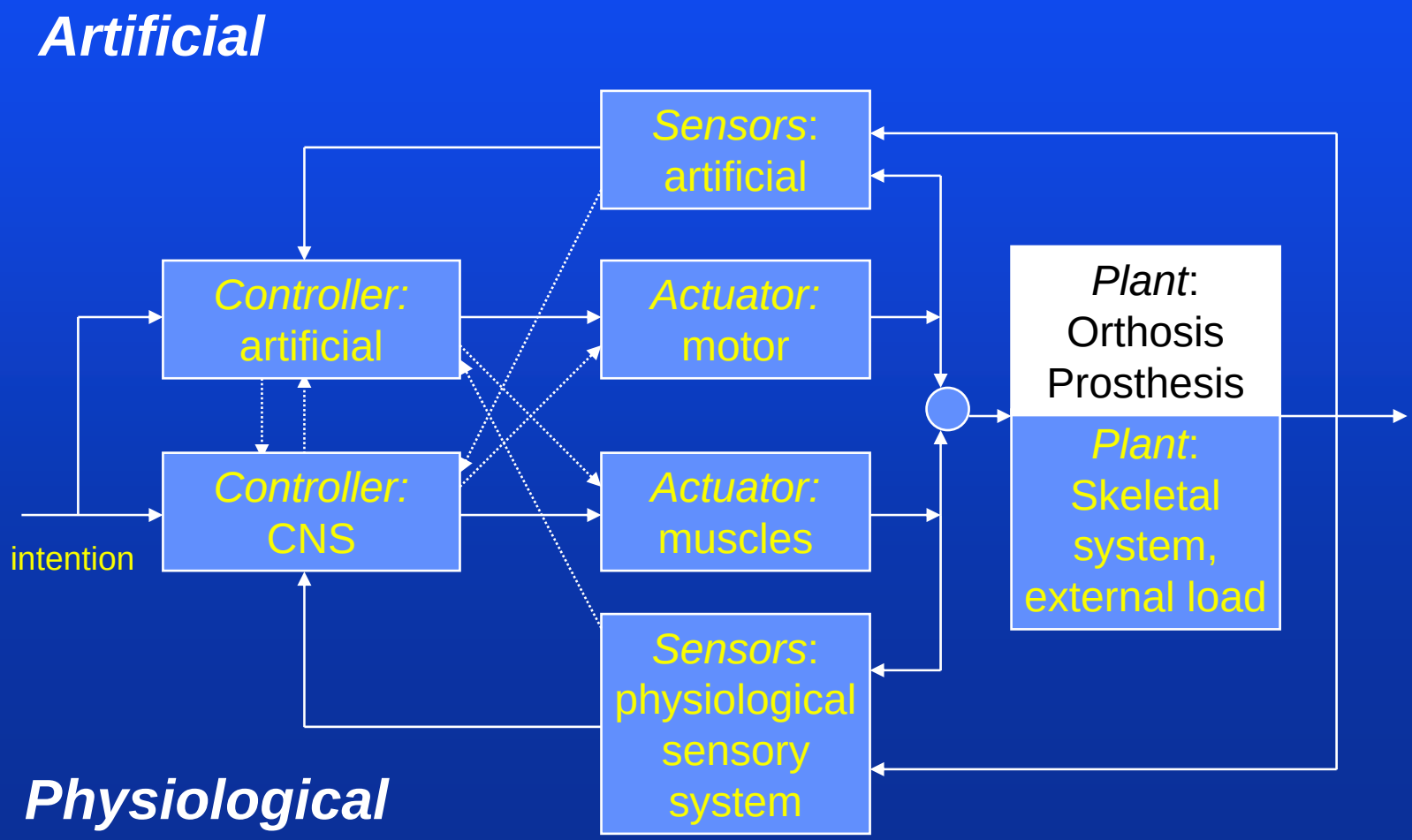
Biomechatronics

Bart Koopman

lower extremity orthotics and prosthetics

Biomechatronics



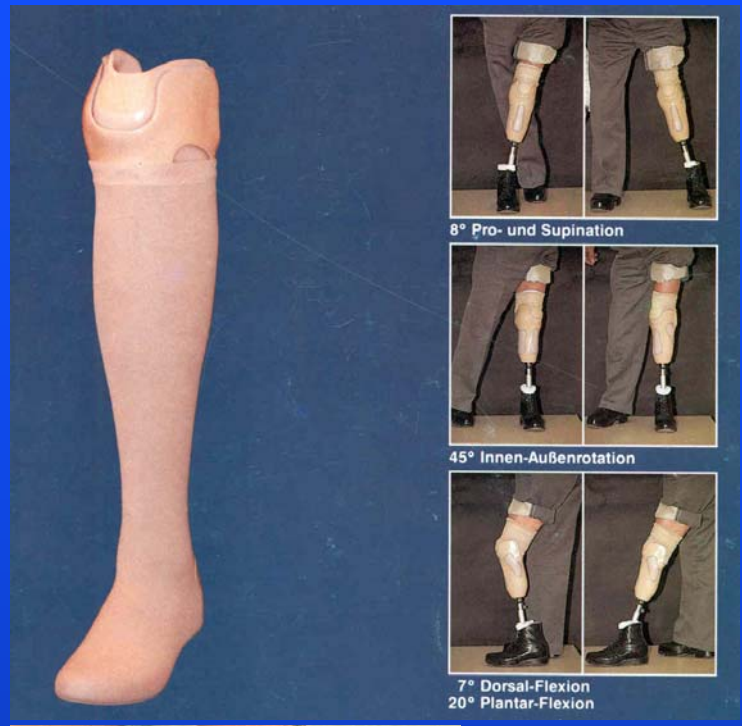
Prosthetics and Orthotics

Prosthesis:

- Replacement of body parts and/or functions

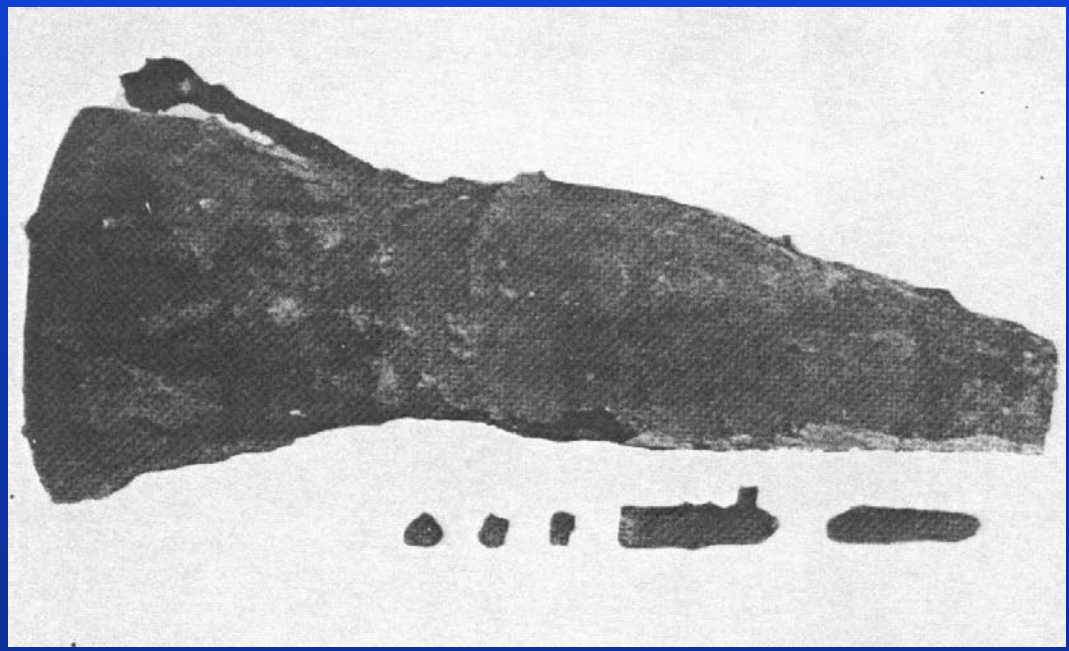
Orthosis:

- Support of body functions



Short history: amputation and prosthesiology

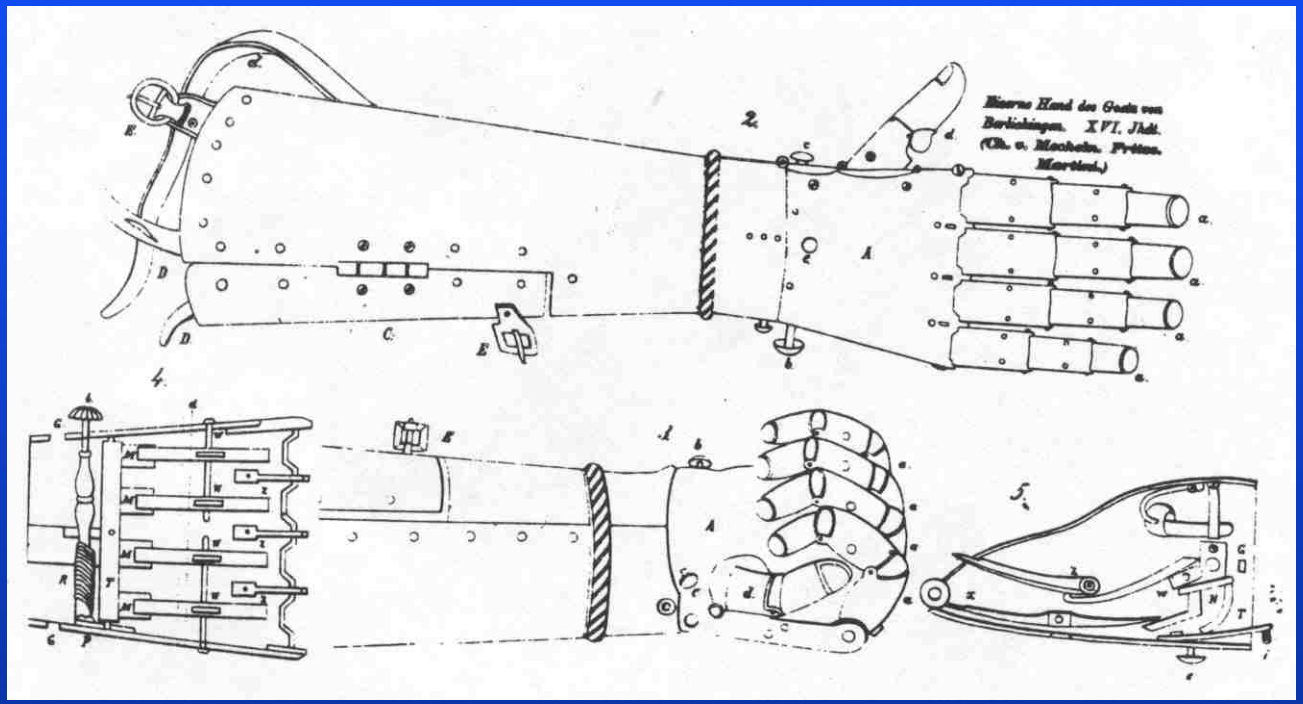
- 1000 bC: Rig-Veda (sanskriet)
- 400 bC: Hippocrates
- 300 bC: eldest prosthesis



Amputation in middle ages

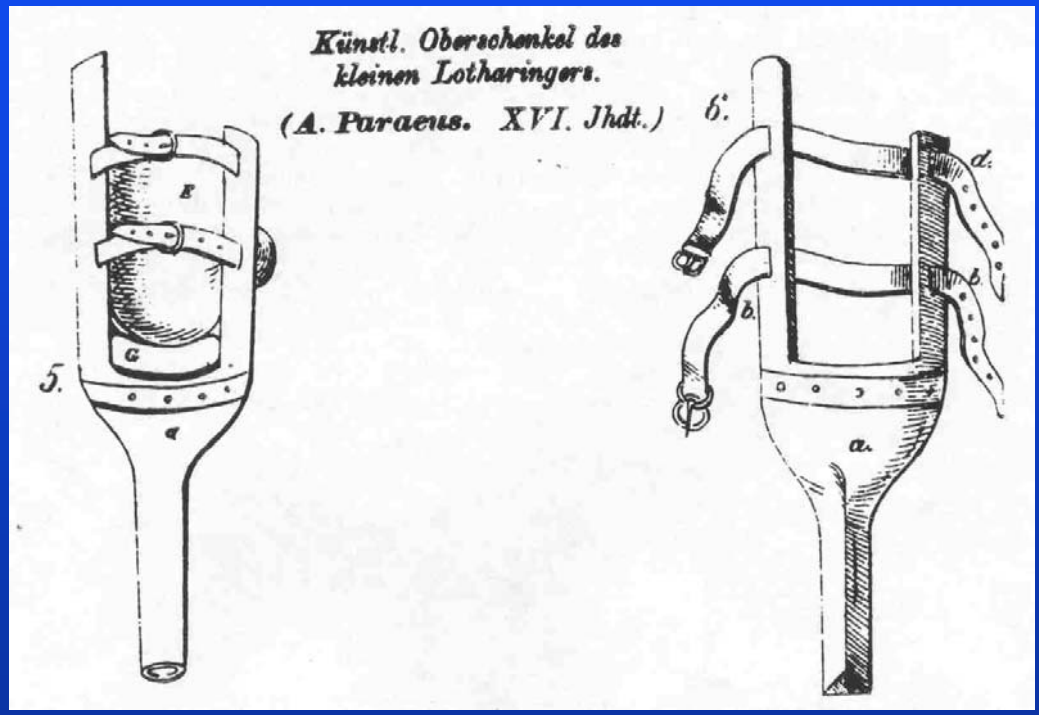
H. Von Gerßdorf, 1517,
Feldtbuch der Wundarztney

Armprosthesis

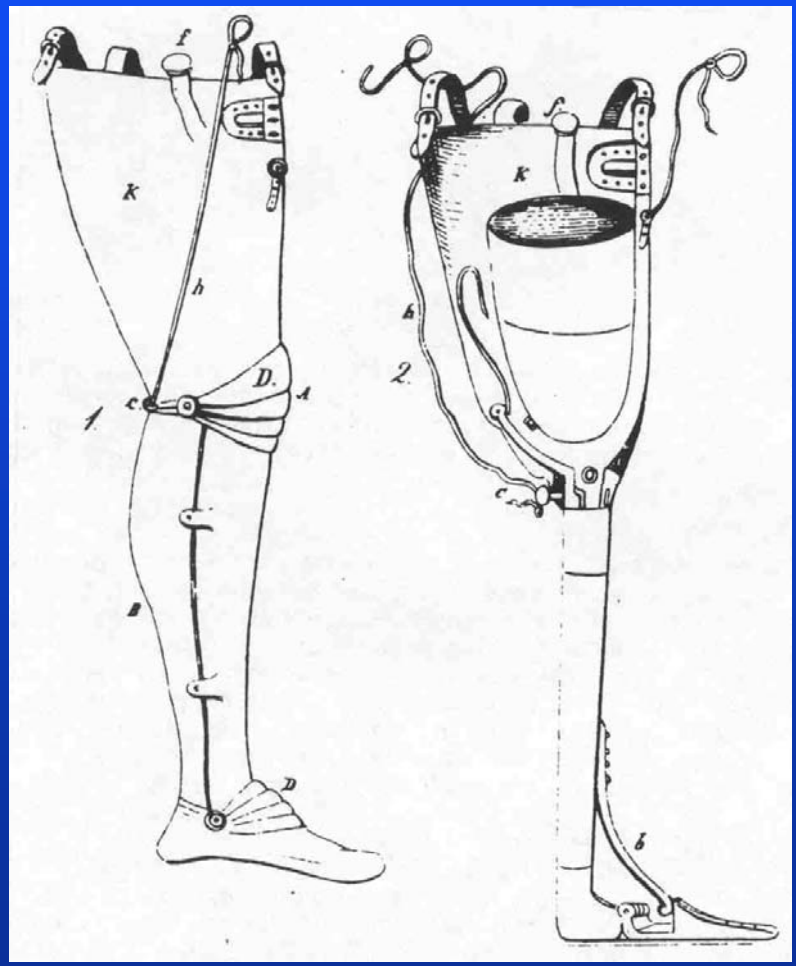


Götz von Berlichingen, Landshut
1504

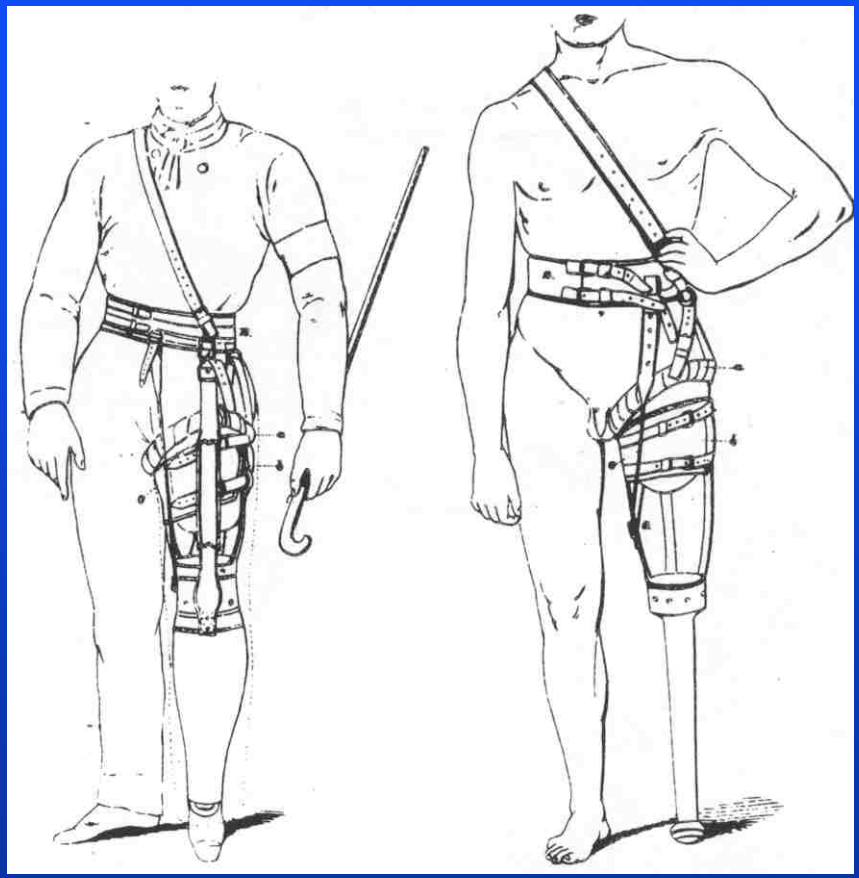
Ambroise Paré (1510-1590)



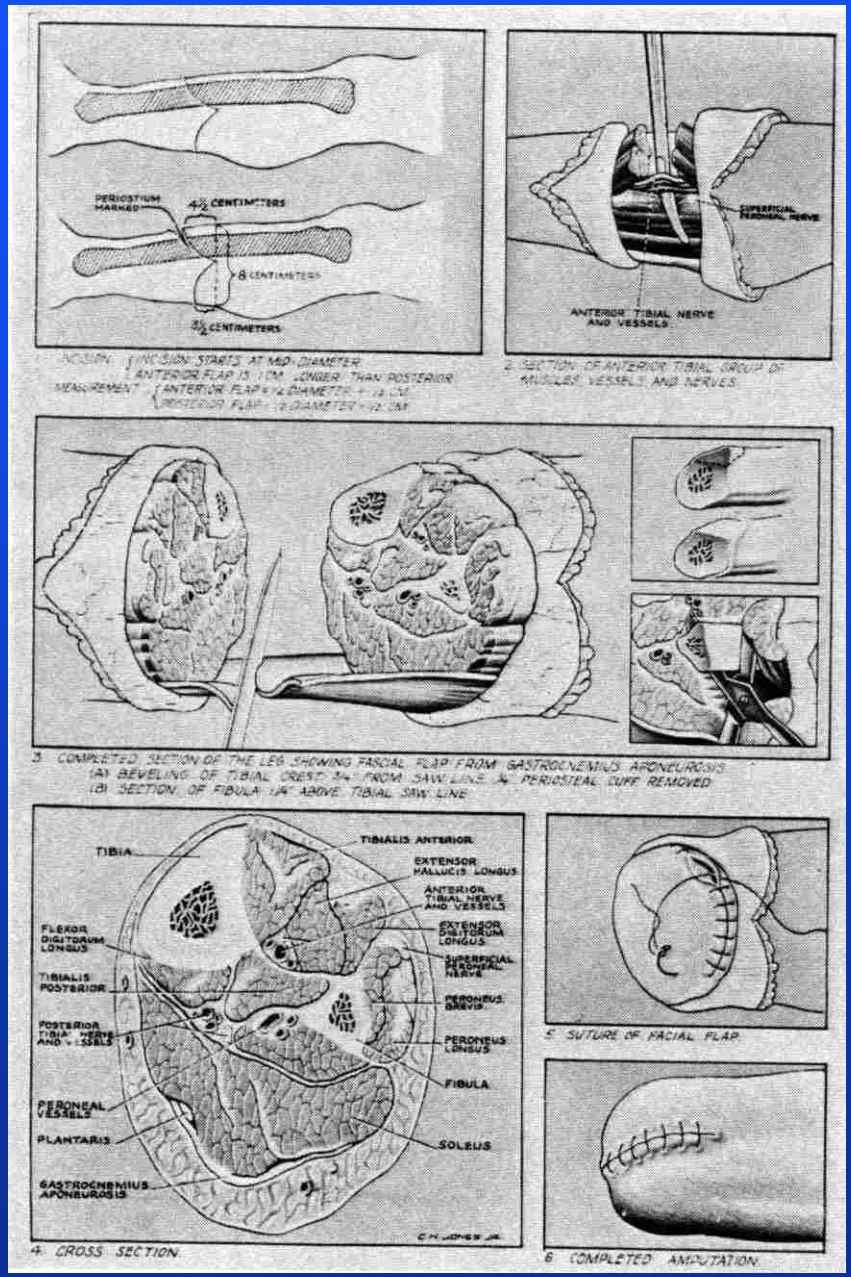
Prosthesis of Paré



Dominique Jean Larrey (1766-1843)




C
B
D
K



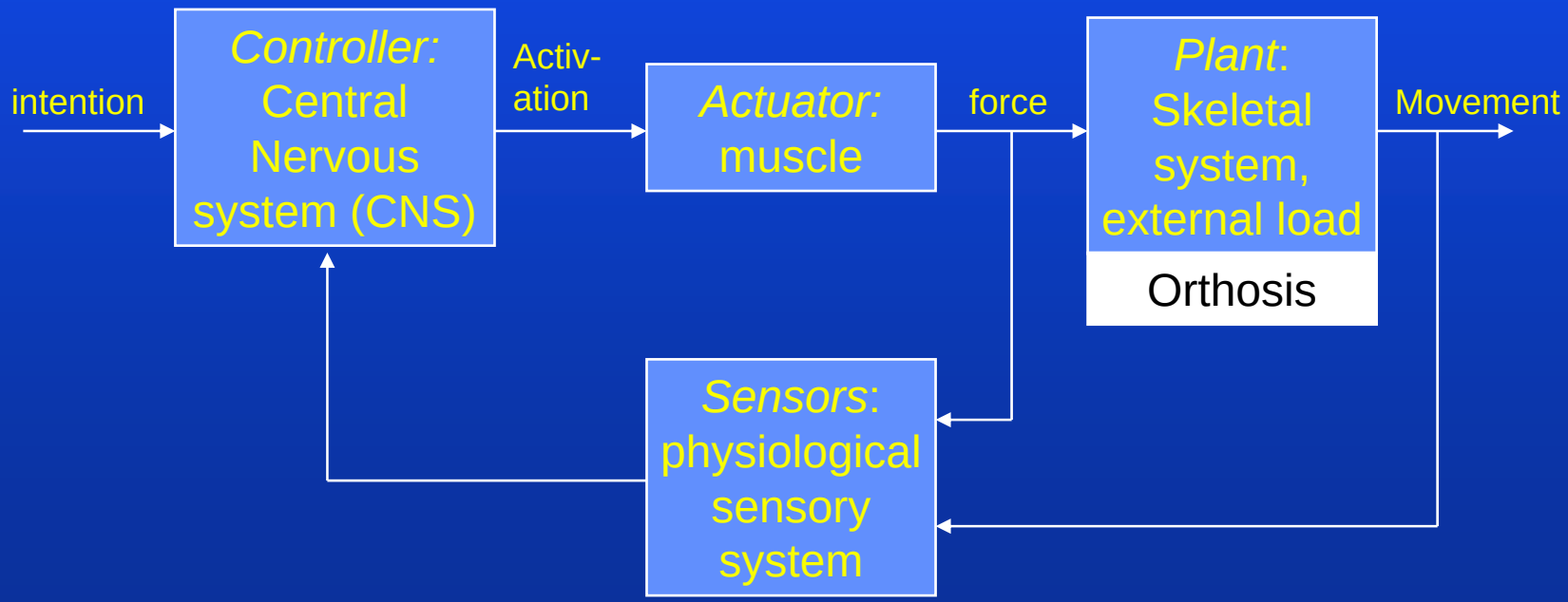
Modern amputation techniques

Orthotics

Functions:

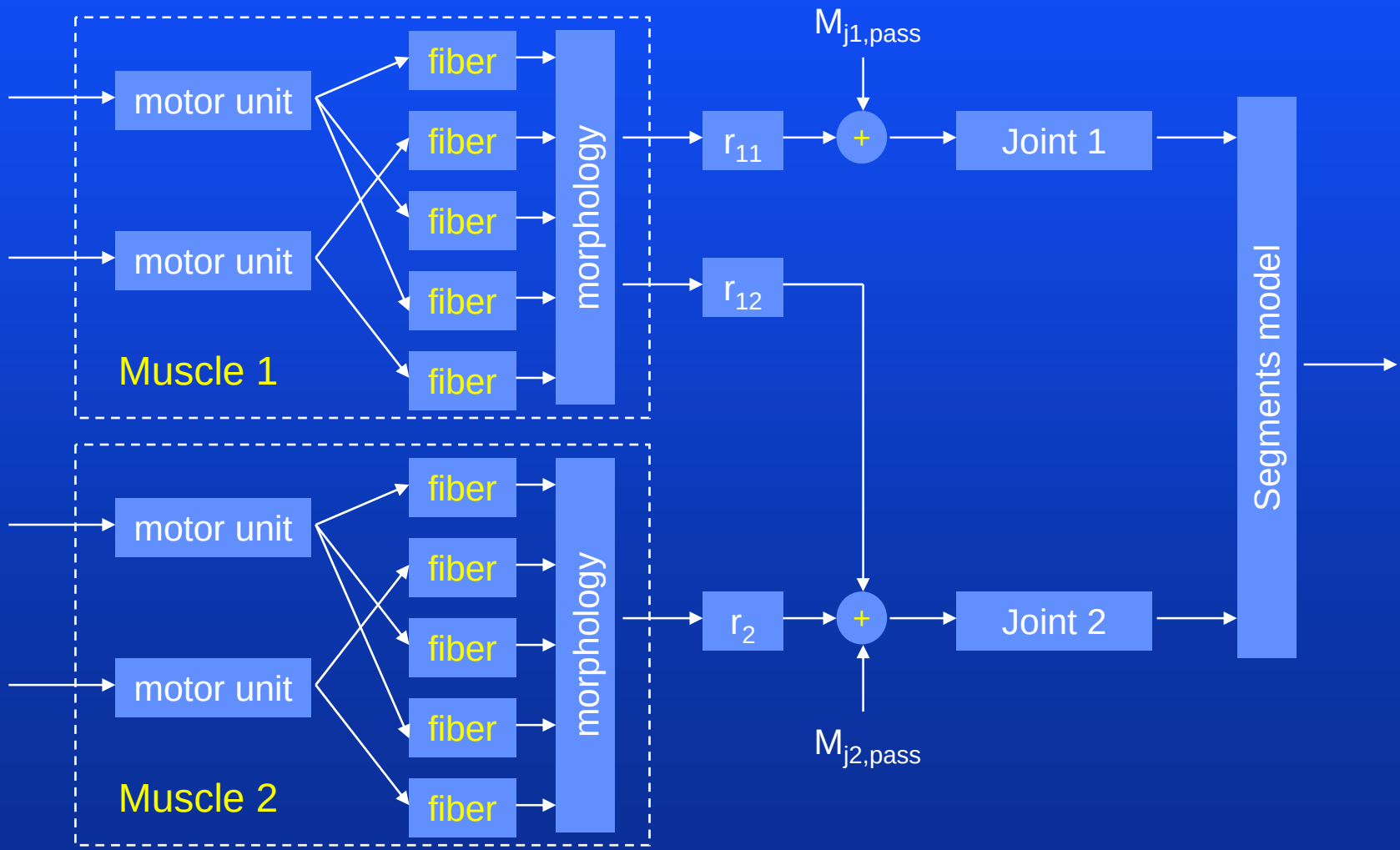
- Support
- Redressing
- Stabilization (immobilization)
- Cosmetic

Control orthosis

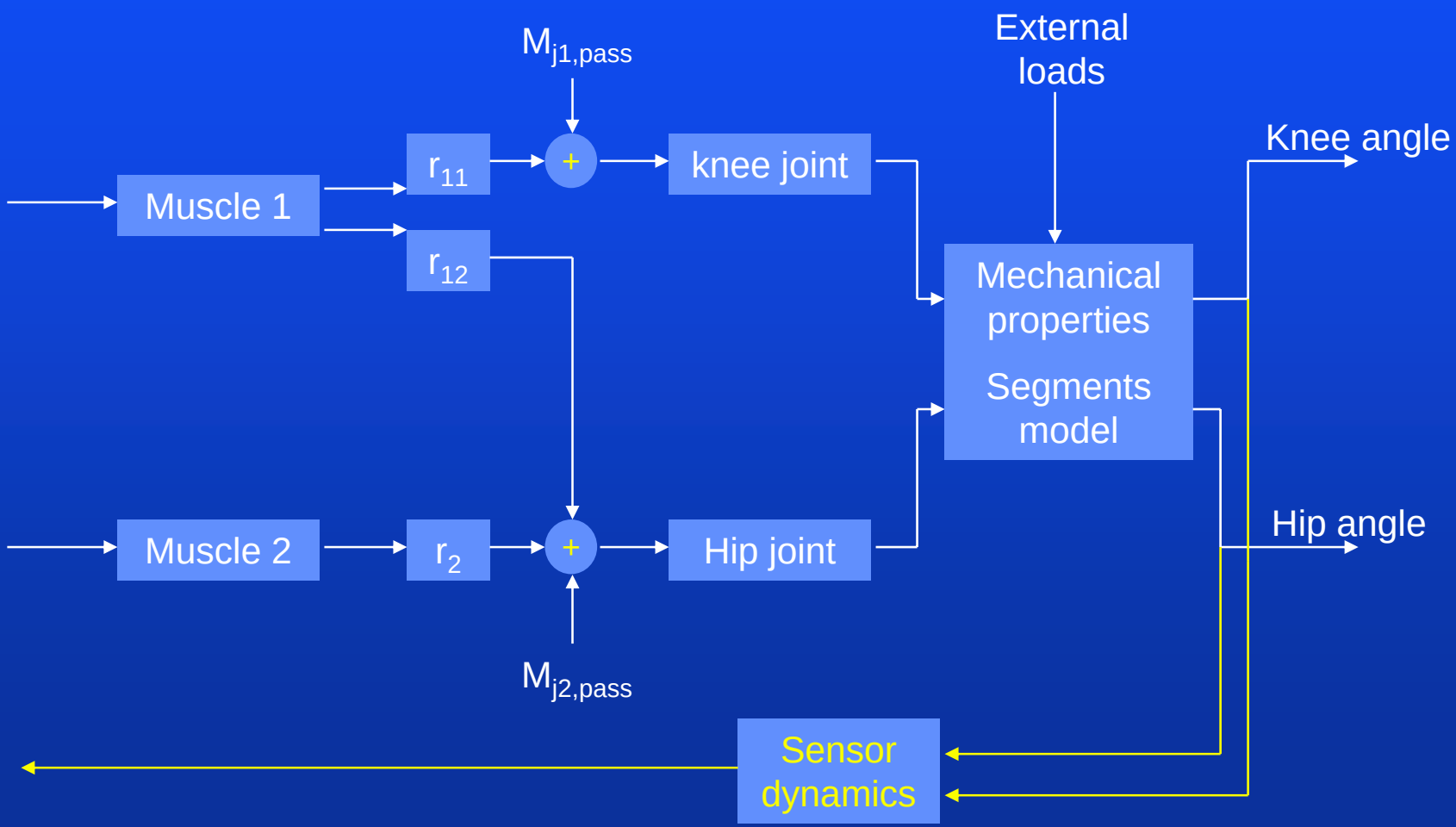


Muscle control

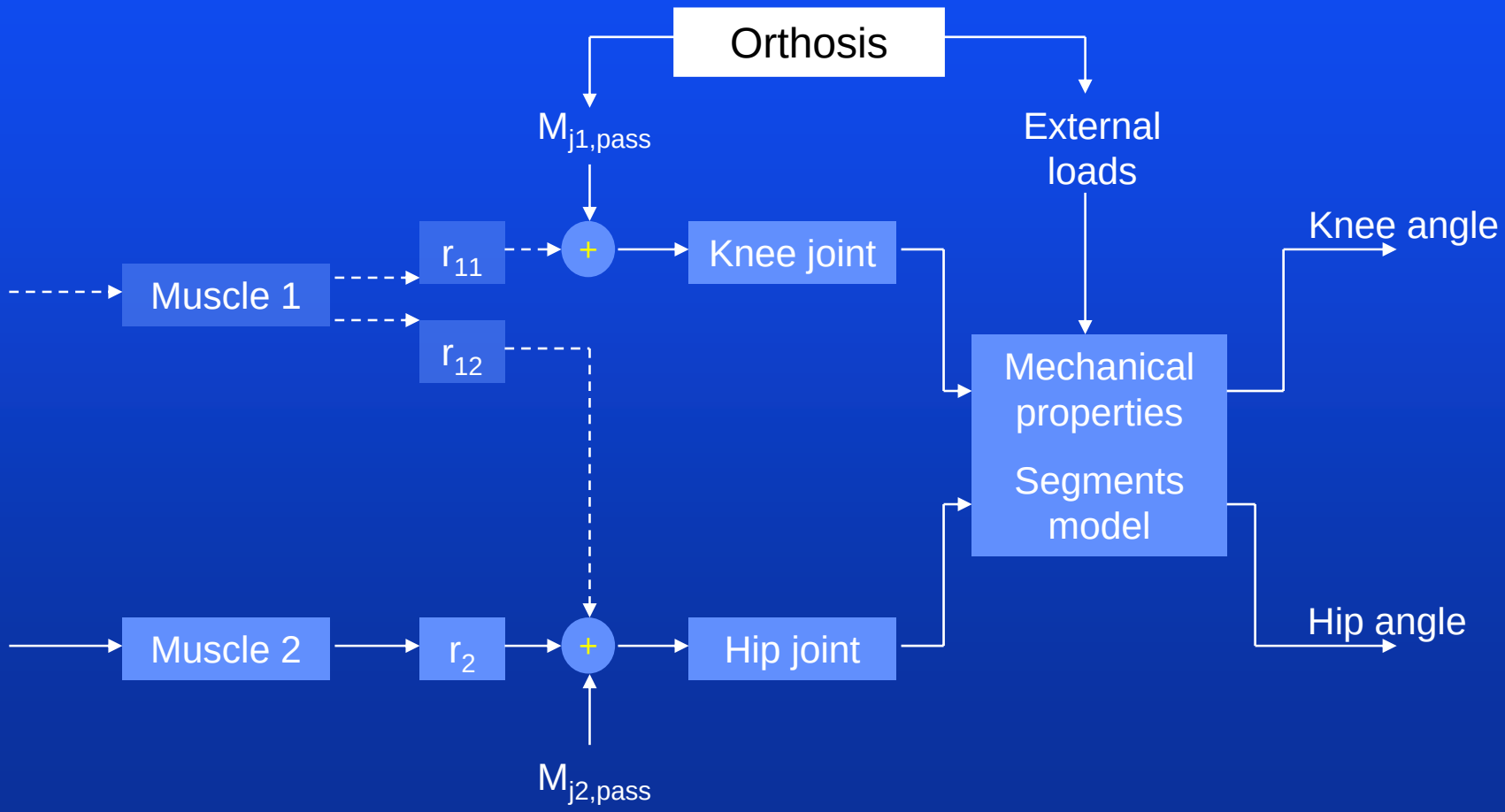
10^4 10^6 47 3



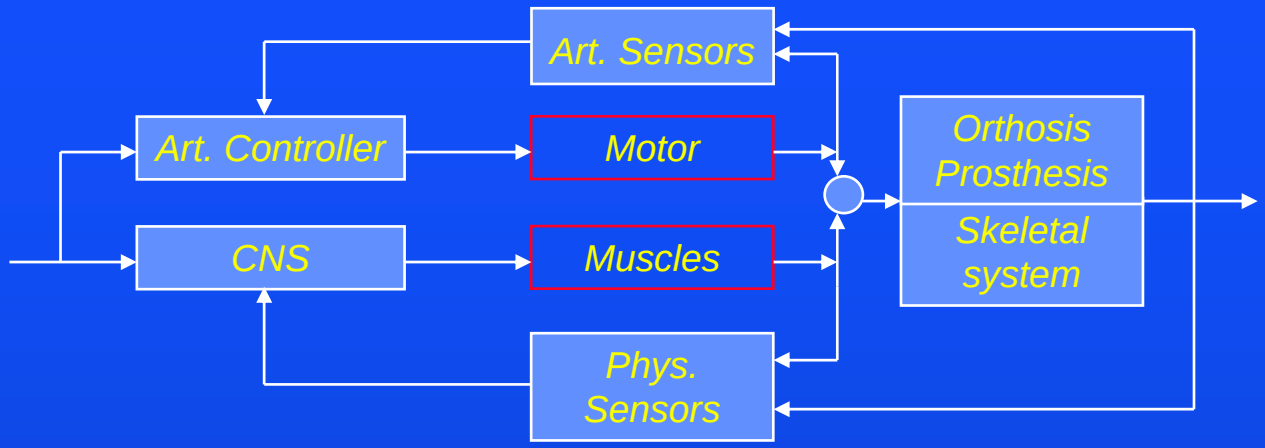
Normal control

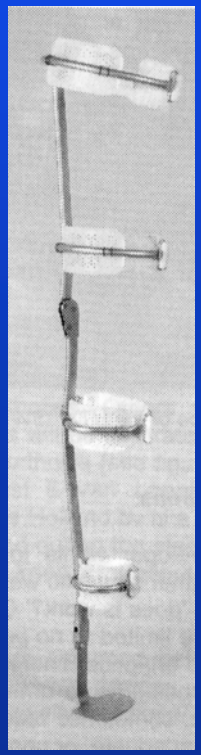


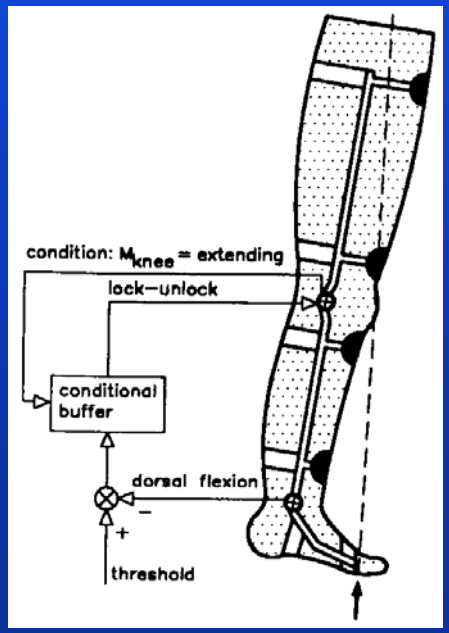
control orthosis



Example







UTX-swing orthosis

- Knee Ankle Foot Orthosis for paralyzed knee muscles
- controller allows flexion during swing and locking during stance

Leg orthoses

Old KAFO

UTX-swing

Prosthetics

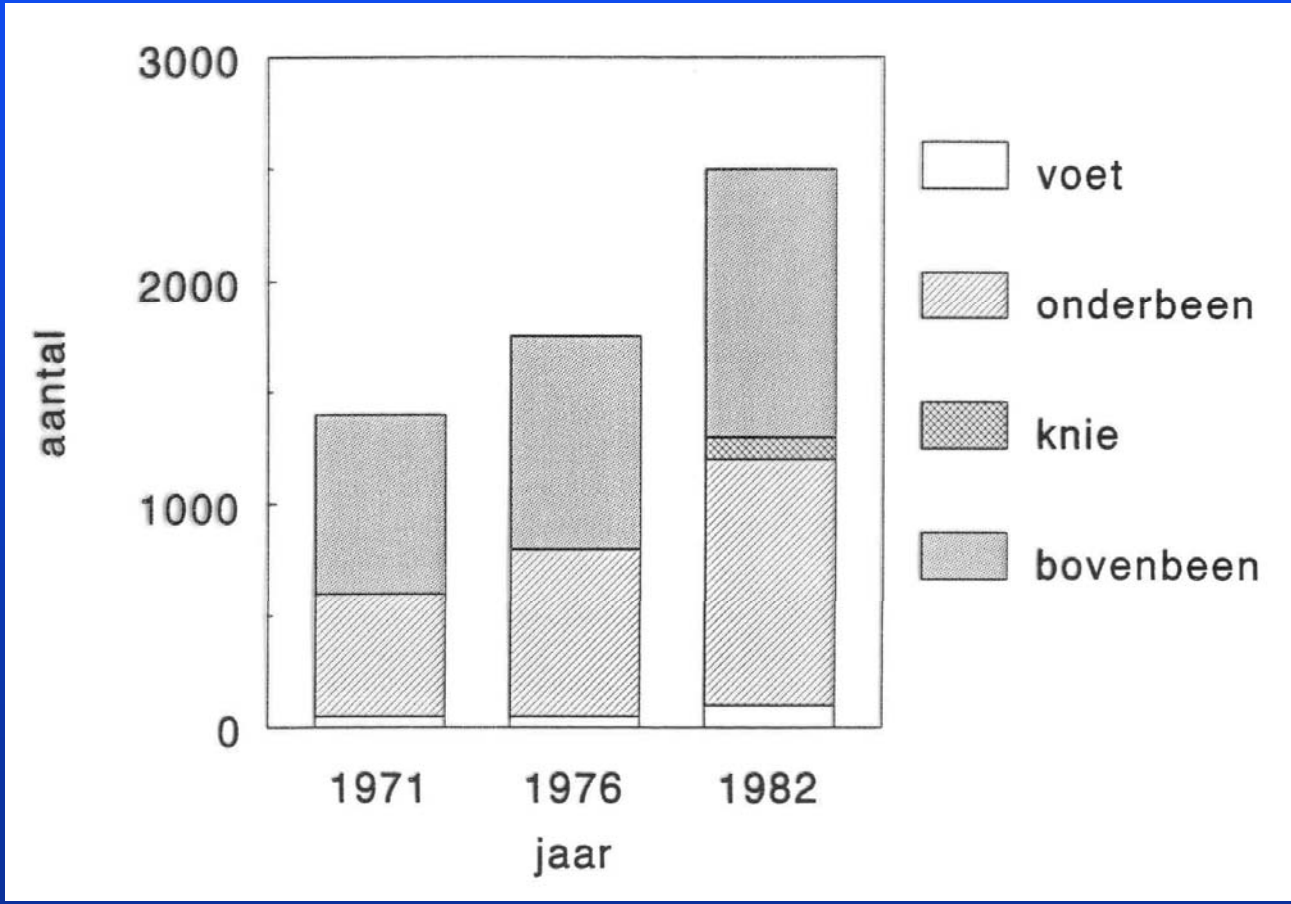
Functions:

- Support
- Cosmetic

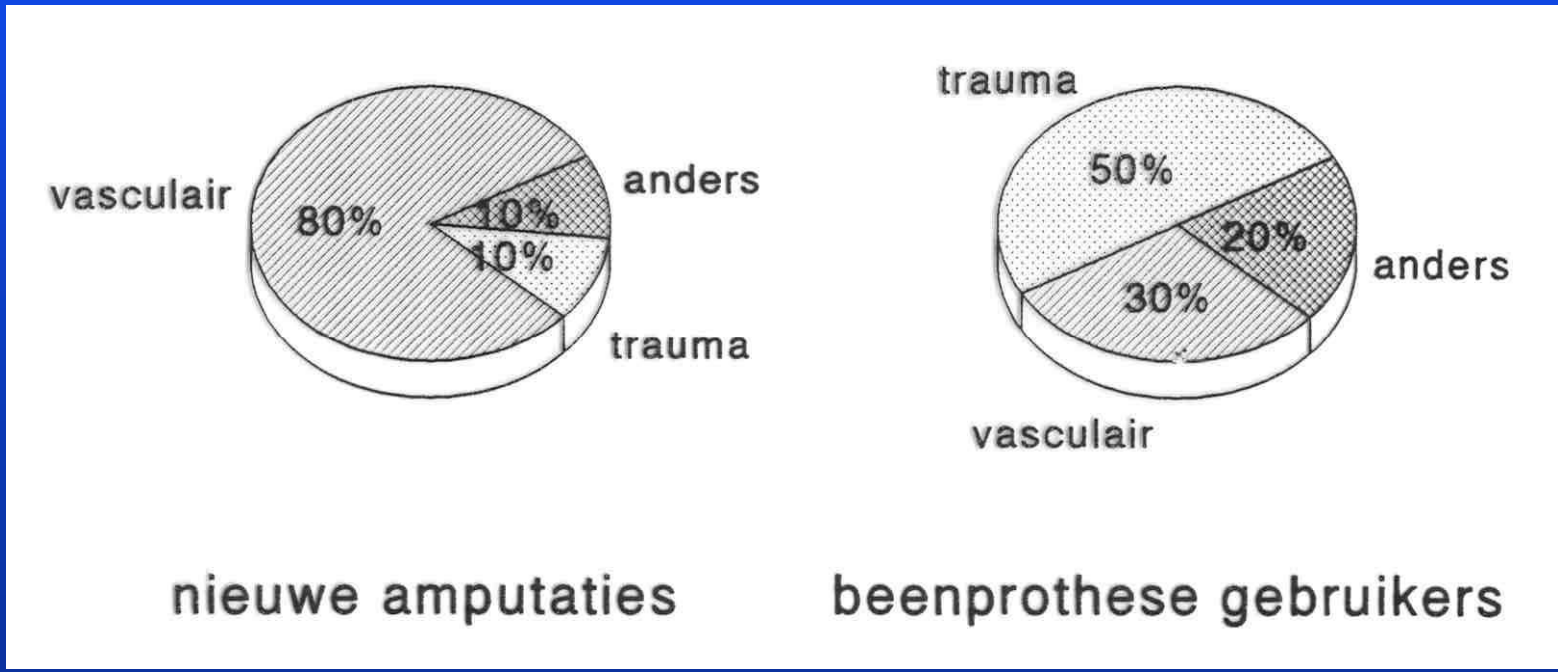
TF-prosthesis:

- modular
- 1,5 – 4 kg
- 3 – 30 k€

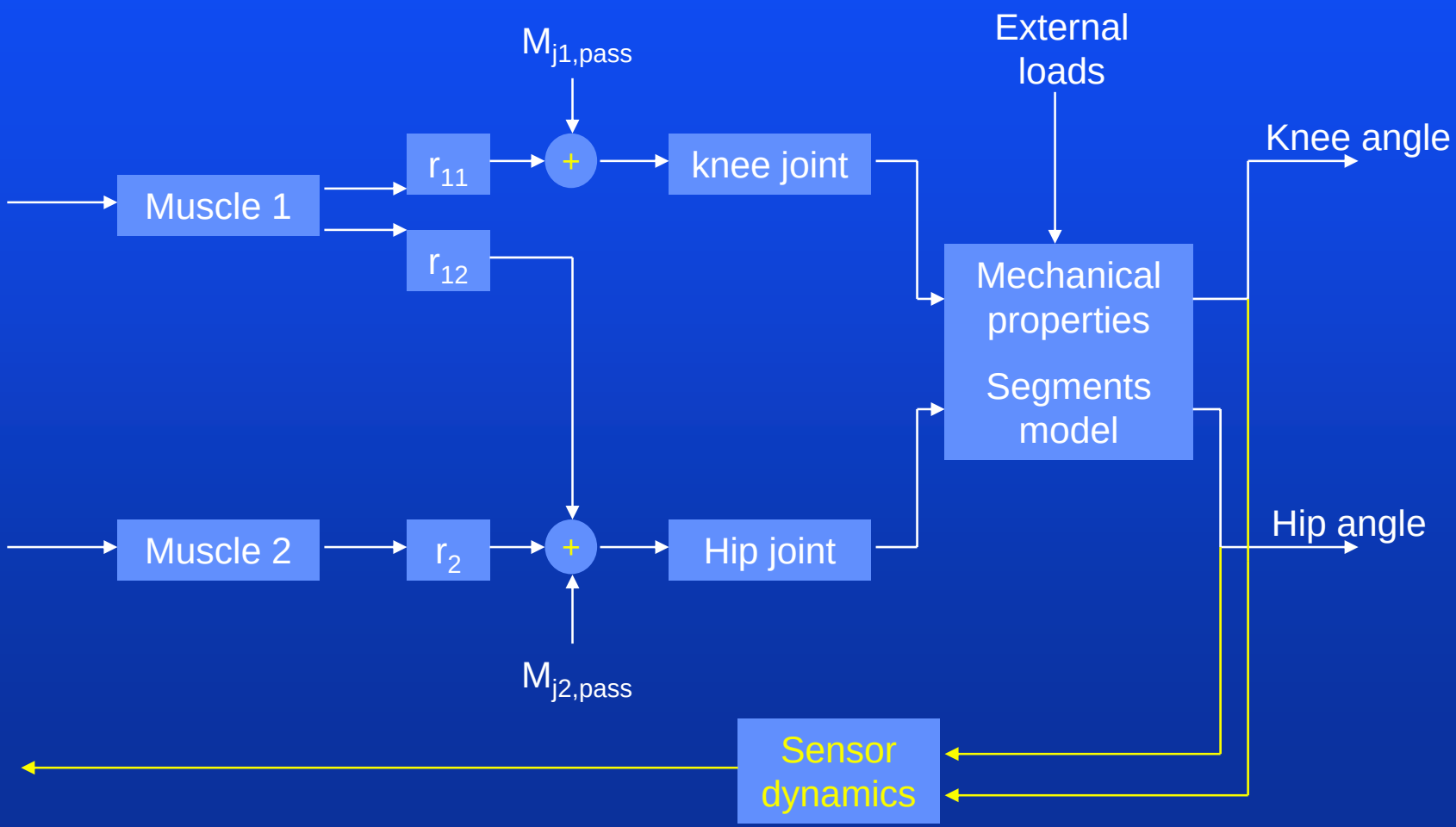
Amputations in NL



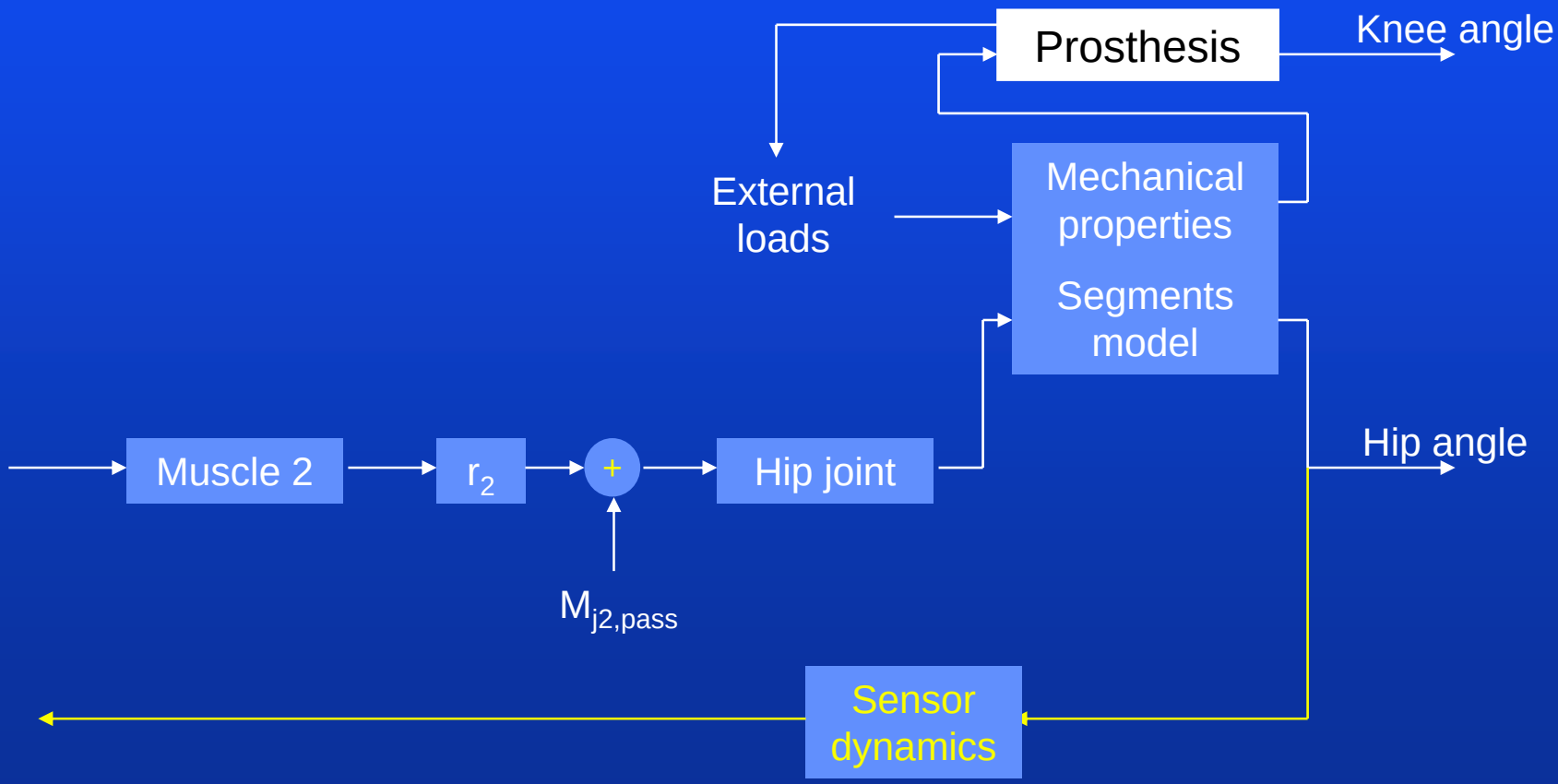
Amputation causes



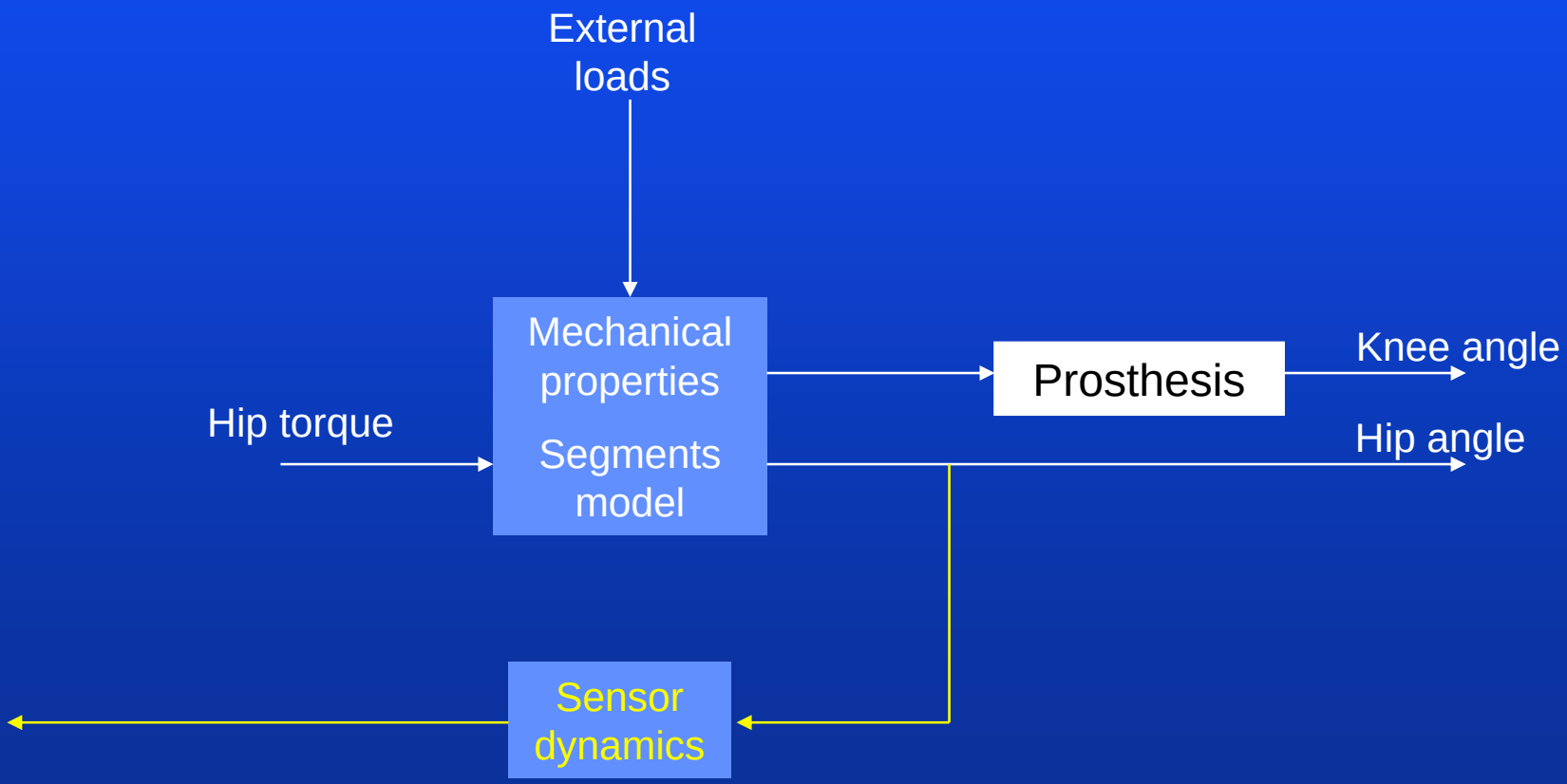
Normal control



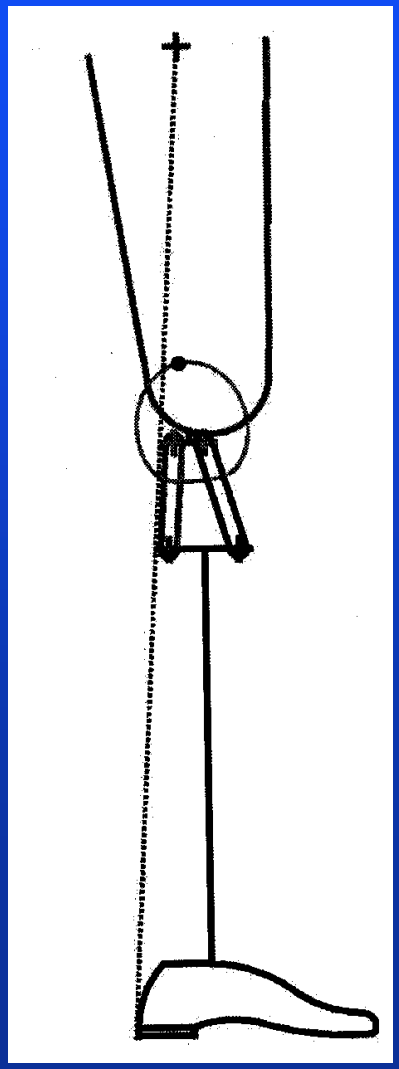
control prosthesis

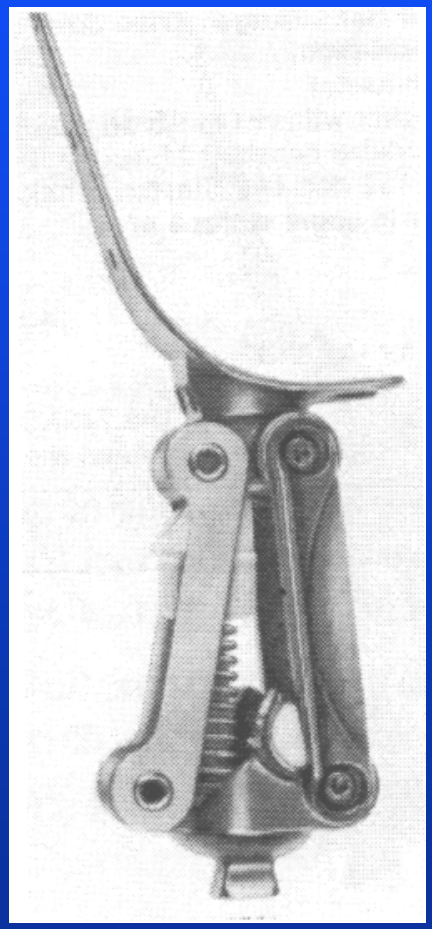


control prosthesis



Prostetic knee design

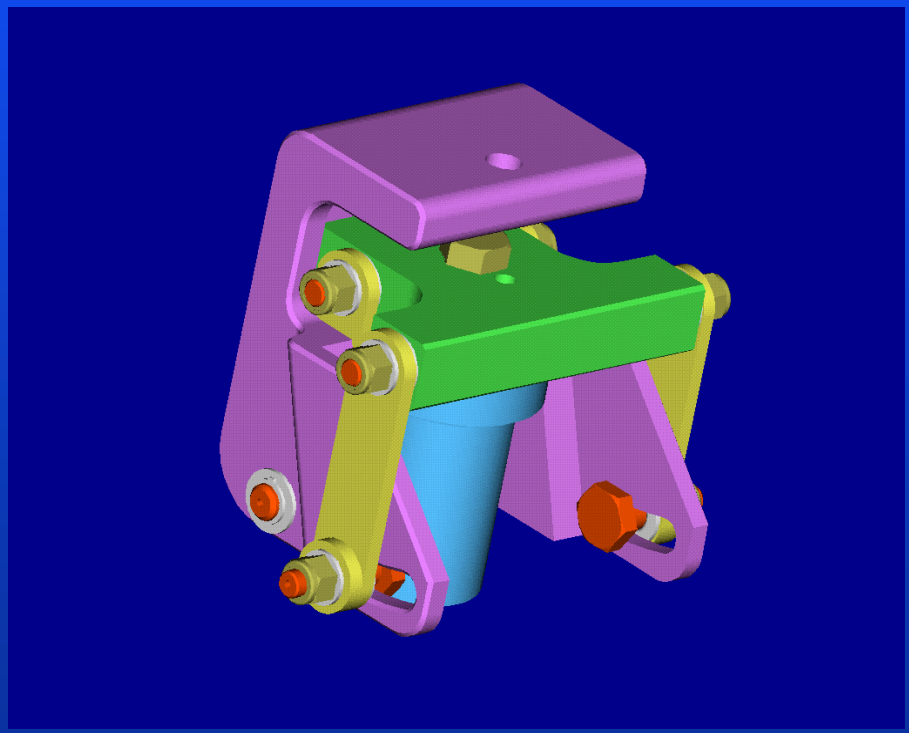




4-axial knee:

- Improve local stability
- Improve controllability
- No actuation!

Inverted knee design

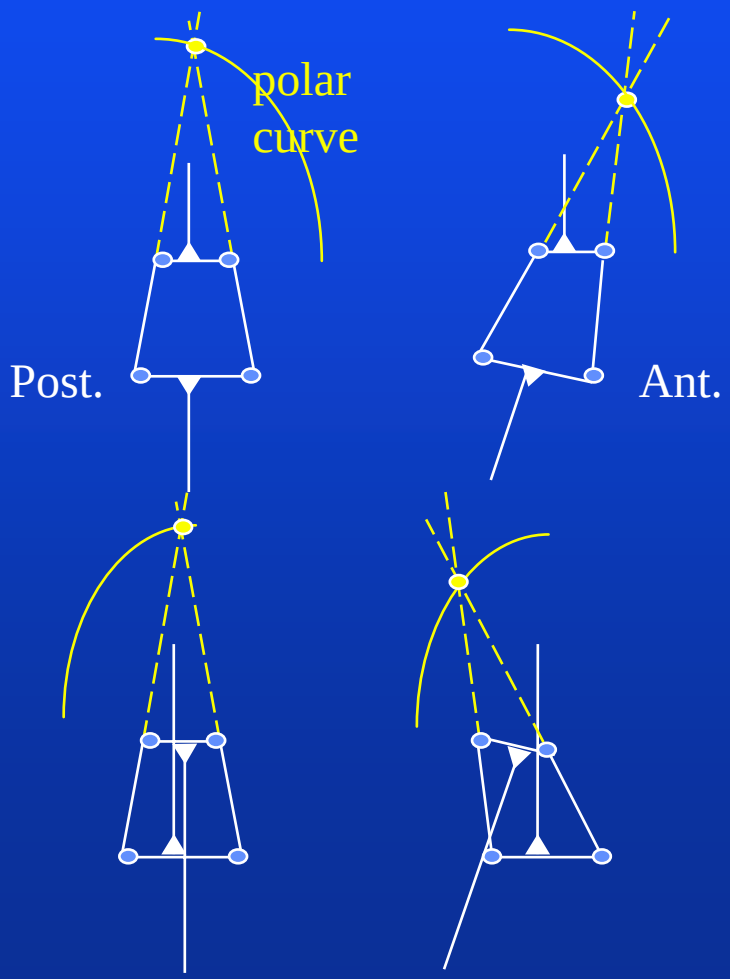


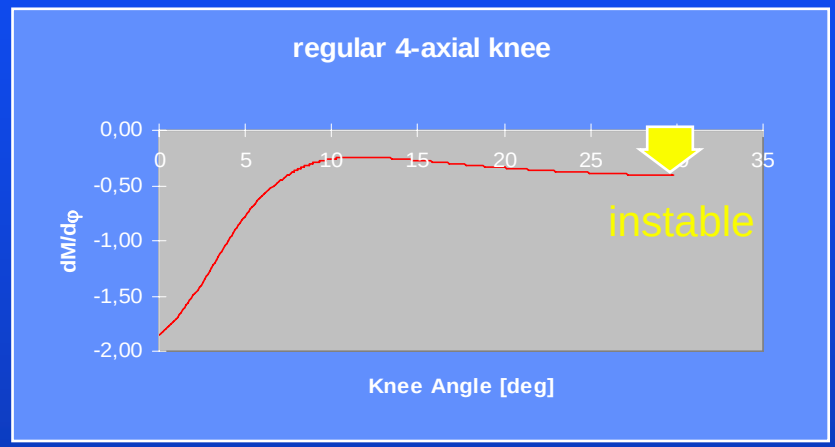
Posterior view

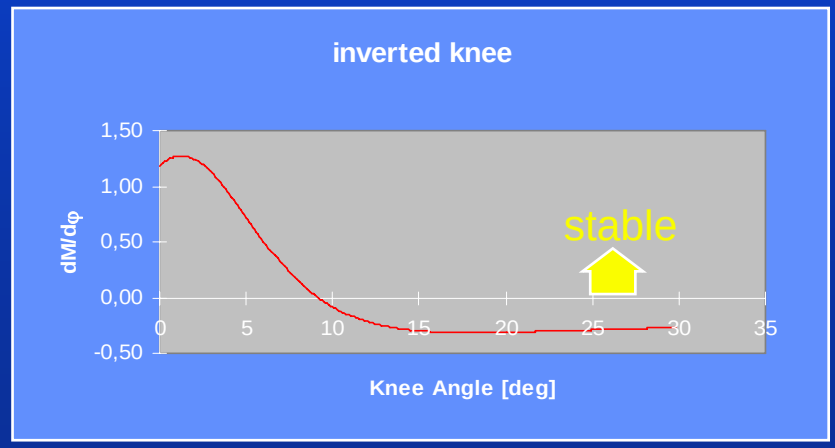
Model predictions:

- increased push-off time
- increased velocity

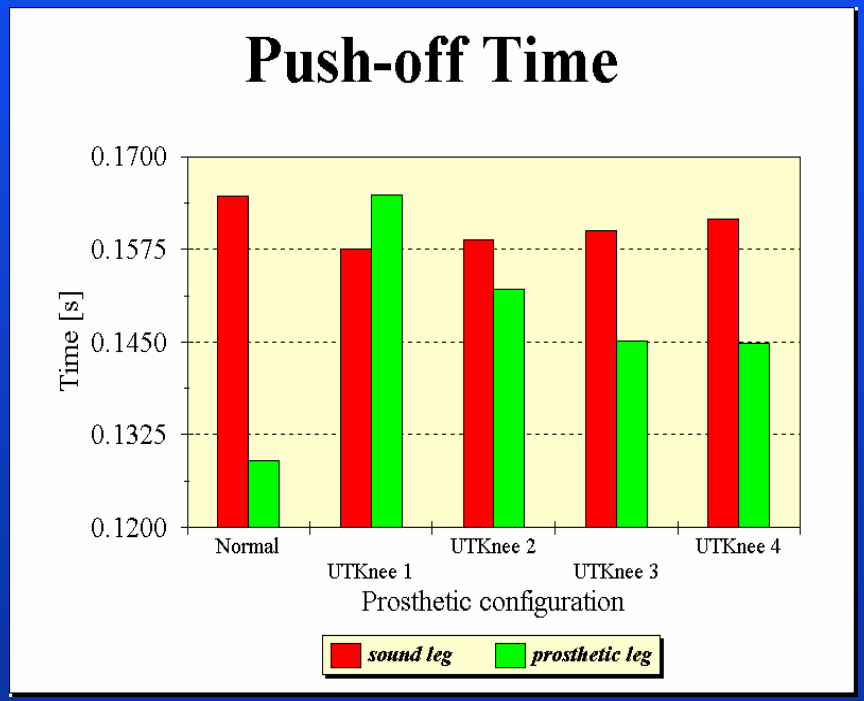
Regular vs. inverse knee

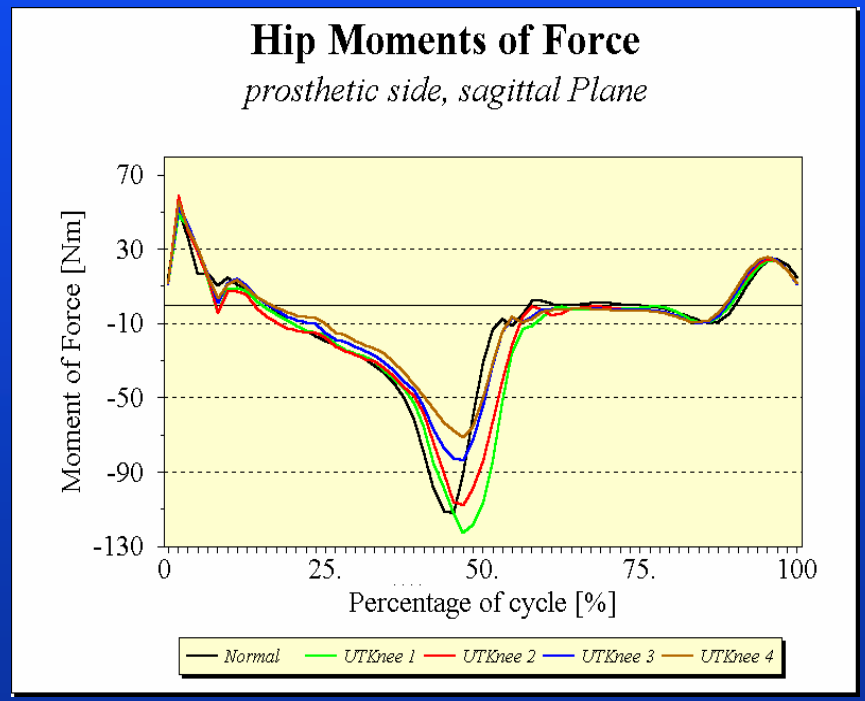




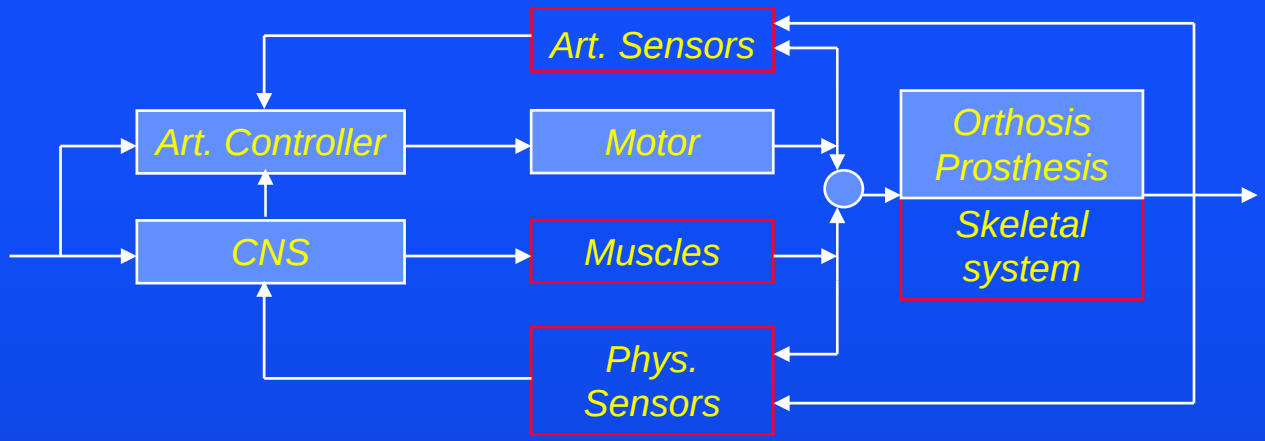


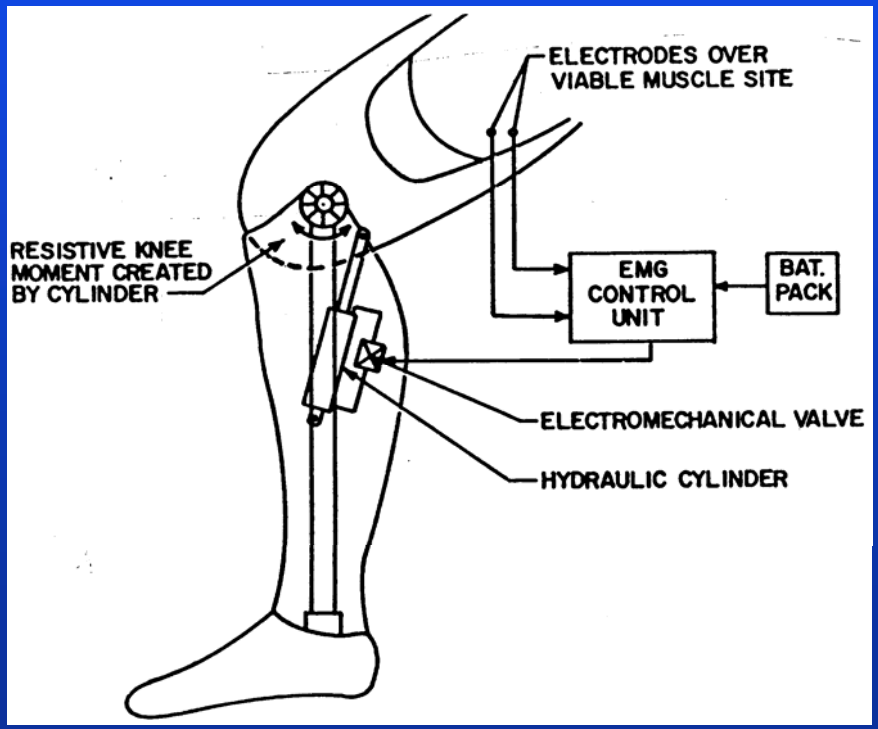
Experimental results





Example

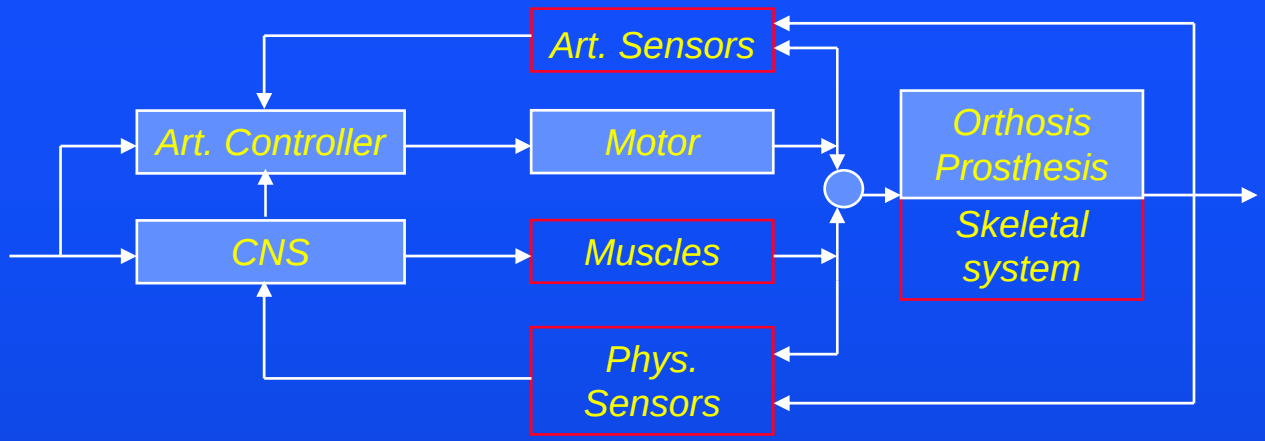


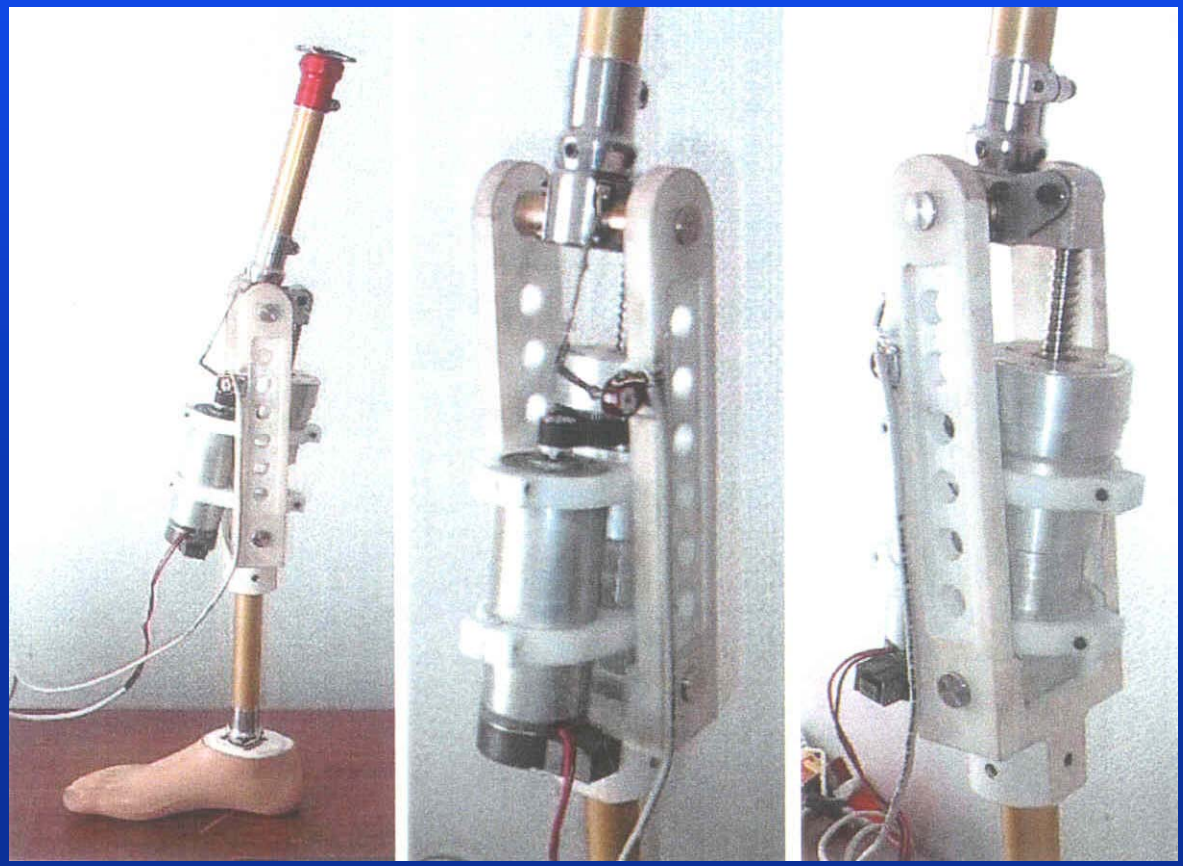


EMG-activated prostheses

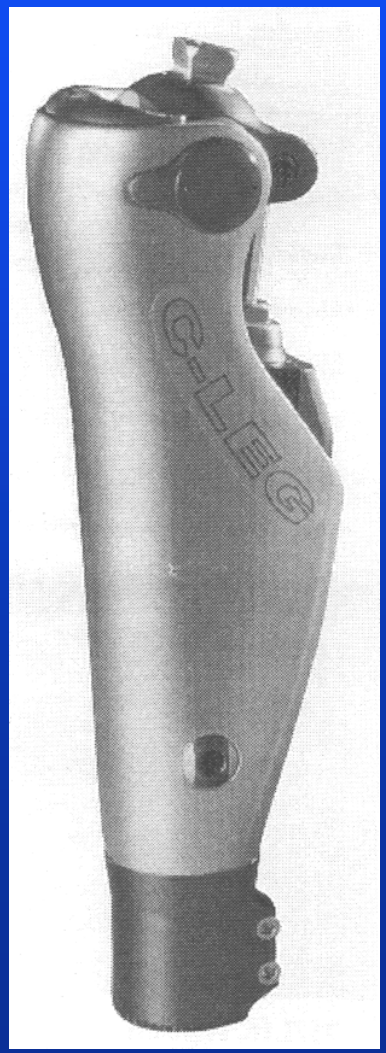
- lower extremities: controlled damping, no motor, artificial sensors
- upper extremities: myo-electric arm prosthesis, motor, no artificial sensors

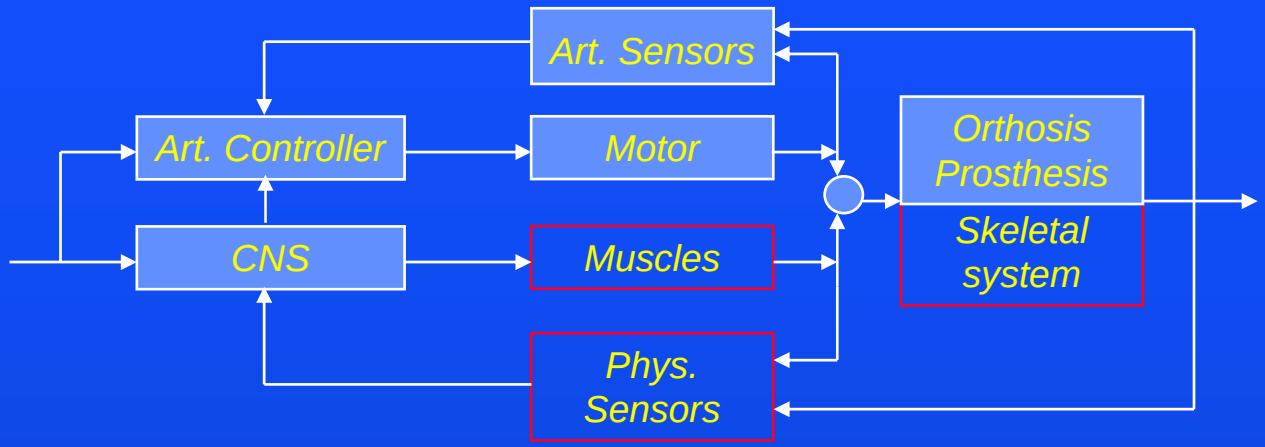
Example


Art. Sensors
Art. Controller
Motor
Orthosis
Prosthesis
Skeletal
system
CNS
Muscles
Phys.
Sensors



Example





Otto Bock C-leg

Prosthetic foot design

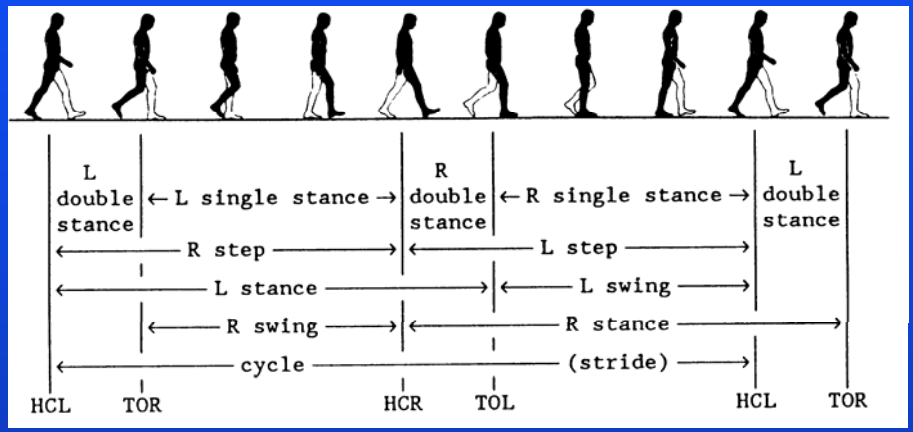
passive mechanism:

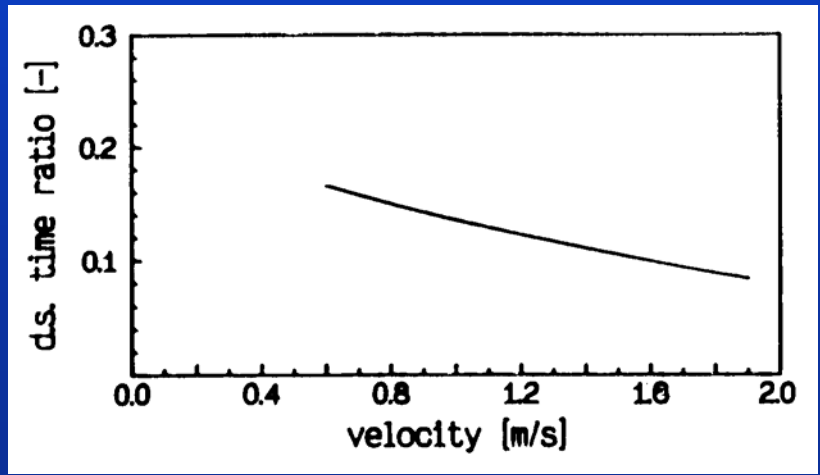
- damping 10 J
- energy storing??
- No actuation!

Concepts of gait

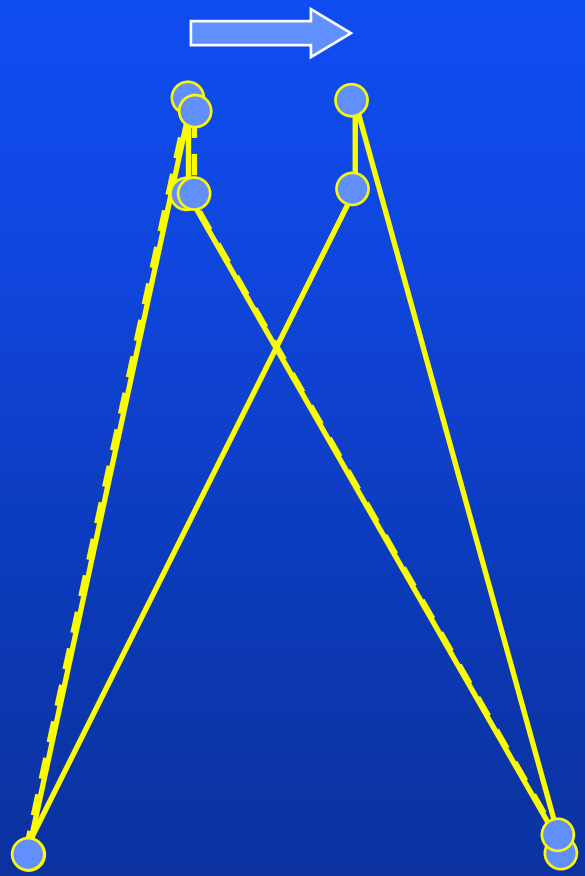
- Walking is:
  - preventing to fall
  - cyclical movement with left/right foot placements in front of the other supporting body weight
- The purpose of bipedal walking is to maximize the double support time while maintaining the forward velocity.
- Stability is maintained by balancing the trunk through coordinated actions of joints.

Double support phase



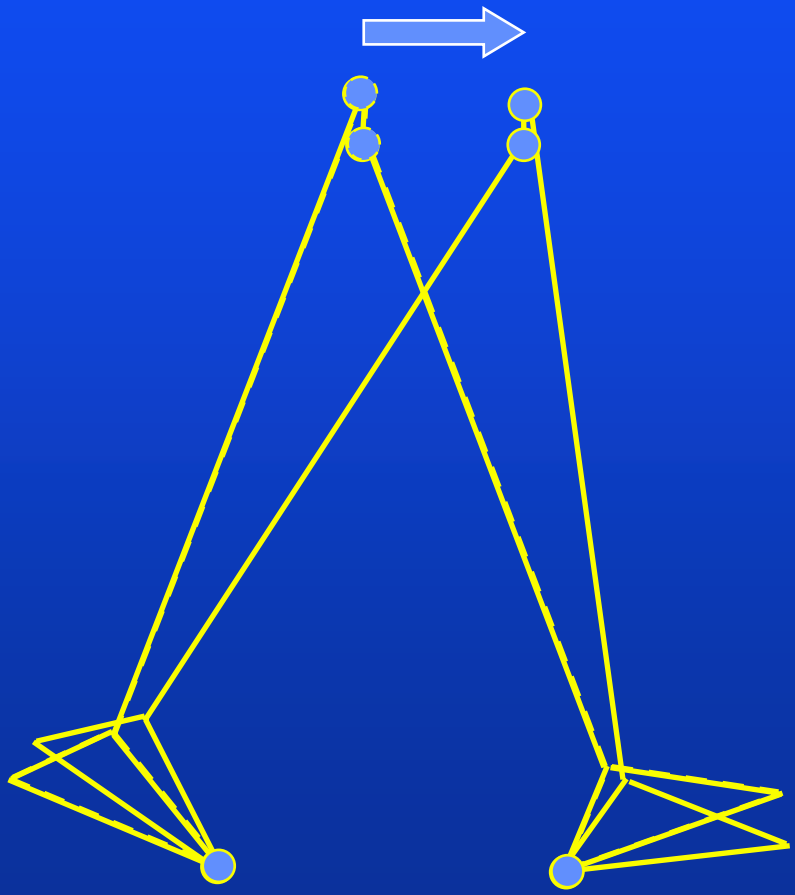


Stilt walking

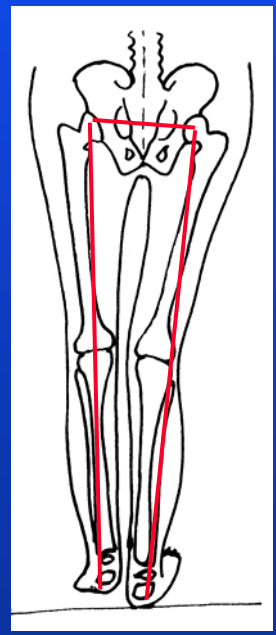


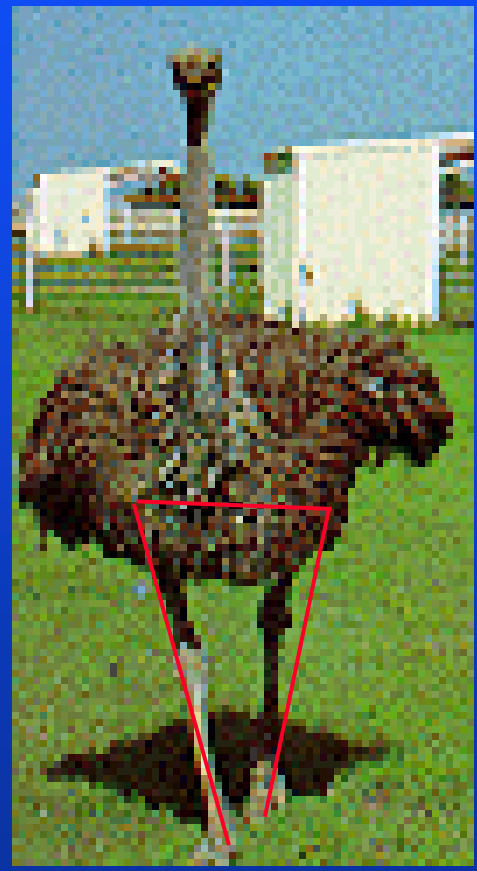
Pelvic tilt: ±35°

Stilt walking + feet

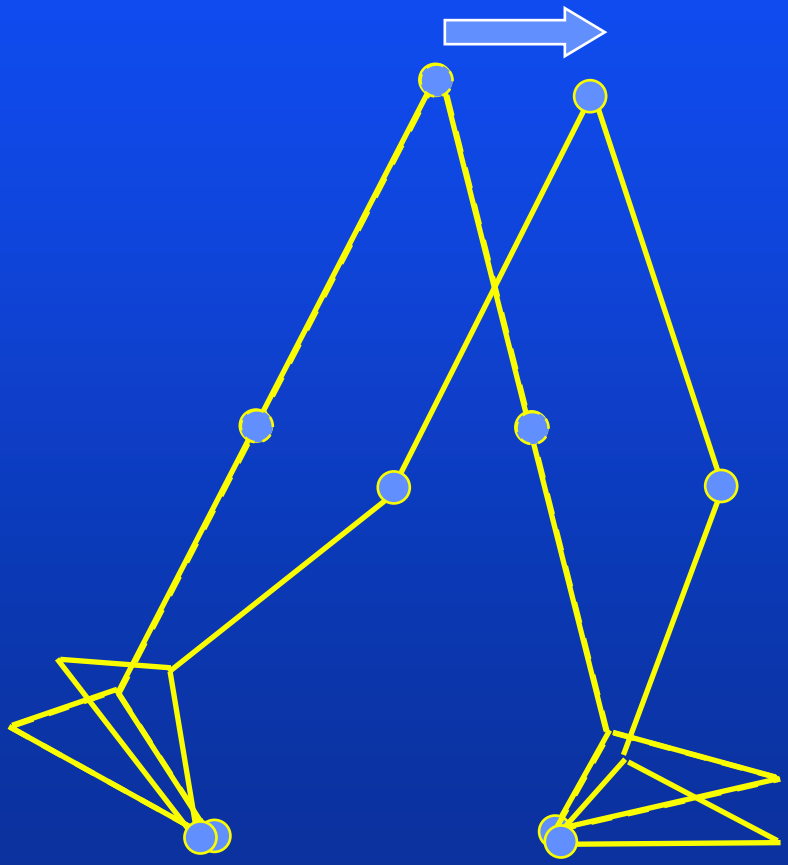


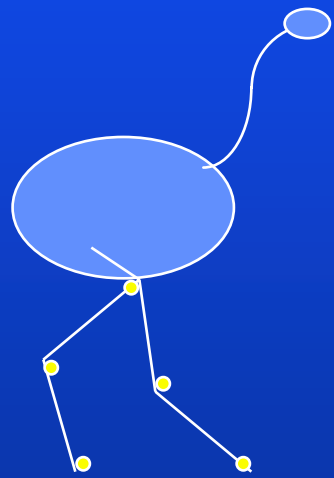
Pelvic tilt: ±15°





Stilt walking + feet + knees

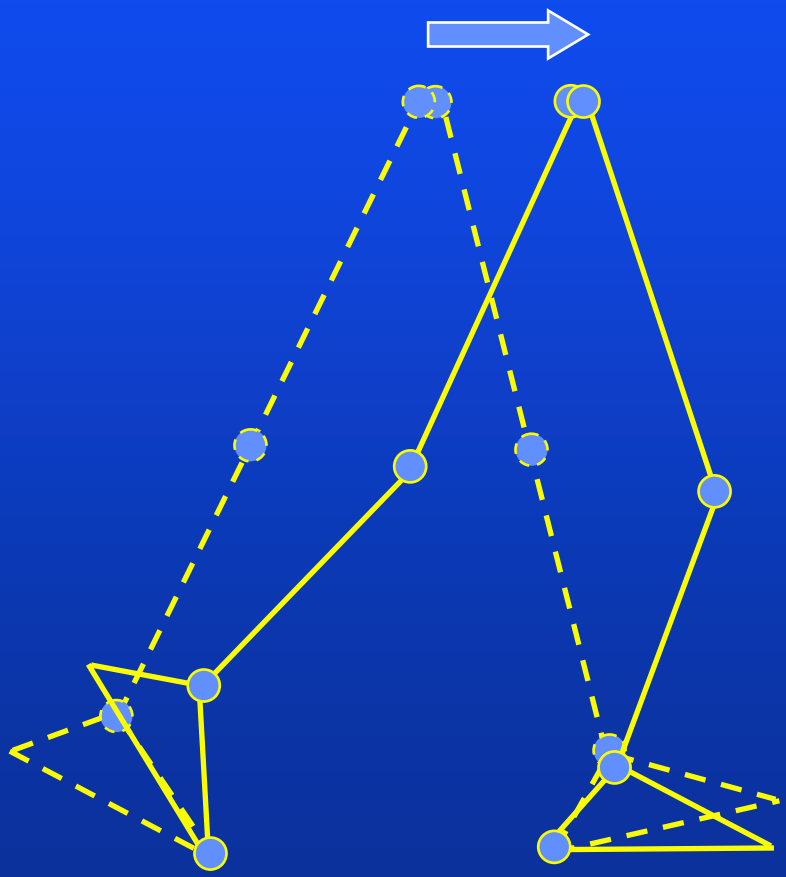




Pelvic tilt: ±0°

Normal walking

(feet, knees, ankles, pelvic rotation)



Pelvic tilt: free

Why is d.s. phase important ?

- Largest ground reaction forces
- largest muscle forces
- almost all mechanical work
- stable position

other phases are more or less ballistic

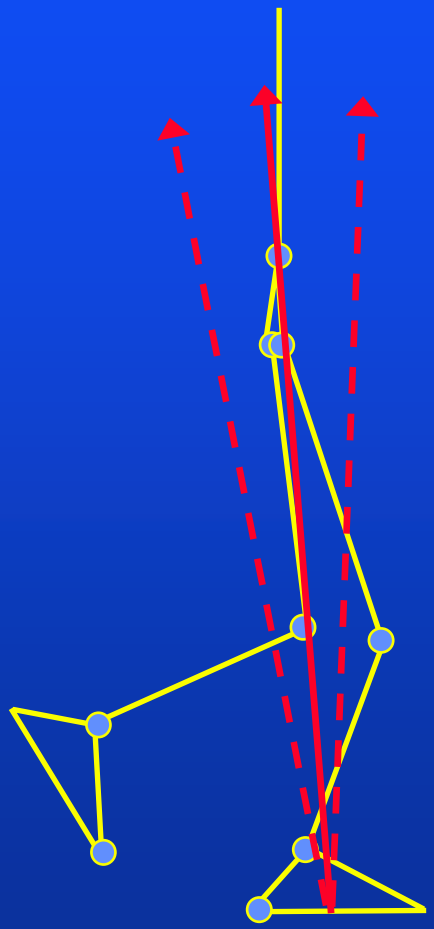
✍ *Maximize double support time !*

Prosthetic / orthotic gait

Walking without knee function would result in…

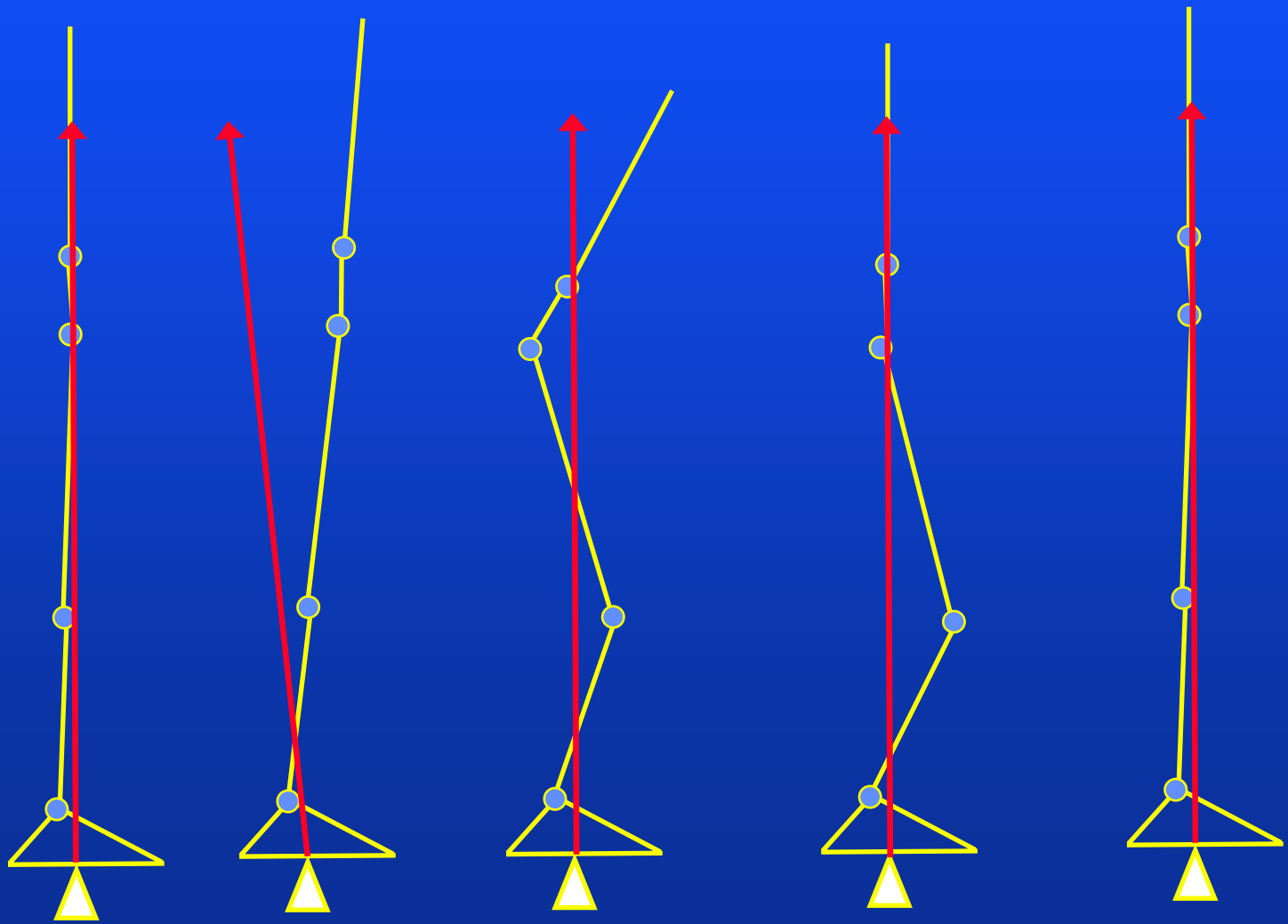
- Reduced velocity
- Reduced double support time
- Reduced step length
- Increased pelvic tilt

Balancing mechanism

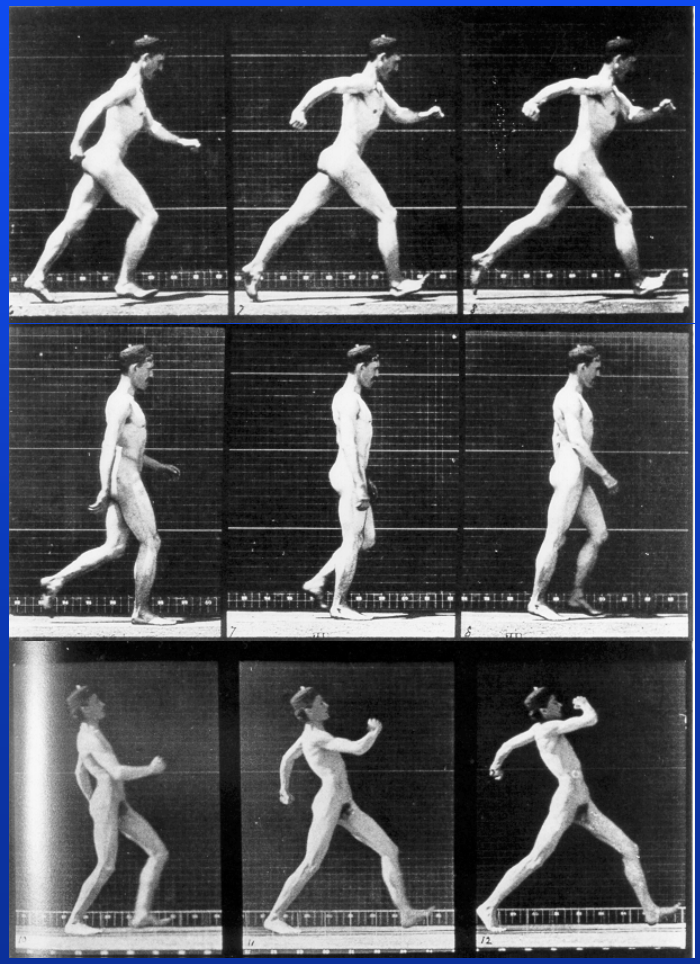


- *direct* ground reaction force (push against large mass of trunk)
- trunk will rotate (a little)
- requires coordinated joint actions

Balancing mechanism



Trunk movement in walking



Fast walking

Normal walking

Walking with large steps