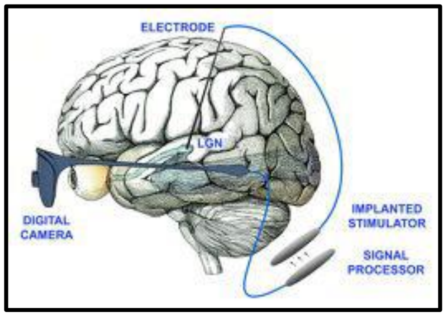
LECTURES 1-2: INTRODUCTION

1.1 Types of Prostheses

Prostheses: artificial devices that replace injured or diseased body parts



Ocular prosthesis Visual prosthesis Artificial kidney

Also: Craniofacial (hemifacial, auricular, nasal, dental), neck (larynx substitutes, trachea and upper esophageal replacements), internal organs (bladder, stomach, heart), etc.

1.2 Prosthetic Limbs

Many people incur an illness or experience an accident that results in the loss of a limb. They may also have been born with a congenital condition in which one or more of their limbs are missing. Fortunately, there are artificial limbs that enable those people to still do things such as run, walk, reach, and grip. These apparatuses are known as prosthetics. The purposes range from cosmesis to function

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1.2.1 Reasons for Amputation

There are many reasons why a person may lose a limb. In the United States, the most common cause of amputation is diabetes. Additionally, every year, at least 15,000 people lose feet or legs due to land mines in past war zones. The wars in Iraq also contribute to the vast amount of people who have lost limbs; soldiers, as well as civilians, have lost legs and feet due to the war.

The main causes of lost limbs:

- Diseases,
- Industrial accidents
- Car accidents
- Trauma
- Burns
- Peripheral Vascular Disease
- Malignant Tumors
- Neurologic Conditions
- Infections
- Congenital Deformities

1.3 History and Development of Prostheses

Prosthetic technology began to increase after World War I and World War II due to the increase in amputees. A special sock, which improved comfort and stability, was invented for above-knee prostheses. In the years that followed, better materials were made to construct prosthetics. Carbon fiber was a stronger and more lightweight material. Also, silicone was used to produce realistic-looking skin.

After World War II, the Artificial Limb Program began to do research regarding prosthetic limbs and to develop prostheses. As a result, the older wooden and leather models were replaced by new prostheses. New methods for attachment and fitting were also developed.

1.4 Materials for Prostheses

The most commonly used materials in current prosthetic devices are **leather**, **metal, wood, thermoplastic** and **thermosetting materials, foamed plastics,** and **viscoelastic polymers**.

Five characteristics are considered when deciding what materials to use to construct a prosthesis: **strength, stiffness, durability, density,** and **corrosion resistance**.

Strength, which is determined by the amount of weight that the material can withstand, is important in lower appendage prostheses. **Stiffness** is the amount of bending that is allowed when the material is loaded. For example, a stiffer material is desired for a rigid prosthetic frame, but a more flexible material is desired for a flexible transfemoral prosthetic socket.

Durability, or fatigue resistance, is determined by its ability to withstand repeated loading and unloading. **Density**, the weight per unit of volume, is important because it is a determinant of energy cost while a person is wearing the prosthesis. If a material is susceptible to **corrosion**, it is vulnerable to damage by chemicals.

1.5 Types of Prostheses Limbs

- A transtibial prosthesis replaces the lower leg and foot;
- A transfemoral prosthesis replaces the entire leg and foot.
- A trans-radial prosthesis replaces a missing lower arm and hand;
- A transhumeral prosthesis replaces the entire arm and hand.

There are specific needs that lower limb and upper limb prostheses need to meet. Although prosthetic legs and feet may be less complicated since they do not need to grip and handle objects such as upper limb prostheses, they do, however, need to sustain the weight of the body and provide for locomotion.

There are four basic levels of prosthetic feet:

- Persons at the K1 level possess limited functionality; they have the potential to use a prosthesis on level surfaces.
- Persons at the K2 level can walk around at home and in the community at a slow speed.
- If a patient can participate in all daily activities and walk at a varying tempo, they are classified with K3 feet.
- K4 feet are for serious athletes and weekend runners.

➢ **Transtibial prostheses** are composed of a **socket design**, **shin-socket interface**, **suspension strategy**, and additional modular components, such as **feet, shock absorbers**, **torque absorbers**, and **dynamic pylons**.

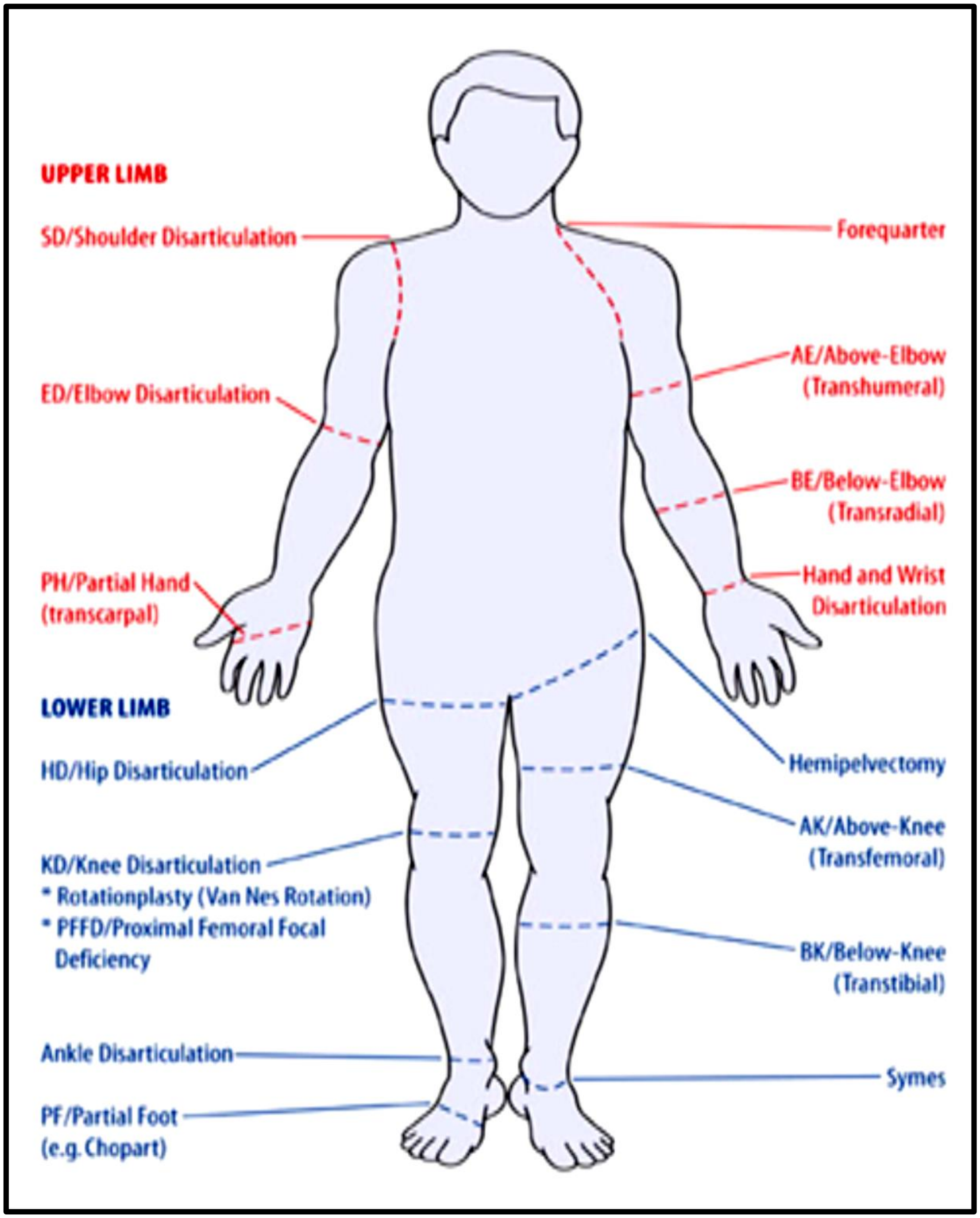
➢ **Patellar tendon-bearing socket** and total surface-bearing socket are two socket designs. Hard sockets, socks and sheaths, soft inserts, flexible inner sockets, expandable wall sockets, and gel liners are interface materials.

➢ Waist belts, joints and corsets, cuff straps, supracondylar suspensions, supracondylar/suprapatellar sockets, sleeves, suction, locking liners, semirigid locking liners, and elevated vacuum are suspension techniques.

➢ There are four main socket designs for **transfemoral prostheses**: **quadrilateral, ischial-ramal containment (IRC), Marlo Anatomical Socket (MAS),** and **sub ischial (elevated vacuum) socket**.

➢ There are also **many transfemoral suspension systems**: traditional pull-in suction suspension, roll-on suspension liners, shuttle lock systems, lanyard systems, cushion liners with air expulsion valves, elevated vacuum, Silesian belt suspension, total elastic suspension belts, pelvic belts, and hip joint.

- There is also a variety of **prosthetic knee units**: single-axis, polycentric, manual locking, hydraulic, and pneumatic knee units.
- The **microprocessor technology for knee units**:
  - Microprocessor knees are typically equipped with sensors that monitor the knee position during the swing;
  - they are also equipped with pressure sensors detecting and evaluating ground-related forces during stance. Sensor technology is capable of measuring angels, moments, and pressures at the rate of 50 times per second.
  - Customized adjustments are commonly made to microprocessor knees using a laptop or handheld computer.
  - Unique software algorithms determine the phase of gait, then immediately adjust the knee functions to compensate during both the stance and swing phases of gait.
  - Most knee mechanisms provide a stumble recovery feature that limits unintentional bending of the knee that sometimes occurs when walking on uneven terrain.
- Conventional (body-powered) systems consist of any prosthesis that uses a control cable system to translate volitional muscle force and shoulder or arm movement to operate a prosthetic elbow.
- Externally powered systems consist of an electric power cell that provides electrical current to prosthetic components.
- Hybrid prostheses that combine conventional and externally powered systems may be the best solution for some individuals.



1.5.1 Limb prostheses/ Upper extremity:

- forequarter
- shoulder disarticulation
- transhumeral prosthesis
- elbow disarticulation

- transradial prosthesis
- wrist disarticulation
- full hand
- partial hand
- finger
- partial finger

1.5.2 Limb prostheses/ Lower extremity:

- hip disarticulation
- transfemoral prosthesis
- knee disarticulation
- transtibial prosthesis
- Syme's amputation
(through ankle joint)
- foot
- partial foot
- toe

PROSTHETICS: LOWER EXTREMITY

			
BELOW KNEE	**KNEE DISARTICULATION**	**ABOVE KNEE**	**HIP DISARTICULATION**

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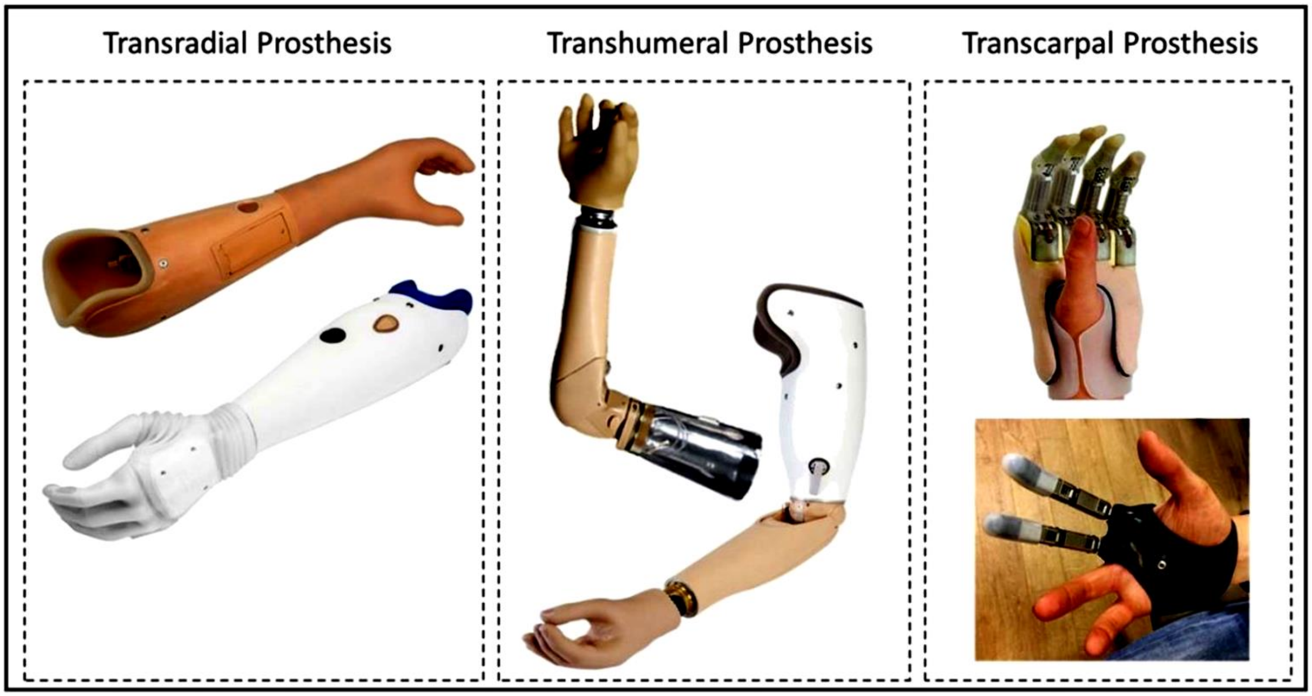

Figure: Different types of upper-limb prosthesis

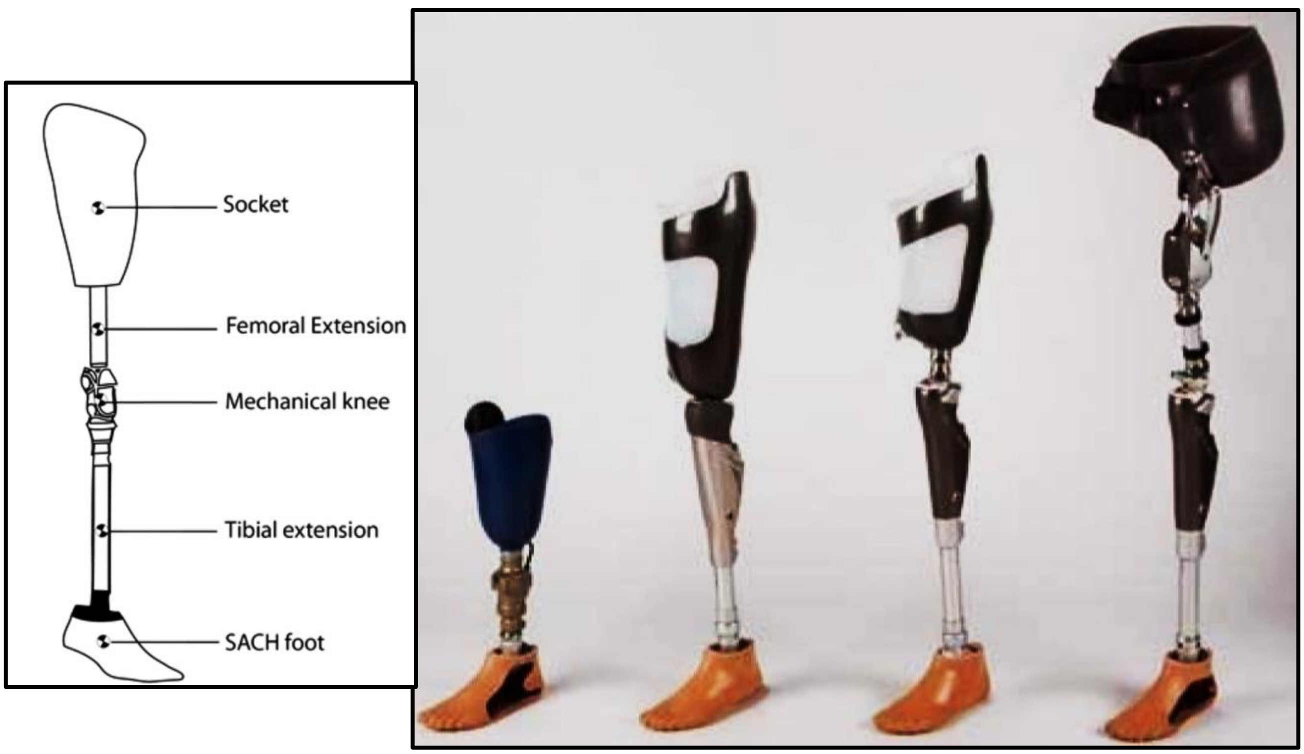

Figure: Different types of lower-limb prosthesis

1.6 Prosthetic Limb Construction

The process of construction of a prosthesis consists of six steps:

1) Taking accurate measurements of the limb
2) Making a negative impression (cast)
3) Creating a three-dimensional positive model of the limb or body segment
4) Modifying the positive model to incorporate the desired controls
5) Fabricating the prosthetic socket around the positive model
6) Fitting of the device to the patient.

A prosthesis must be properly constructed, for the following factors affect energy expenditure:

1) weight of the prosthesis,
2) quality of the socket fit,
3) accuracy of alignment of the prosthesis, and
4) functional characteristics of the prosthetic components

1.7 Rehabilitation

- The level of rehabilitation success after amputation is influenced by factors such as age, health, cognitive status, sequence of the onset of the disability, concurrent diseases, and the level of the amputation.
- The periprosthetic phase consists of managing the part of the limb that remains, and this includes tasks such as caring for the wound, controlling edema, shaping, desensitizing, and increasing joint and muscle flexibility.
- Besides strengthening the extremities for the use of the prosthesis, it is also extremely important to strengthen the trunk or core.

- Physical therapists are responsible for deciding whether a patient is ready for prosthetic fitting, coordinating prosthetic training, and consulting with prosthetists if issues with alignment result.
- When a person undergoes an amputation, many people are included in the rehabilitation process such as physicians, nurses, prosthetists, orthotists, physical therapists, occupational therapists, dietitians, vocational rehabilitation counselors, and caregivers.

1.8 Further Developments

Although it was not available for public use until the 1960s, the first biomechanical prosthesis, which used myoelectricity, was created in the 1940s. The product continued to be tested and perfected before being sold.

Prostheses such as these are connected to the body in a manner that permits electrical impulses to go from the muscles into the prosthesis, causing movement in the prosthesis.

Additionally, the nerves in the appendage are surgically adapted to direct movement in a muscle that has been attached to biosensors. Biosensors sense movement that occurs in a muscle and convey it to a controller that is located in the prosthesis. A flexed muscle, therefore, causes the prosthetic to move.

There is now a new way to attach prostheses to the body; a titanium bolt is screwed into the bone of the stump. The bolt gets attached to an abutment, or support, that is then attached to the prosthesis. This method reduces pain for the patient since it reduces the pressure on the stump; following this practice also permits greater control of the prosthesis by muscles.

Athletes who are missing legs now have access to special apparatuses that can help them run. Known as Cheetah blades, these devices are made out of carbon fiber and formed like sickles. They do not imitate the look or feel of real lower limbs; rather, they are made to permit running.

Every year, prosthetic technology improves. For example, next-generation prosthetic knees feature motors that dynamically raise and excite the patient's muscles to participate in activities such as walking up stairs and ramps. Researchers are also working on prosthetic limbs that can be operated by the brain.