irish god, was a left arm amputee who had a four fingered prosthetic hand made of silver.
- Pelops, the grandson of Zeus, killed by his father Tantalus was to be eaten by the gods, but Demeter, the Greek goddess of agriculture, ate Pelops' shoulder. When she realized what she did, she brought him back to life, giving him an ivory shoulder.

**3500 BC**

- An Indian poem, Rig-Veda, is the first recorded document about a prosthesis. The poem tells the tragic story of Queen Vishplha, a warrior, who lost her leg in battle. After the battle, she had an iron prosthesis made, and she was able to go back to battle.

**5th C BC**

- Aristophanes included a character with a prosthetic leg in his play "Birds."

  Aristophanes
  (http://www.aristophanes.com/)

**218 BC**

- The Roman general named Marcus Sergius guided his troops against Carthage in the Second Punic War and suffered over 20 injuries, including the loss of his right arm. An iron hand was created so that he could fight for the rest of the war. Because of his amputation, he was not allowed to be a priest because he did not have two hands.
- Most of the prosthetics during Roman times were just wooden or steel pegs.

**1st C BC**

- Archeologists discovered bronze peg prosthetic. Although it was rusted, it is the oldest usable artifact of a prosthetic. It is still recognizable so that one could see how it connected to one's body.

**1508**

- The German knight Gotz von Berlichingen (1480-1562) is known as the German Robin Hood because he defended the serfs from the rich. He had to have his right arm amputated after the Battle of Landshut because a cannon ball caused his sword to fall and cut his arm. Gotz had two prosthetic iron hands to replace his right arm. Gotz's were different than previous prosthetic
limbs; he was able to move each joint by setting one hand which was settled by a release and springs. The hand could move because of hanging leather straps.

1529

- **Ambroise Pare introduced amputation to the medical community. He is considered the father of prosthetics.** In 1536, he made an artificial limb for the arm and elbow and created other limbs later

  - Ambroise Pare

  (http://www.robinsonresearch.com/HEALTH/PEOPLE/Pare.htm)

1696

- Pieter Andriannszoon Verduyn, a Dutch Surgeon, developed the first non-locking prosthesis for below the knee. This is the basis for the current joint and corset prosthesis.

1843

- Sir James Syme described his method for ankle amputation. Before this procedure, the technique used amputated at the thigh. By amputating at the ankle, the patient could have the possibility to walk again. The longer leg length allowed an artificial foot to bear a typical weight.

1858

- In Capri, Italy, the oldest known copper and wood leg (dated 300 B.C.) was discovered. Researchers determined it was from 300 BC.

1861-1865

- The American Civil War caused the start of the American prosthetics field.
• It is reported that there were at least 30,000 amputations on the Union side alone.
• Business ads for prosthetics from the time Civil War were usually familiar and tried to depict the primitive technology

![Amputation being performed in a hospital tent, Gettysburg, July 1863.](http://www.nara.gov/nara/nn/nns/civil036.jpg)

1914-1918

• Because the United States entered World War I late, not as many Americans suffered as the European nations. But prosthetics were further enhanced because of telephones and phone directories. Medical doctors were able to place illustrated ads, creating more customers.

![Sample ads from a Chicago phone book](http://www.prosthetics-culture.org/history/history.html)

1939-1945
Because of the low amount of amputees during World War I, there were not any significant prosthetic developments until World War II. Because World War II veterans found the current technology insufficient, those in the medical field saw the need for necessary advancements. The United States government made a deal with some military companies to improve prosthetics rather than weapons. In addition, the government standardized prosthetics training, instead of the previous apprenticeships, as well as increased funding for engineering research at universities. Because of the expanded awareness, people started to understand more about artificial limbs.


1960's

The Russians created a functional moving fake hand. Soon after Americans successfully developed an entire working arm. Although moving prosthetics were made decades ago, they have not become popular until recently because now they are more comfortable.

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A Brief History of Prosthetics

by Kim M. Norton

From the ancient pyramids to World War I, the prosthetic field has morphed into a sophisticated example of man’s determination to do better.

The evolution of prosthetics is a long and storied history, from its primitive beginnings to its sophisticated present, to the exciting visions of the future. As in the development of any other field, some ideas and inventions have worked and been expanded upon, such as the fixed-position foot, while others have fallen by the wayside or become obsolete, such as the use of iron in a prosthesis.

The long and winding road to the computerized leg began about 1500 B.C. and has been evolving ever since. There have been many refinements to the first peg legs and hand hooks that have led to the highly individualized fitting and casting of today's devices. But to appreciate how far the prosthetics field has come, we must first look to the ancient Egyptians.

For every plight, man seeks solutions

The Egyptians were the early pioneers of prosthetic technology. Their rudimentary, prosthetic limbs were made of fiber and it is believed that they were worn more for a sense of “wholeness” than function. However, scientists recently discovered what is said to be the world's first prosthetic toe from an Egyptian mummy and it appears to have been functional.

424 B.C. to 1 B.C.

An artificial leg dating to about 300 B.C. was unearthed at Capua, Italy, in 1858. It was made of bronze and iron, with a wooden core, apparently for a below-knee amputee.

In 424 B.C., Herodotus wrote of a Persian seer who was condemned to death but escaped by amputating his own foot and making a wooden filler to walk 30 miles to the next town.
The Roman scholar Pliny the Elder (23-79 A.D.) wrote of a Roman general in the Second Punic War (218-210 B.C.) who had a right arm amputated. He had an iron hand fashioned to hold his shield and was able to return to battle.

**The Dark Ages (476 to 1000)**

The Dark Ages saw little advancement in prosthetics other than the hand hook and peg leg. Most prostheses of the time were made to hide deformities or injuries sustained in battle. A knight would be fitted with a prosthesis that was designed only to hold a shield or for a leg to appear in the stirrups, with little attention to functionality. Outside of battle, only the wealthy were lucky enough to be fitted with a peg leg or hand hook for daily function.

It was common for tradesmen, including armorers, to design and create artificial limbs. People of all trades often contributed to making the devices; watchmakers were particularly instrumental in adding intricate internal functions with springs and gears.

**The Renaissance (1400s to 1800s)**

The Renaissance ushered in new perspectives of art, philosophy, science and medicine. By returning to the medical discoveries of the Greeks and Romans concerning prosthetics, the Renaissance proved to be a rebirth in the history of prosthetics. Prostheses during this period were generally made of iron, steel, copper and wood.
Early 1500s

In 1508, German mercenary Gotz von Berlichingen had a pair of technologically advanced iron hands made after he lost his right arm in the Battle of Landshut. The hands could be manipulated by setting them with the natural hand and moved by relaxing a series of releases and springs while being suspended with leather straps.

Around 1512, an Italian surgeon traveling in Asia recorded observations of a bilateral upperextremity amputee who was able to remove his hat, open his purse, and sign his name. Another story surfaced about a silver arm that was made for Admiral Barbarossa, who fought the Spaniards in Bougie, Algeria, for a Turkish sultan.

Mid- to late 1500s

French Army barber/surgeon Ambroise Paré is considered by many to be the father of modern amputation surgery and prosthetic design. He introduced modern amputation procedures (1529) to the medical community and made prostheses (1536) for upper- and lower-extremity amputees. He also invented an above-knee device that was a kneeling peg leg and foot prosthesis that had a fixed position, adjustable harness, knee lock control and other engineering features that are used in today’s devices. His work showed the first true understanding of how a prosthesis should function. A colleague of Paré's, Lorrain, a French locksmith, offered one of the most important contributions to the field when he used leather, paper and glue in place of heavy iron in making a prosthesis.

The 17th through 19th centuries

In 1696, Pieter Verduyn developed the first nonlocking below-knee (BK) prosthesis, which would later become the blueprint for current joint and corset devices. The Verduyn Leg consists of external hinges, wooden foot, and a leather cuff with a copper outer shell to hold the weight of the wearer.¹²¹

In 1800, a Londoner, James Potts, designed a prosthesis made of a wooden shank and socket, a steel knee joint and an articulated foot that was controlled by catgut tendons from the knee to the ankle. It would become known as the “Anglesey Leg” after the Marquess of Anglesey, who lost his
leg in the Battle of Waterloo and wore the leg. William Selpho would later bring the leg to the U.S. in 1839 where it became known as the “Selpho Leg.”

In 1843, Sir James Syme discovered a new method of ankle amputation that did not involve amputating at the thigh. This was welcome among the amputee community because it meant that there was a possibility of walking again with a foot prosthesis versus a leg prosthesis.

In 1846, Benjamin Palmer saw no reason for leg amputees to have unsightly gaps between various components and improved upon the Selpho leg by adding an anterior spring, smooth appearance, and concealed tendons to simulate natural-looking movement.

Douglas Bly invented and patented the Doctor Bly's anatomical leg in 1858, which he referred to as “the most complete and successful invention ever attained in artificial limbs.”

In 1863, Dubois Parmlee invented an advanced prosthesis with a suction socket, polycentric knee and multi-articulated foot. Later, Gustav Hermann suggested in 1868 the use of aluminum instead of steel to make artificial limbs lighter and more functional. However, the lighter device would have to wait until 1912, when Marcel Desoutter, a famous English aviator, lost his leg in an airplane accident, and made the first aluminum prosthesis with the help of his brother Charles, an engineer.

**Moving toward modern times**

As the U.S. Civil War dragged on, the number of amputations rose astronomically, forcing Americans to enter the field of prosthetics. James Hanger, one of the first amputees of the Civil War, developed what he later patented as the “Hanger Limb” from whittled barrel staves. People such as Hanger, Selpho, Palmer and A.A. Marks helped transform and advance the prosthetics field with their refinements in mechanisms and materials of the devices of the time.

Unlike the Civil War, World War I did not foster much advancement in the field. Despite the lack of technological advances, the Surgeon General of the Army at the time realized the importance of the discussion of technology and development of prostheses; this eventually led to the formation of the American Orthotic & Prosthetic Association (AOPA). Following World War II, veterans were dissatisfied with the lack of technology in their devices and demanded improvement. The U.S. government brokered a deal with military companies to improve prosthetic function rather than that of weapons. This agreement paved the way to the development and production of modern prostheses. Today's devices are much lighter, made of plastic, aluminum and composite materials to provide amputees with the most functional devices.
In addition to lighter, patient-molded devices, the advent of microprocessors, computer chips and robotics in today's devices are designed to return amputees to the lifestyle they were accustomed to, rather than to simply provide basic functionality or a more pleasing appearance. Prostheses are more realistic with silicone covers and are able to mimic the function of a natural limb more now than at any time before.

In exploring the history of prosthetics, we can appreciate all that went into making a device and the generations of perseverance required to ensure that man can not only have four limbs but that he can have function.
The Verduyn, sometimes spelled Verduuin, Leg consists of external hinges, wooden foot, and a leather cuff with a copper outer shell to hold the weight of the wearer. The Verduyn leg fulfilled the needs of many amputees. The leg seemingly disappeared until a surgeon reintroduced it in 1826 and the Verduyn leg remained popular until the 1960's, with some slight modifications along the way.
Limb prostheses or artificial limbs have a long history. Many different devices have been invented to replace the function of a missing arm or leg. Missing limbs may be the result of birth defects, accidents, or surgical amputation. The three main categories of disease that may require surgical removal of a limb include cancer, infection, and circulatory disease.

The earliest description of a limb prosthesis is found in Herodotus' The Histories written in 484 BCE. Herodotus tells of a soldier, Hegesistratus, who was imprisoned by the enemy. In order to escape from the stocks, Hegesistratus cut off part of his own foot. He later wore a wooden replacement.

The oldest known prosthesis, which was discovered in a tomb in Capua, Italy, was an artificial leg made out of copper and wood dating back to 300 BCE. Unfortunately the leg was destroyed by bombing during World War II. In the 15th and 16th centuries many prostheses were made from iron. They were created for soldiers by the same craftsmen who made their suits of armor. Ambroise Pare, a French army surgeon, contributed both to the practice of surgical amputation and to the design of limb prostheses.

Many innovations were made in the 19th century. Lighter-weight prostheses made from wood instead of metal gained popularity. In 1800, James Potts designed his famous wooden "Anglesey leg" which lifted the toe when bending the knee through the use of artificial tendons. In 1812 an arm prosthesis was developed which produced movement in the arm and hand using straps connected to the opposite
shoulder. Interest in artificial limbs increased late in the century due to the large number of amputations during the American Civil War. That prosthesis technology advanced during this time was primarily due to two factors - the availability of government funding of prostheses for war veterans and the discovery of anesthetics such as chloroform and ether, which allowed longer surgeries during which more functional amputation stumps could be shaped. These more carefully designed stumps enabled prosthetists to improve the fit of their devices.

103. Civil War Leg Prostheses, circa 1865. Leg prostheses worn by Corporal David D. Cole for an amputation performed at the knee joint. Courtesy of the National Museum of Health and Medicine

In response to the plight of World War II amputees, the National Academy of Sciences established the Artificial Limb Program in 1945. This agency promoted and coordinated scientific research with the goal of improving the design of prosthetic devices. Much emphasis was placed on investigating the movement of normal human limbs so that prostheses could be designed to appear as life-like as possible. Doctors and engineers worked together in many of these projects. Advances in biomechanical understanding, the development of new materials such as plastic, and the use of computer-aided design and manufacturing have all contributed to the creation of many new prosthetic devices.
A brilliant German scientist and engineer, Hans Mauch was fascinated by the field of rehabilitative medicine. From the late 1950s he devoted his energies to prosthetic development. Building on studies sponsored by America's Veterans Administration, he collaborated with fellow scientist Ulrich Henschke to design the **Mauch hydraulic knee system**. Made by Ossur.

Enhanced with the latest materials technologies over recent years, the Mauch knee has stood the test of time and remains a popular choice for active amputees worldwide.

**From Jeff Sobil's lecture “Spare Parts”**

Mauch was a German aeronautical engineer who specialised in hydraulics, pneumatics and mechanics and had previously worked on the V-1 rockets, ME 262 jet-propelled fighter, remote-controlled missiles, the first climate controlled flight suite and airfield cranes.

After WWII he came to the states to work for the US Air Force and designed prosthetics in his spare time. The Mauch Knee is still the most widely used high-activity knee in the world. It uses viscous fluid to regulate movement of the joint for natural gait and flexibility and provides maximum control and minimum strain when walking. This is usually one of the most ideal and affordable knee joints, especially for young, active patients.
Prosthetics have been mentioned throughout history. The earliest recorded mention is the warrior queen Vishpala in the Rigveda. The Egyptians were early pioneers of the idea, as shown by the wooden toe found on a body from the New Kingdom. Roman bronze crowns have also been found, but their use could have been more aesthetic than medical.

Another early mention of a prosthetic comes from the Greek historian Herodotus, who tells the story of Hegesistratus, a Greek diviner who cut off his own foot to escape his Spartan captors and replaced it with a wooden one. Pliny the Elder also recorded that a Roman general who had his arm cut off had an iron one made to hold his shield up when he returned to battle. A famous and quite refined historical prosthetic arm was that of Götz von Berlichingen, made at the beginning of the 16th century.

Around the same time, François de la Noue is also reported to have had an iron hand, as is, in the 1600s century, René-Robert Cavalier de la Salle. During the Dark Ages, prosthetics remained quite basic in form. Debilitated knights would be fitted with prosthetics so they could hold up a shield. Only the wealthy could afford anything that would assist in daily life. During the Renaissance, prosthetics developed with the use of iron, steel, copper, and wood. Functional prosthetics began to make an appearance in the 1500s.

Götz von Berlichingen, a German mercenary, developed a pair of iron hands that could be moved by a series of catches and springs. An Italian surgeon recorded the existence of an amputee who had an arm that allowed him to remove his hat, open his purse, and sign his name. Improvement in amputation surgery and prosthetic design came at the hands of Ambroise Paré. Among his inventions was an above-knee device that was a kneeling peg leg and foot prosthesis with a fixed position, adjustable harness, and knee lock control. The functionality of his advancements showed how future prosthetics could develop.

Other major improvements before the modern era:

- **Pieter Verduyn** - First nonlocking below-knee (BK) prosthesis.
- **James Potts** - Prosthesis made of a wooden shank and socket, a steel knee joint and an articulated foot that was controlled by catgut tendons from the knee to the ankle. Came to be known as “Anglesey Leg” or “Selpho Leg.”
• **Sir James Syme** - A new method of ankle amputation that did not involve amputating at the thigh.

• **Benjamin Palmer** - Improved upon the Selpho leg. Added an anterior spring and concealed tendons to simulate natural-looking movement.

• **Dubois Parmlee** – Created prosthetic with a suction socket, polycentric knee, and multi-articulated foot.

• **Marcel Desoutter & Charles Desoutter** – First aluminum prosthesis

At the end of World War II, the NAS (National Academy of Sciences) began to advocate better research and development of prosthetics. Through government funding, a research and development program was developed within the Army, Navy, Air Force, and the Veterans Administration.

The following organizations have been created to help and inform the general public about prosthetics:

• **American Orthotic and Prosthetic Association, American Board for Certification in Prosthetics and Orthotics, American Academy of Orthotics and Prosthetics** – These three groups work together to take responsibility for the academic side of orthotics and prosthetics and provide certification of individuals and facilities working with orthotics and prosthetics.

• **National Association for the Advancement of Orthotics and Prosthetics**. This is a patient advocacy organization.

• **The International Society for Prosthetics and Orthotics** – Founded in 1970 and headquartered in Copenhagen, helps with the progression in research and clinical practice worldwide. They hold an international conference every three years and publish their own technical journal. The next convention is Feb. 4-7 2013 in Hyderabad, India.

• **Association of Children’s Orthotic-Prosthetic Clinics** – The organization was started in 1950s to advocate research and development of children’s prosthetics. They meet annually and have their own publication.

• **Amputee Coalition of America** – The organization was created in 1990 to improve the lives of amputees. Advocate the improvement of amputee lifestyle through education and also have their own publication, inMotion.

• **Canadian Association for Prosthetics and Orthotics**. It represents professionals in both these fields.

[edit] Lower extremity prosthetics

Lower extremity prosthetics describes artificially replaced limbs located at the hip level or lower. The two main subcategories of lower extremity prosthetic devices are 1. trans-tibial (any amputation transecting the tibia bone or a congenital anomaly resulting in a tibial deficiency) and 2. trans-femoral (any amputation transecting the femur bone or a congenital anomaly resulting in a femoral deficiency). In the prosthetic industry a trans-tibial prosthetic leg is often referred to as a "BK" or below the knee prosthesis while the trans-femoral prosthetic leg is often referred to as an "Ak" or above the knee prosthesis.

Other, less prevalent lower extremity cases include the following:
1. Hip disarticulations - This usually refers to when an amputee or congenitally challenged patient has either an amputation or anomaly at or in close proximity to the hip joint.
2. Knee disarticulations - This usually refers to an amputation through the knee disarticulating the femur from the tibia.
3. Symes - This is an ankle disarticulation while preserving the heel pad.

**[edit] Lower extremity modern history**

Socket technology for lower extremity limbs saw a revolution of advancement during the 1980s when Sabolich Prosthetics, John Sabolich C.P.O., invented the Contoured Adducted Trochanteric-Controlled Alignment Method (CATCAM) socket, later to evolve into the Sabolich Socket. He followed the steps of science led by Ivan Long and Ossur Christensen as they developed alternatives to the scientifically developed quadrilateral socket, which followed the open ended plug socket created from wood. The advancement was due to the difference in the socket to patient contact model. Prior, sockets were made in the shape of a square bucket with no specialized containment for either the patient's bony prominences' or muscular tissue. Sabolich's design held the patient's limb like a glove, locking it into place and distributing the weight evenly over the existing limb as well as the bone structure of the patient. This was the first instance of ischial containment and led to an extreme advancement in patient accomplishment. Because of Sabolich's dedication to research and development in lower extremity prosthetics, Sabolich Prosthetics saw the first above the knee prosthetic patients walk and run step over step with both one leg and two legs missing, walking down stairs, suction sockets, modern plastic and bio elastic sockets, sense of feel technology, and numerous other inventions in the prosthetic field. Others who contributed to socket development include Tim Staats, Chris Hoyt, Frank Gottschalk (who undermined in a scientific article the efficacy of the CAT-CAM socket - indicating the surgical procedure done by the amputation surgeon was most important to prepare the amputee for good use of a prosthesis of any type socket design.

The first microprocessor-controlled prosthetic knees became available in the early 1990s. The Intelligent Prosthesis was first the commercially available microprocessor controlled prosthetic knee. It was released by Chas. A. Blatchford & Sons, Ltd., of Great Britain, in 1993 and made walking with the prosthesis feel and look more natural. An improved version was released in 1995 by the name Intelligent Prosthesis Plus. Blatchford released another prosthesis, the Adaptive Prosthesis, in 1998. The Adaptive Prosthesis utilized hydraulic controls, pneumatic controls, and a microprocessor to provide the amputee with a gait that was more responsive to changes in walking speed. Little evidence exists to support the tremendous financial burden to third parties who pay essentially the cost of a cheap home for the microprocessor knee, ischial containment socket, flexfoot leg. Some amputees from the Iraq and Afghanistan conflicts have returned to service with sophisticated prostheses. Cost analysis reveals that a sophisticated above knee prosthesis will be in the neighborhood of $1 million in 45 years, given only annual cost of living adjustments.

**[edit] Prosthetic enhancement**

Further information: Powered exoskeleton#Research

In addition to the standard artificial limb for everyday use, many amputees or congenital patients have special limbs and devices to aid in the participation of sports and recreational activities.

Within science fiction, and, more recently, within the scientific community, there has been consideration given to using advanced prostheses to replace healthy body parts with artificial mechanisms and systems to improve function. The morality and desirability of such technologies are being debated. Body parts such as legs, arms, hands, feet, and others can be replaced.

The first experiment with a healthy individual appears to have been that by the British scientist Kevin Warwick. In 2002, an implant was interfaced directly into Warwick's nervous system. The electrode array, which contained around a hundred electrodes, was placed in the median nerve. The signals...
produced were detailed enough that a robot arm was able to mimic the actions of Warwick's own arm and provide a form of touch feedback again via the implant.\[20]\n
In early 2008, Oscar Pistorius, the "Blade Runner" of South Africa, was briefly ruled ineligible to compete in the 2008 Summer Olympics because his prosthetic limbs were said to give him an unfair advantage over runners who had ankles. One researcher found that his limbs used twenty-five percent less energy than those of an able-bodied runner moving at the same speed. This ruling was overturned on appeal, with the appellate court stating that the overall set of advantages and disadvantages of Pistorius' limbs had not been considered. Pistorius did not qualify for the South African team for the Olympics, but went on to sweep the 2008 Summer Paralympics, and has been ruled eligible to qualify for any future Olympics. He qualified for the 2011 World Championship in South Korea and reached the semifinal where he ended last timewise, he was 14th in the first round, his personal best at 400m would have given him 5th place in the finals.

Dean Kamen's company DEKA developed the "Luke arm", an advanced prosthesis currently under trials as of 2008.\[21]\n
[edit] Types

There are two main types of artificial legs -- the transtibial, transfemoral. The type of prosthesis depends on what part of the limb is missing.

[edit] Transtibial prosthesis

A transtibial prosthesis is an artificial limb that replaces a leg missing below the knee. Transtibial amputees are usually able to regain normal movement more readily than someone with a transfemoral amputation, due in large part to retaining the knee, which allows for easier movement. In the prosthetic industry a trans-tibial prosthetic leg is often referred to as a "BK" or below the knee prosthesis.

[edit] Transfemoral prosthesis

A transfemoral prosthesis is an artificial limb that replaces a leg missing above the knee. Transfemoral amputees can have a very difficult time regaining normal movement. In general, a transfemoral amputee must use approximately 80% more energy to walk than a person with two whole legs.\[21] This is due to the complexities in movement associated with the knee. In newer and more improved designs, after employing hydraulics, carbon fibre, mechanical linkages, motors, computer microprocessors, and innovative combinations of these technologies to give more control to the user. In the prosthetic industry a trans-femoral prosthetic leg is often referred to as an "AK" or above the knee prosthesis.\[23]\n
[edit] Current technology/manufacturing

Knee prosthesis manufactured using WorkNC Computer Aided Manufacturing software
In recent years there have been significant advancements in artificial limbs. New plastics and other materials, such as carbon fiber, have allowed artificial limbs to be stronger and lighter, limiting the amount of extra energy necessary to operate the limb. This is especially important for transfemoral amputees. Additional materials have allowed artificial limbs to look much more realistic.\[24\]

In addition to new materials, the use of electronics has become very common in artificial limbs. Myoelectric limbs, which control the limbs by converting muscle movements to electrical signals, have become much more common than cable operated limbs. Myoelectric signals are picked up by electrodes, the signal gets integrated and once it exceeds a certain threshold, the prosthetic limb control signal is triggered which is why inherently, all myoelectric controls lag. Conversely, cable control is immediate and physical, and through that offers a certain degree of direct force feedback that myoelectric control does not. Computers are also used extensively in the manufacturing of limbs. Computer Aided Design and Computer Aided Manufacturing are often used to assist in the design and manufacture of artificial limbs.\[24\]

Most modern artificial limbs are attached to the stump of the amputee by belts and cuffs or by suction. The stump either directly fits into a socket on the prosthetic, or—more commonly today—a liner is used that then is fixed to the socket either by vacuum (suction sockets) or a pin lock. Liners are soft and by that, they can create a far better suction fit than hard sockets. Silicone liners can be obtained in standard sizes, mostly with a circular (round) cross section, but for any other stump shape, custom liners can be made. The socket is custom made to fit the residual limb and to distribute the forces of the artificial limb across the area of the stump (rather than just one small spot), which helps reduce wear on the stump. The custom socket is created by taking a plaster cast of the stump or, more commonly today, of the liner worn over the stump, and then making a mold from the plaster cast. Newer methods include laser guided measuring which can be input directly to a computer allowing for a more sophisticated design.

One problems with the stump and socket attachment is that a bad fit will reduce the area of contact between the stump and socket or liner, and increase pockets between stump skin and socket or liner. Pressure then is higher, which can be painful. Air pockets can allow sweat to accumulate that can soften the skin. Ultimately, this is a frequent cause for itchy skin rashes. Further down the road, it can cause breakdown of the skin.\[22\]

Artificial limbs are typically manufactured using the following steps:\[24\]

1. Measurement of the stump
2. Measurement of the body to determine the size required for the artificial limb
3. Fitting of a silicone liner
4. Creation of a model of the liner worn over the stump
5. Formation of thermoplastic sheet around the model – This is then used to test the fit of the prosthesis
6. Formation of permanent socket
7. Formation of plastic parts of the artificial limb – Different methods are used, including vacuum forming and injection molding
8. Creation of metal parts of the artificial limb using die casting
9. Assembly of entire limb

[edit] Myoelectric

A myoelectric prosthesis uses electromyography signals or potentials from voluntarily contracted muscles within a person's residual limb on the surface of the skin to control the movements of the prosthesis, such as elbow flexion/extension, wrist supination/pronation (rotation) or hand opening/closing of the fingers. A prosthesis of this type utilizes the residual neuro-muscular system of the human body to control the functions of an electric powered prosthetic hand, wrist or elbow. This is as opposed to an electric switch prosthesis, which requires straps and/or cables actuated by body movements to actuate or operate switches that control the movements of a prosthesis or one that is
totally mechanical. It is not clear whether those few prostheses that provide feedback signals to those muscles are also myoelectric in nature. It has a self suspending socket with pick up electrodes placed over flexors and extensors for the movement of flexion and extension respectively.

The first commercial myoelectric arm was developed in 1964 by the Central Prosthetic Research Institute of the USSR, and distributed by the Hangar Limb Factory of the UK.[26][27]

[edit] Robotic limbs
Main article: Neural prosthetics
Further information: Robotics#Touch

Advancements in the processors used in myoelectric arms has allowed for artificial limbs to make gains in fine tuned control of the prosthetic. The Boston Digital Arm is a recent artificial limb that has taken advantage of these more advanced processors. The arm allows movement in five axes and allows the arm to be programmed for a more customized feel. Recently the i-Limb hand, invented in Edinburgh, Scotland, by David Gow has become the first commercially available hand prosthesis with five individually powered digits. The hand also possesses a manually rotatable thumb which is operated passively by the user and allows the hand to grip in precision, power and key grip modes.[26] Raymond Edwards, Limbless Association Acting CEO, was the first amputee to be fitted with the i-LIMB by the National Health Service in the UK.[20] The hand, manufactured by "Touch Bionics" of Scotland (a Livingston company), went on sale on 18 July 2007 in Britain.[31] It was named alongside the Large Hadron Collider in Time magazine's top fifty innovations.[32] Another robotic hand is the RSLSteeper bebionic.[33]

Another neural prosthetic is Johns Hopkins University Applied Physics Laboratory Proto 1. Besides the Proto 1, the university also finished the Proto 2 in 2010.[24]

Robotic legs exist too: the Argo Medical Technologies ReWalk is an example or a recent robotic leg, targeted to replace the wheelchair. It is marketed as a "robotic pants".[35]

Targeted muscle reinnervation (TMR) is a technique in which motor nerves which previously controlled muscles on an amputated limb are surgically rerouted such that they reinnervate a small region of a large, intact muscle, such as the pectoralis major. As a result, when a patient thinks about moving the thumb of his missing hand, a small area of muscle on his chest will contract instead. By placing sensors over the reinervated muscle, these contractions can be made to control movement of an appropriate part of the robotic prosthesis.[38][39]

An emerging variant of this technique is called targeted sensory reinnervation (TSR). This procedure is similar to TMR, except that sensory nerves are surgically rerouted to skin on the chest, rather than motor nerves rerouted to muscle. The patient then feels any sensory stimulus on that area of the chest, such as pressure or temperature, as if it were occurring on the area of the amputated limb which the nerve originally innervated. In the future, artificial limbs could be built with sensors on fingertips or other important areas. When a stimulus, such as pressure or temperature, activated these sensors, an electrical signal would be sent to an actuator, which would produce a similar stimulus on the "rewired" area of chest skin. The user would then feel that stimulus as if it were occurring on an appropriate part of the artificial limb.[36]

Recently, robotic limbs have improved in their ability to take signals from the human brain and translate those signals into motion in the artificial limb. DARPA, the Pentagon’s research division, is working to make even more advancements in this area. Their desire is to create an artificial limb that ties directly into the nervous system.[38]

[edit] Direct bone attachment / osseointegration
Main article: Osseointegration
Osseointegration is a new method of attaching the artificial limb to the body. This method is also sometimes referred to as exoprosthesis (attaching an artificial limb to the bone), or endo-exoprosthesis.

The stump and socket method can cause significant pain in the amputee, which is why the direct bone attachment has been explored extensively. The method works by inserting a titanium bolt into the bone at the end of the stump. After several months the bone attaches itself to the titanium bolt and an abutment is attached to the titanium bolt. The abutment extends out of the stump and the artificial limb is then attached to the abutment. Some of the benefits of this method include the following:

- Better muscle control of the prosthetic.
- The ability to wear the prosthetic for an extended period of time; with the stump and socket method this is not possible.
- The ability for transfemoral amputees to drive a car.

The main disadvantage of this method is that amputees with the direct bone attachment cannot have large impacts on the limb, such as those experienced during jogging, because of the potential for the bone to break.

[edit] Cost

Transradial and transtibial prostheses typically cost between US $6,000 and $8,000. Transfemoral and transhumeral prosthetics cost approximately twice as much with a range of $10,000 to $15,000 and can sometimes reach costs of $35,000. The cost of an artificial limb does recur because artificial limbs are usually replaced every 3–4 years due to wear and tear. In addition, if the socket has fit issues, the socket must be replaced within several months. If height is an issue components can be changed, such as the pylons.