Rehabilitation Engineering and Assistive Technology

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- **Rehabilitation Engineering**: the application of science and technology to ameliorate the handicaps of individuals with disabilities
- **Assistive Technology**:
  – A product of rehabilitation engineering activities
  – Any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase or improve functional capabilities of individuals with disabilities

TABLE 5.3 Prevalence of Disabling Conditions in the United States

45–50 million persons have disabilities that slightly limit their activities	
	32% hearing
	21% sight
	18% back or spine
	16% leg and hip
	5% arm and shoulder
	4% speech
	3% paralysis
	1% limb amputation
7–11 million persons have disabilities that significantly limit their activities	
	30% back or spine
	26% leg and hip
	13% paralysis
	9% hearing
	8% sight
	7% arm and shoulder
	4% limb amputation
	3% speech

Data from Stolov and Clowers (1981).

TABLE 5.2 Categories of Assistive Devices

- Prosthetics and Orthotics
  - Artificial hand, wrist, and arms
  - Artificial foot and legs
  - Hand splints and upper limb braces
  - Functional electrical stimulation orthoses
- Assistive Devices for Persons with Severe Visual Impairments
  - Devices to aid reading and writing (e.g., closed circuit TV magnifiers, electronic Braille, reading machines, talking calculators, auditory and tactile vision substitution systems)
  - Devices to aid independent mobility (e.g., Laser cane, Binaural Ultrasonic Eyeglasses, Handheld Ultrasonic Torch, electronic enunciators, robotic guide dogs)
- Assistive Devices for Persons with Severe Auditory Impairments
  - Digital hearing aids
  - Telephone aids (e.g., TDD and TTY)
  - Lipreading aids
  - Speech to text converters
- Assistive Devices for Tactile Impairments
  - Cushions
  - Customized seating
  - Sensory substitution
  - Pressure relief pumps and alarms
- Alternative and Augmentative Communication Devices
  - Interface and keyboard emulation
  - Specialized switches, sensors, and transducers
  - Computer-based communication devices
  - Linguistic tools and software
- Manipulation and Mobility Aids
  - Grabbers, feeders, mounting systems, and page turners
  - Environmental controllers
  - Robotic aids
  - Manual and special-purpose wheelchairs
  - Powered wheelchairs, scooters, and recliners
  - Adaptive driving aids
  - Modified personal licensed vehicles
- Recreational Assistive Devices
  - Arm-powered cycles
  - Sports and racing wheelchairs
  - Modified sit-down mono-ski

Categories of Assistive Devices

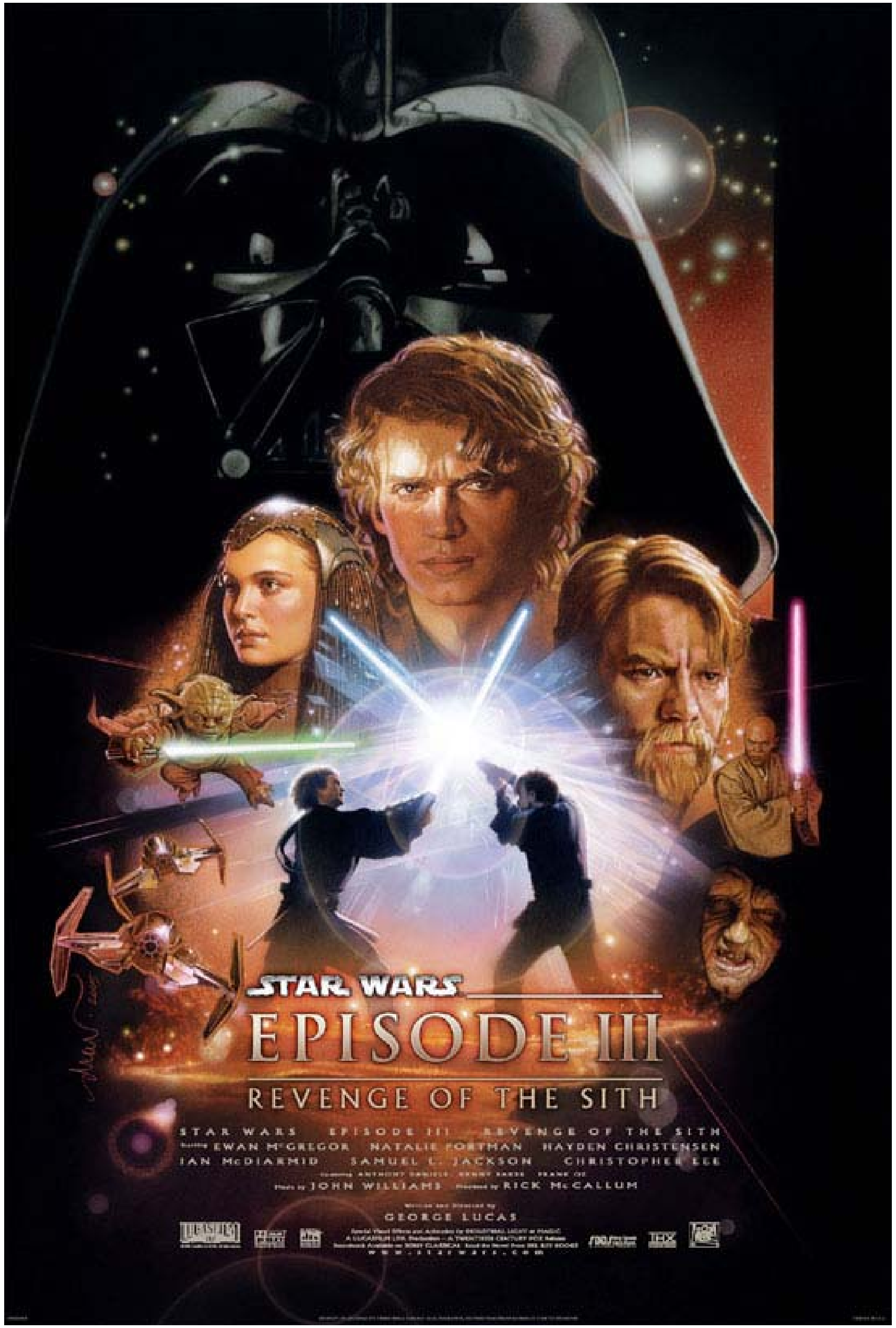
- Prosthetics and Orthotics
- Assistive Devices for persons with severe visual impairments
- Assistive devices for persons with severe auditory impairments
- Assistive devices for tactile impairments
- Alternative and augmentative communication devices
- Manipulation and mobility aids
- Recreational assistive devices

Prosthetics and Orthotics

- Artificial hand, wrist, and arms
- Artificial foot and legs
- Hand splints and upper limb braces
- Functional electrical stimulation orthoses

- Prosthetics

- Orthotics


STAR WARS
EPISODE III
REVENGE OF THE SITH
STAR WARS EPISODE III REVENGE OF THE SITH
EWAN McGREGOR NATALIE PORTMAN HAYDEN CHRISTENSEN
IAN McDIARMID SAMUEL L. JACKSON CHRISTOPHER LEE
JOHN WILLIAMS RICK McCALLUM
GEORGE LUCAS

What is FES

- Functional Electrical Stimulation
  - Patterned electrical stimulation which dedicated to restore functions lost after disabled.
- Functional Neuromuscular Stimulation
  - Electrical stimulation of neuromuscular structures in an organism dedicated to restore the functions lost after disabled. FNS is a subcategory of FES.

Some Historical Milestones

- Liberson et al. (1961): The first investigators to utilize electrical stimulation to restore functional control of a paralyzed limb muscle (Drop foot correction via peroneal nerve stimulation).
- Long and Masciarelli (1963): FES-assisted splint for control of the hand in high quadriplegic patients

Some Historical Milestones

- 半田康延,星宮望(1982): The first FES system developed in Asia (Hand control of a C4 quadriplegia).
- 1995: IFESS (International FES Society) was instituted
- 陳家進等(1999):台灣第一台大型試驗中的FES系統(FES-assisted cycling ergometer for SCI)

Common Categories of FES

Sensory FES	• Auditory Neuroprostheses (Artificial Ear) • Visual Neuroprostheses • Tactile Substitution
FES of Internal Organ	• Heart Pacing • Breathing Pacing（Diaphragm stimulation） • Function Restoration of Genitourinary System
Motor FES	• FES for Paralyzed U/E • FES for Paralyzed L/E • FES for Posture Control
FES for Organ Substitution	• Cardiomyoplasty (Latissimus dorsi -> Heart) • Graciloplasty (Gracilis-> rectus sphincter)

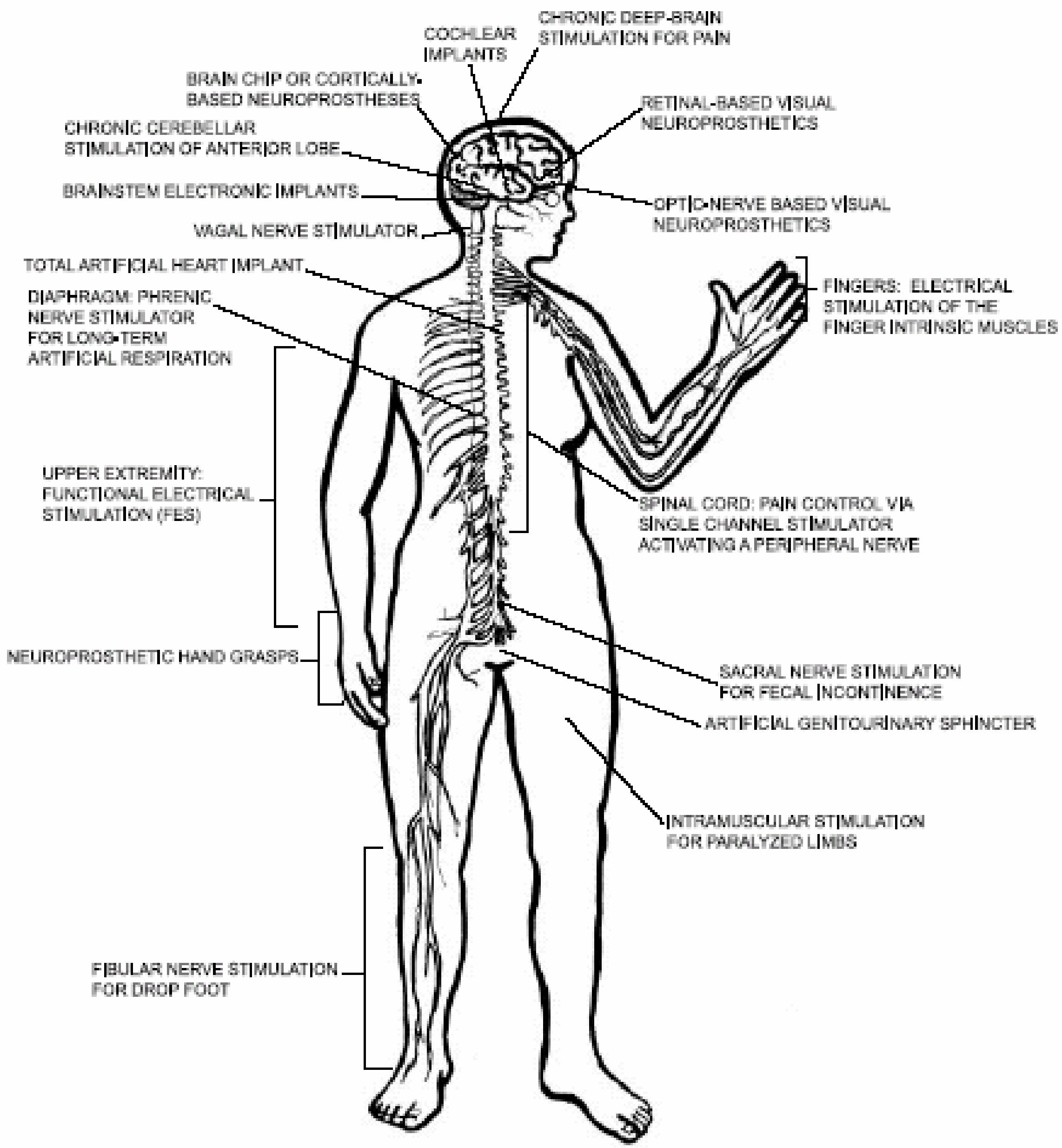


Figure 1.1 Diagram of human body showing many of the neuroprosthetic systems currently employed or in development.

Functional Electrical Stimulation

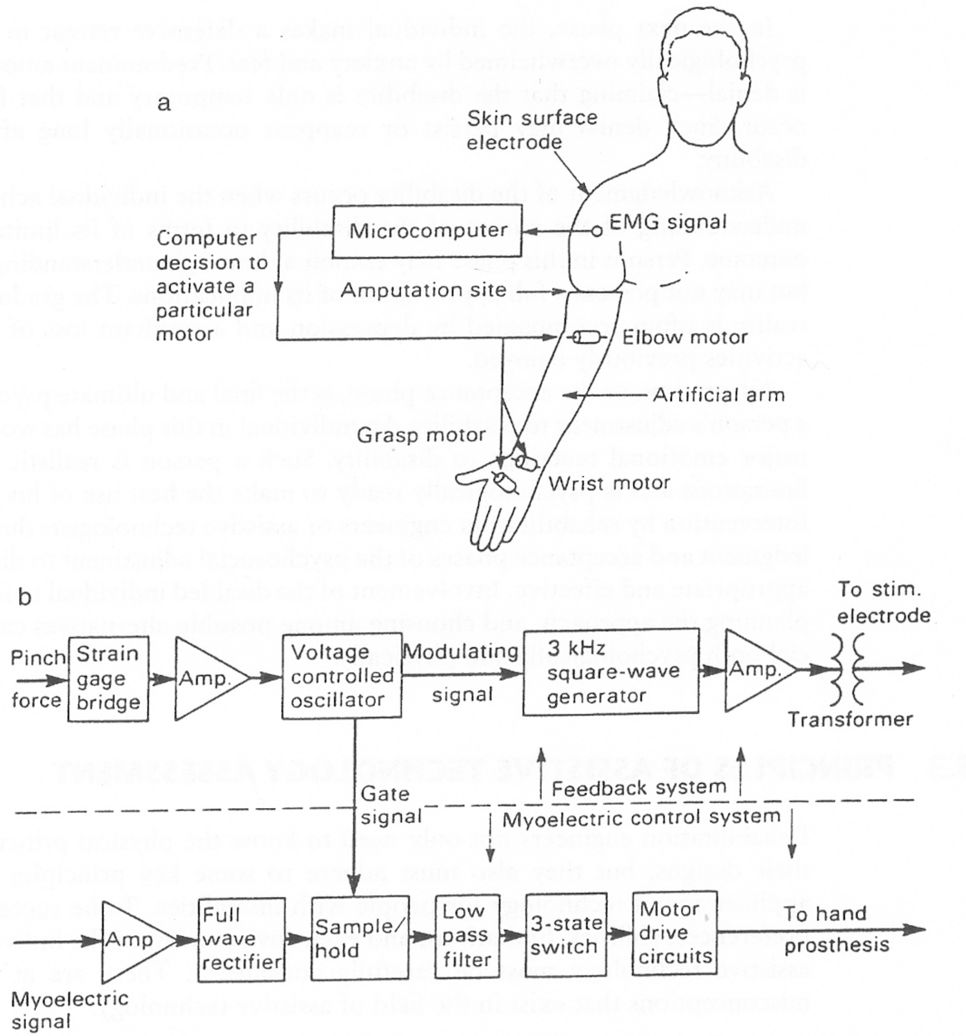
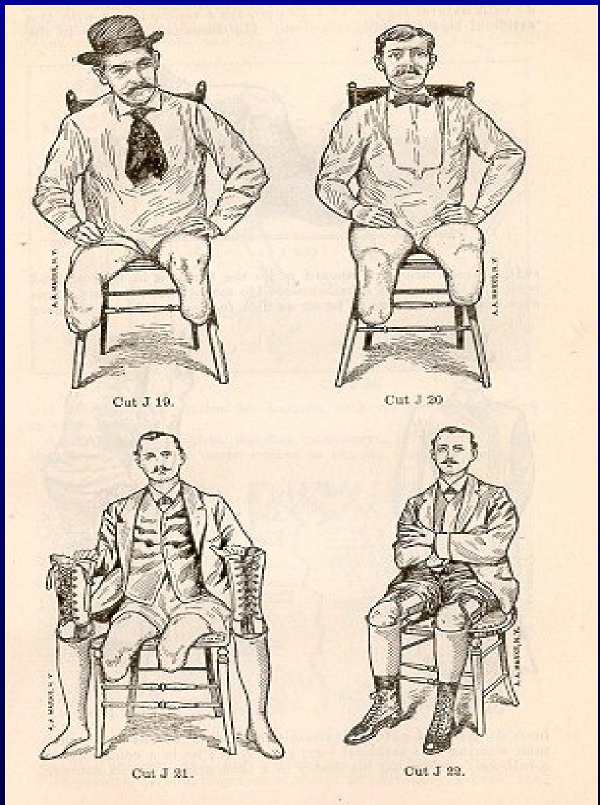


Figure 5.6 (a) This system generates temporal signatures from one set of myoelectric electrodes to control multiple actuators. (b) Electrical stimulaton of the forearm to provide force feedback may be carried out using a system like this one (from Webster et al., 1985).

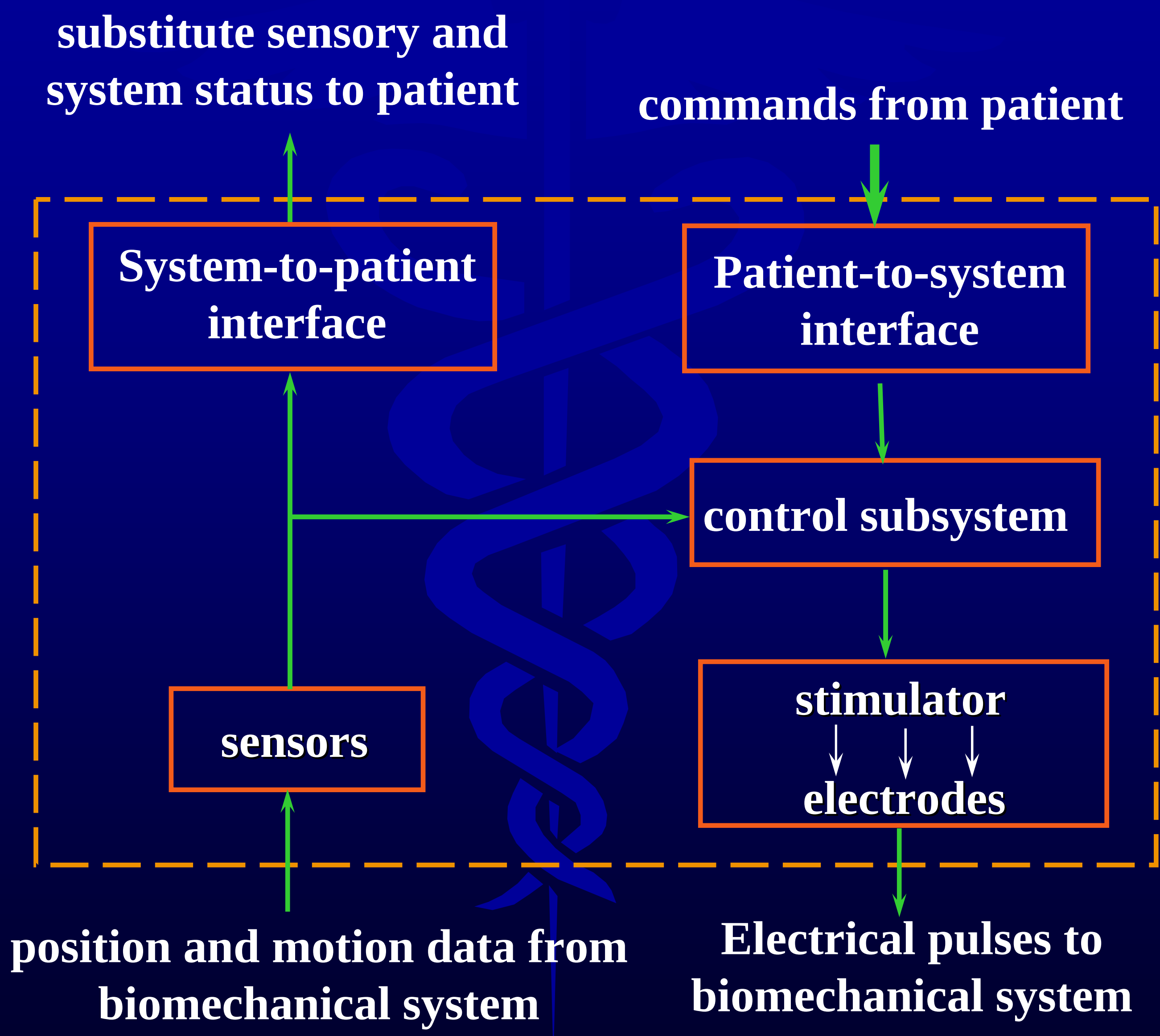
Who can Benefit continued?



Applications of Motor FES

- Correct foot-drop during hemiplegic gait
- Enable paraplegic standing and walking
- Generate the functional hand rehabilitation in quadriplegic patients

Conceptual diagram of FES system



Electrodes

- Implanted Electrodes
  - Implanted electrodes (cuff or percutaneous electrodes) can achieve better muscular selectivity. (lower current, higher specificity)
  - Broken electrode, infection, and poor positioning are common in implanted electrode.
  - Need for surgical intervention

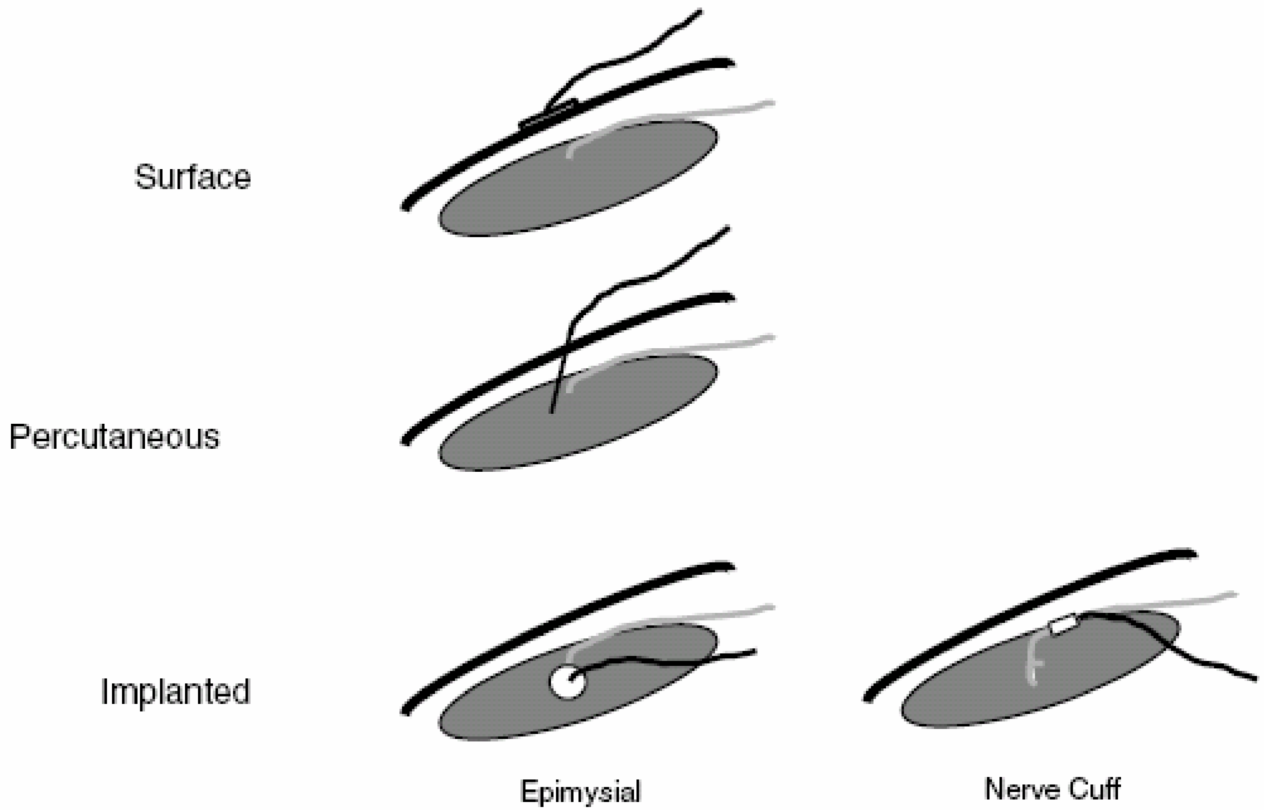
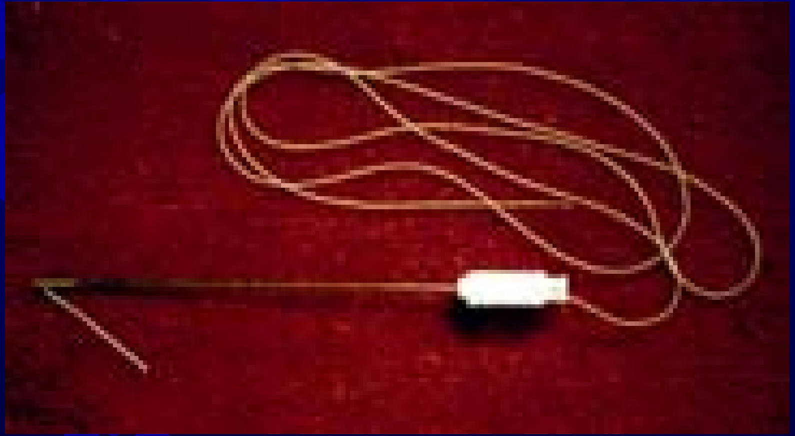


Figure 12.4 Schematic drawing representing the different types of electrode designs. Not represented in this drawing is the intramuscular (implanted) electrode type.


CASTER



Electrode

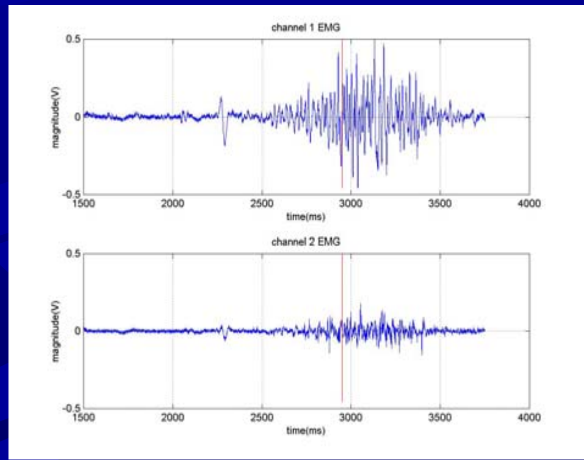
- Surface Electrode
  - Does not require surgical intervention
  - Can be applied at a very early stage of the rehabilitation
  - Can not use on small muscle conveniently

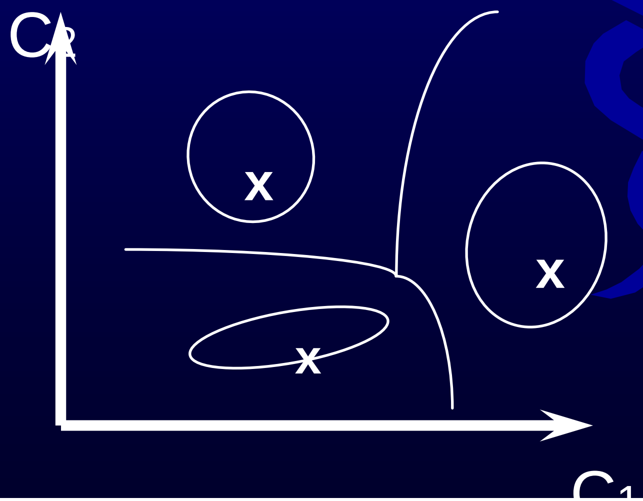
Typical Electrode Positions for Quadricep Stimulation (-ve over motor point)

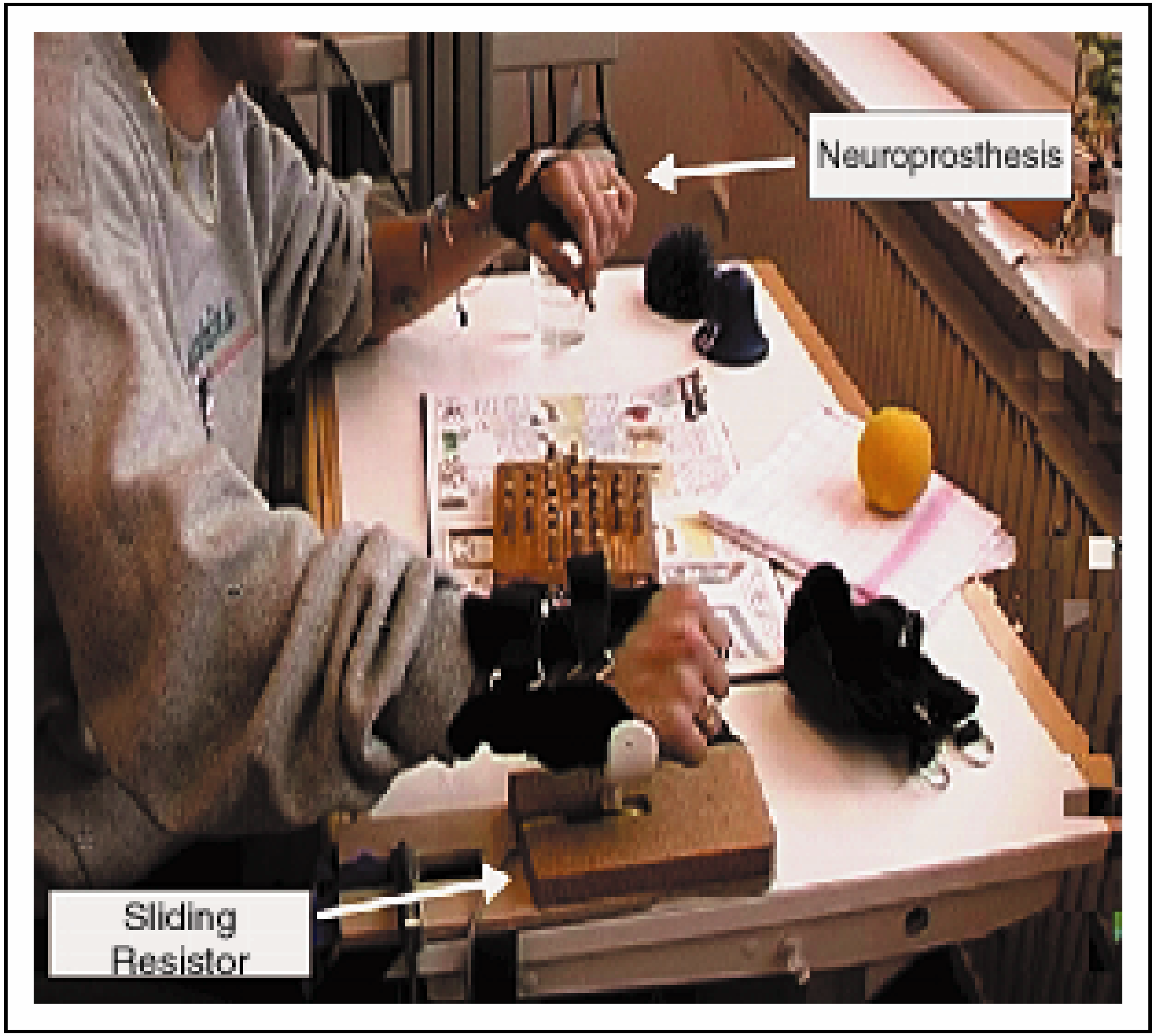
Command Input

- To identify the "will to move"
- Logic input command
  - Push button, voice command, joystick trigger, foot switch,…
- Proportional input command
  - Joystick, slip potentiometer, EMG from a voluntary muscle, respiration controlled…

An Example for Logic Input

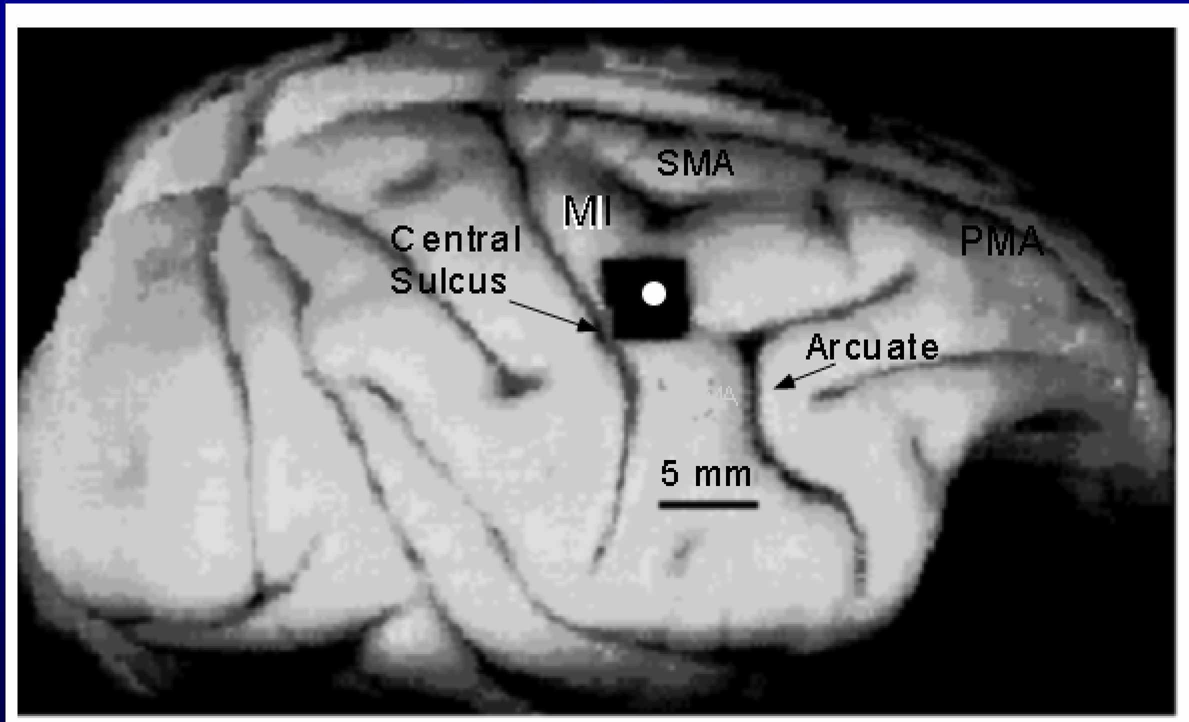






6. Subject D.K. performs a pinch grasp with the grasping neuroprosthesis.

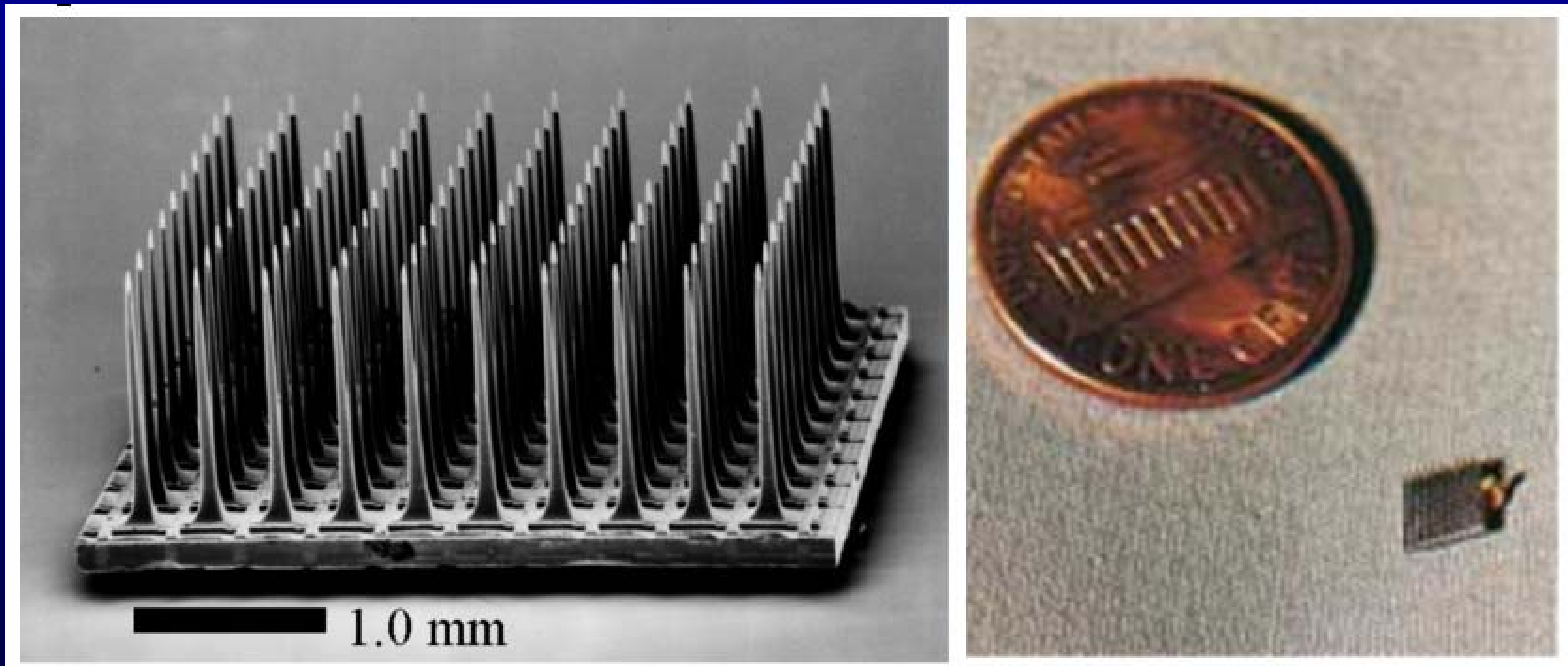
Primary Motor Cortex



MI arm area of motor cortex

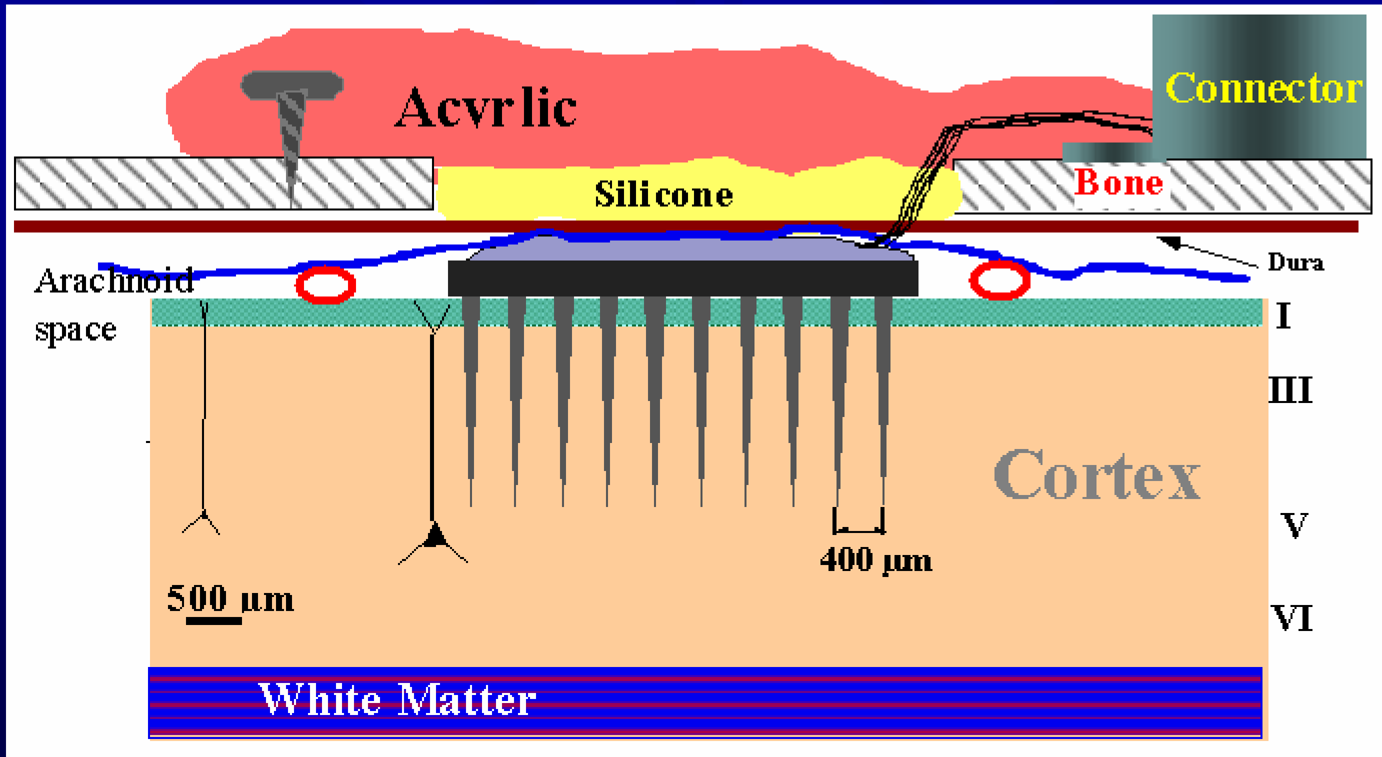
* firing rates of cells correlated with hand motion (velocity, position)

Neural Implant



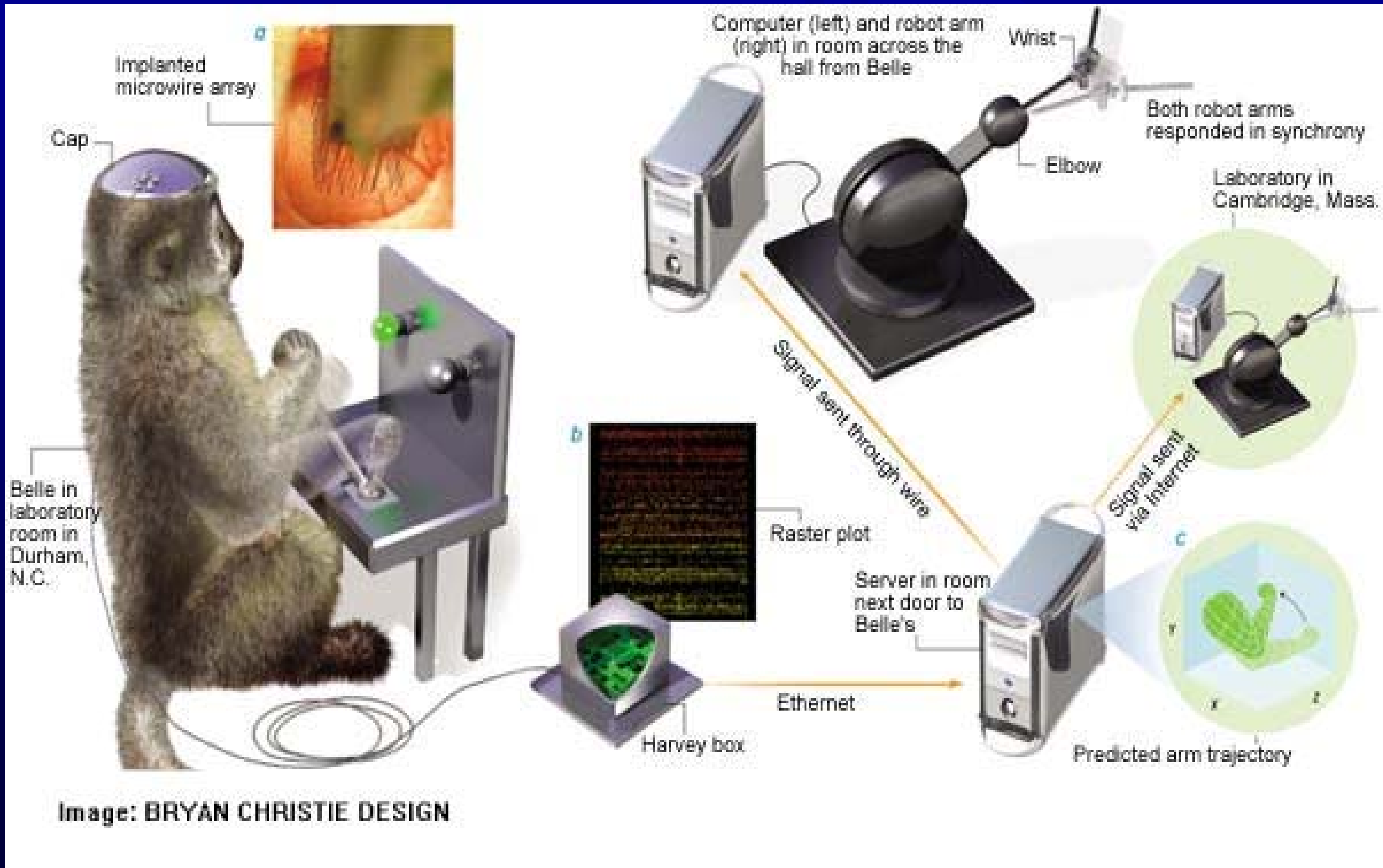
100 electrodes
400 micrometer separate
4x4 mm

Neural Implant



Chronically implanted
Stable recording for 2-3 years
(but not necessarily the same cells every day)
Spikes as well as local field potentials

Diagram of Brain Control



Stimulator

- Constant Voltage
  - Simple to designer
  - Can not provide proper stimuli when the impedance change
- Constant Current
  - Can provide proper stimuli at any condition
  - Complicated design

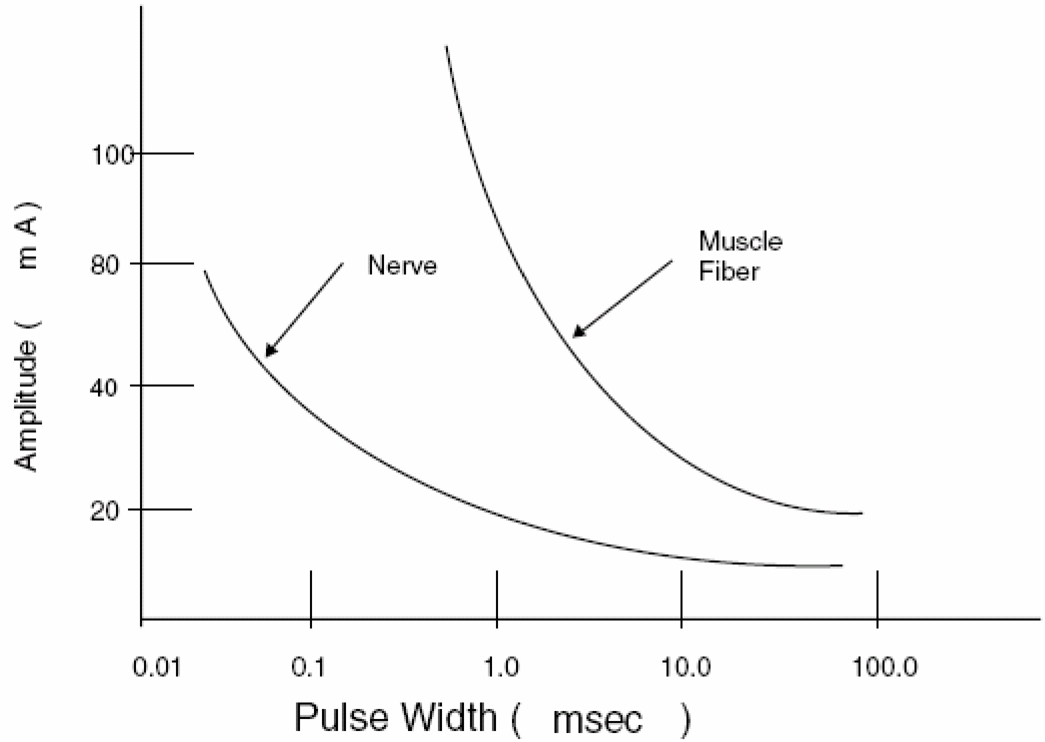


Figure 12.5 Strength–duration curve comparison of the charge required to excite a nerve compared to that of a muscle fiber. The differences in charge required to excite muscle fiber alone preclude this method as a means of restoring function with a motor prosthesis.

Control of Muscle Contraction

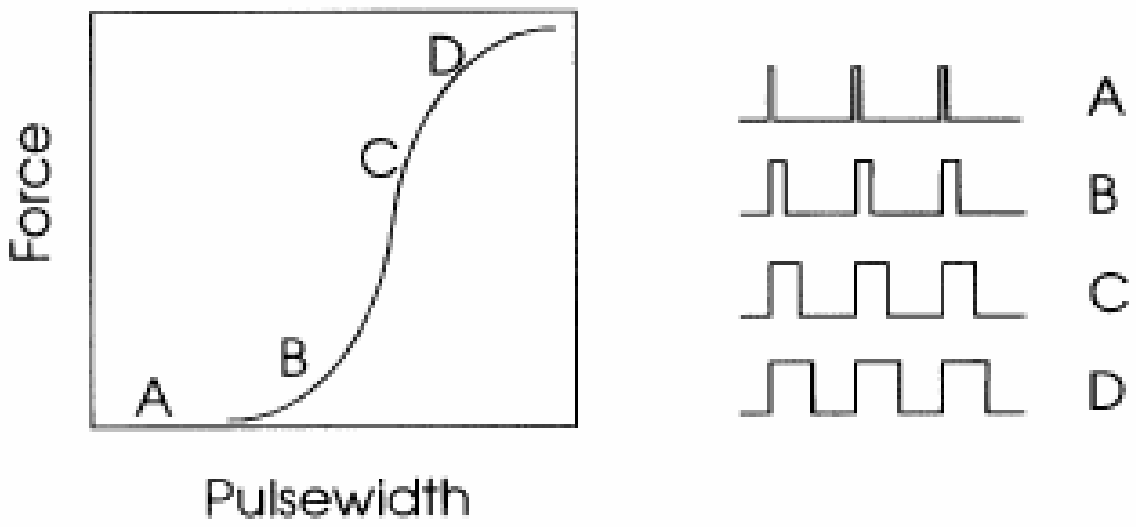


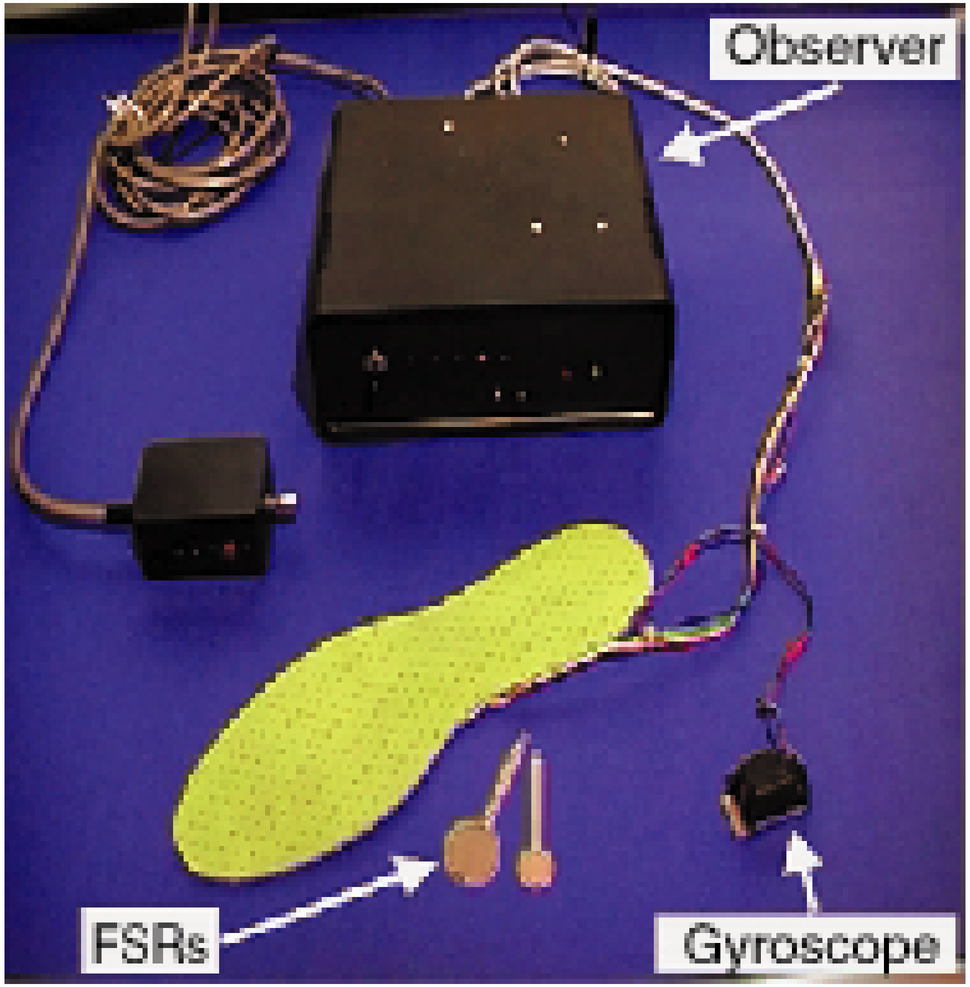
Fig. 2. Grading force by varying the width of the stimulus pulse ("pulsewidth modulation"). Pulse amplitude and repetition rate are constant. Wider pulses activate more motor units, giving larger forces. (Pulse widths have been exaggerated for clarity.)

Control Strategies

- Closed-Loop Control
  - The control algorithm is designed to function with feedback signals.
  - Muscle stimulation patterns are adjusted according the error between the desired and actual trajectory or other physiological parameters.
  - This strategy need to design the control algorithm from the control theory, such as classic control theory, advance control theory, neuronet, fuzzy,…

Sensors

- To provide the command source
  - Foot switch, EMG electrode,…
- To return the physiological parameters to the controller (in closed-loop control strategy)
  - Electrogoniometer, EMG, tactile sensor,…



8. Gait phase identification sensor.

Implanted Joint Angle Transducer (IJAT)

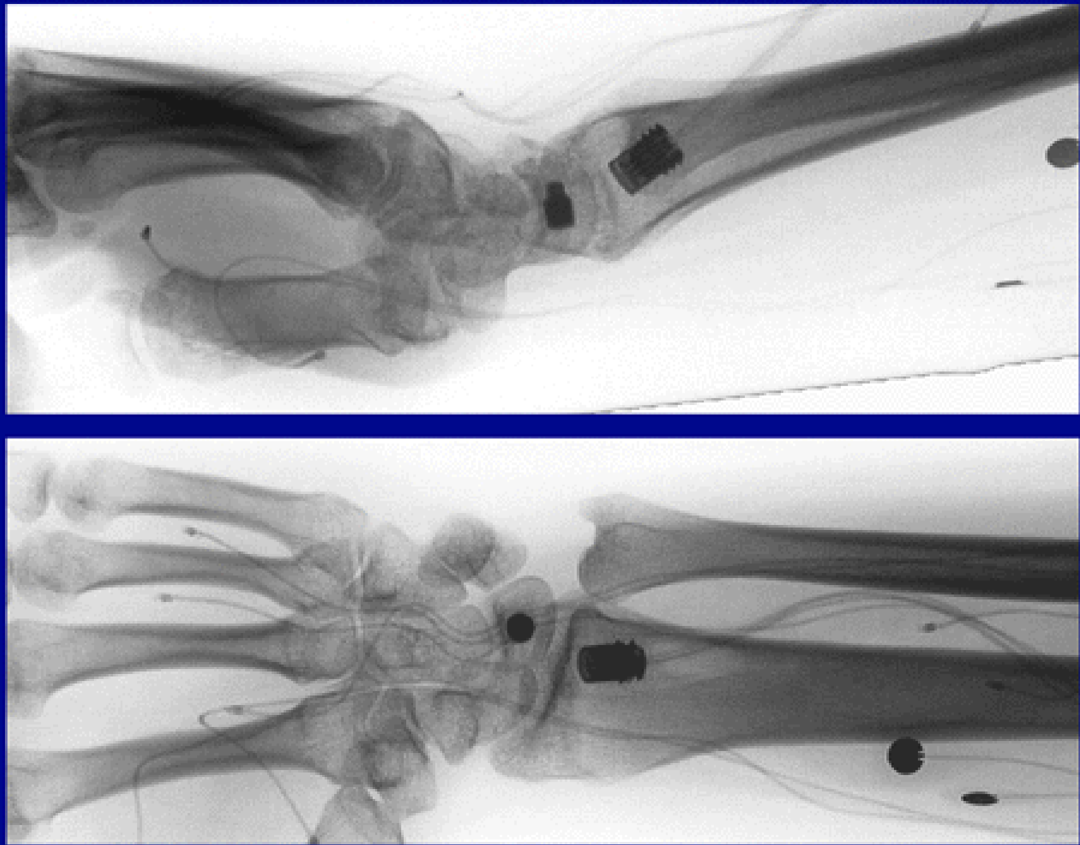
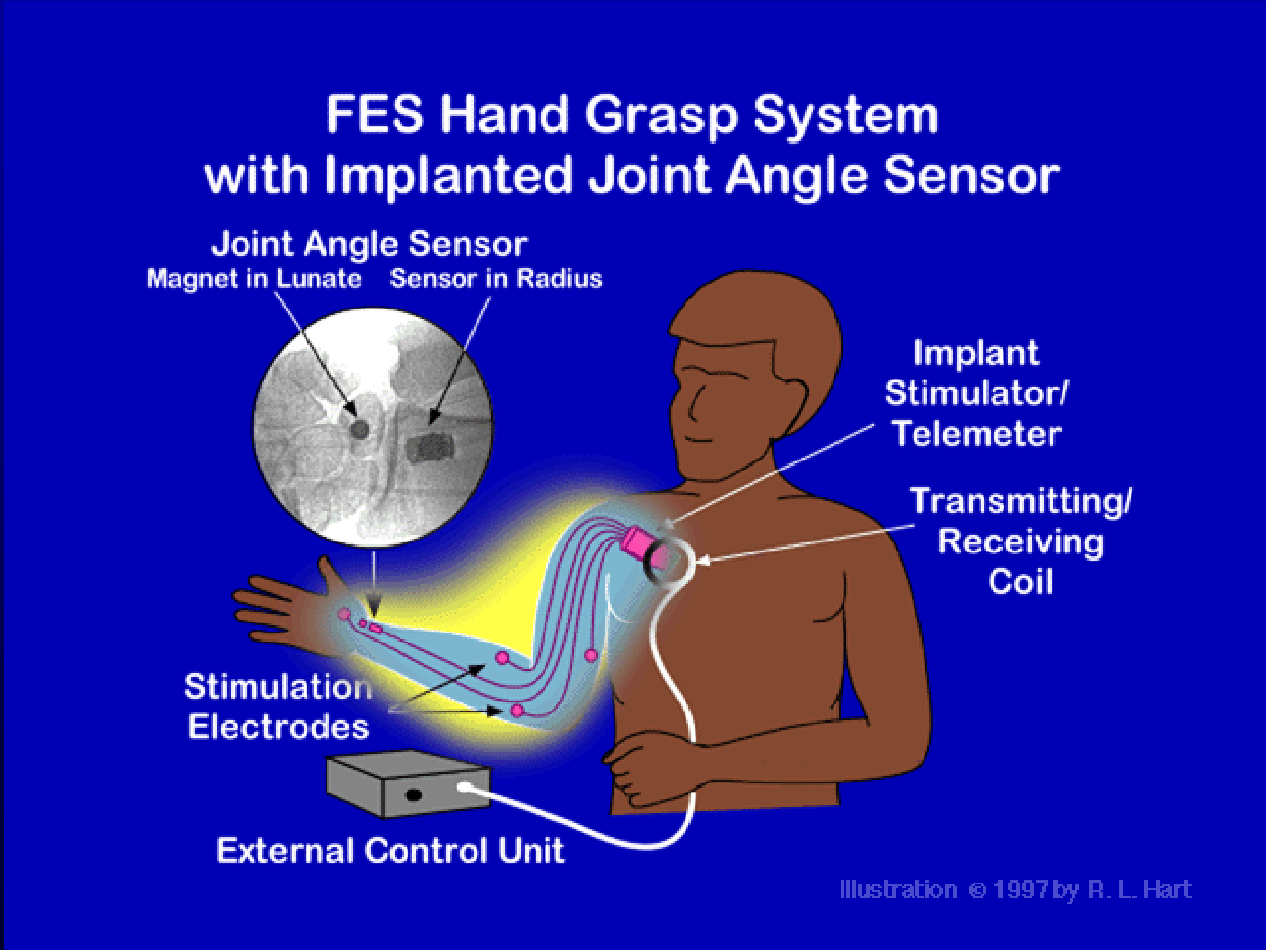
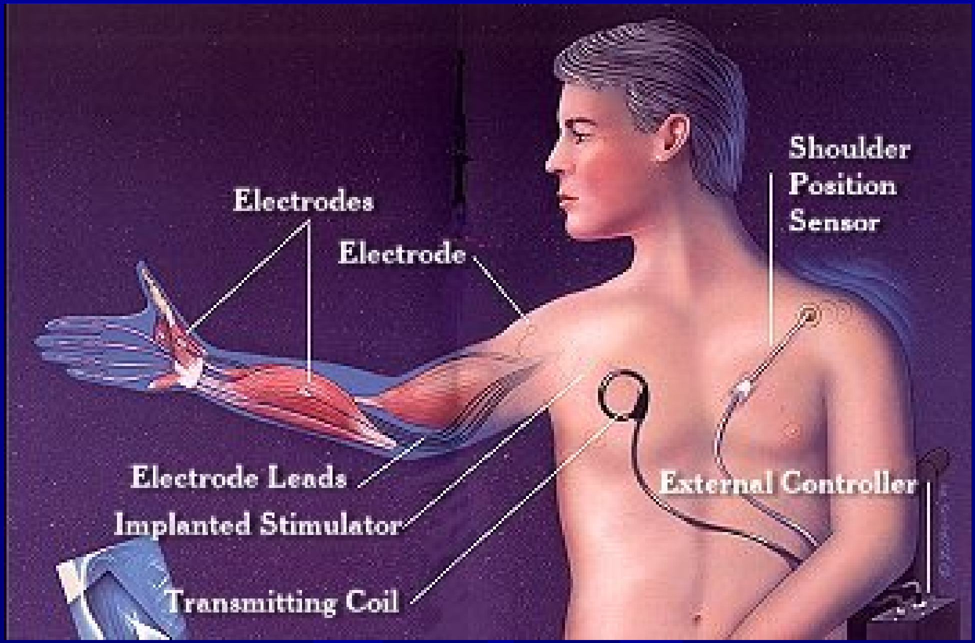


Illustration © 1997 by R. L. Hart

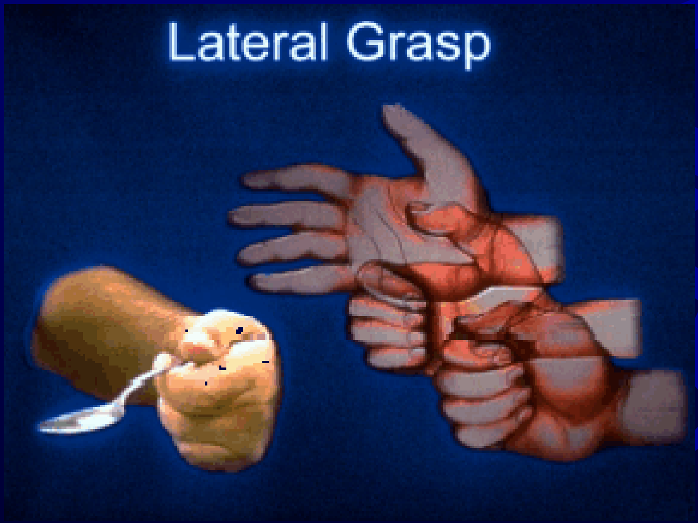
FES FOR UPPER EXTERMITIES

FreeHand System at Cleveland



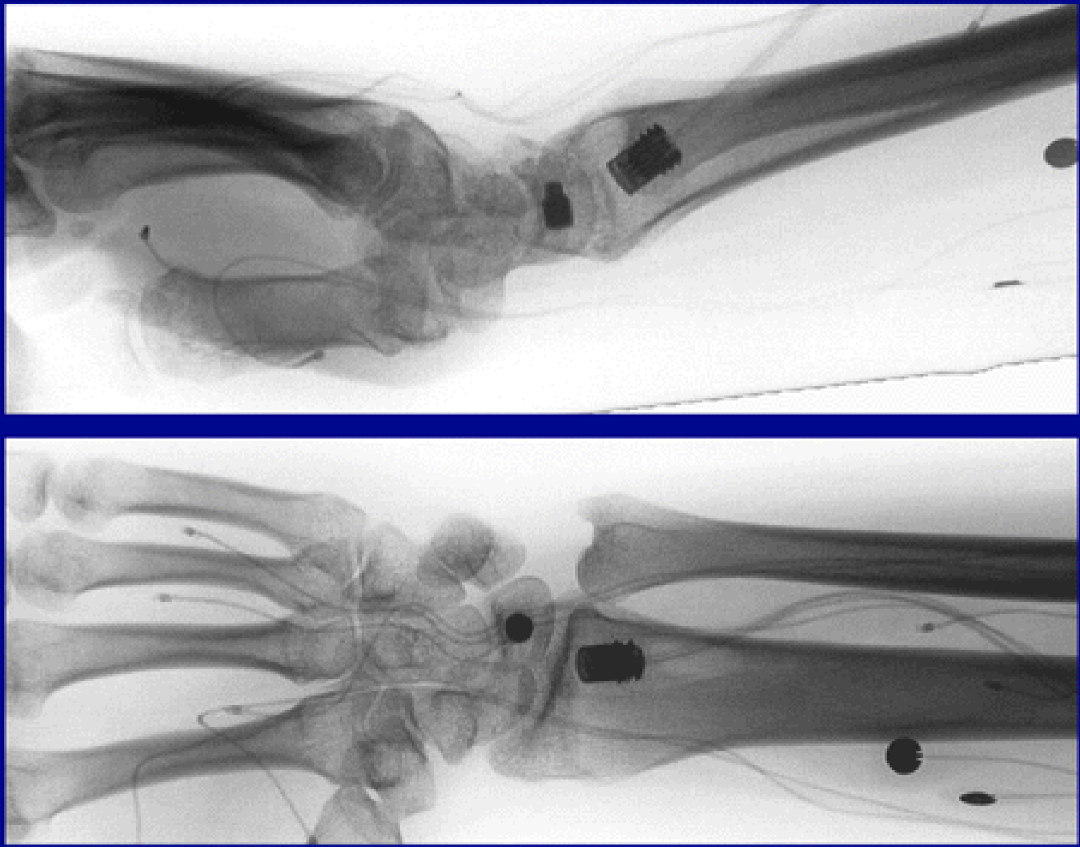


shoulder position sensor

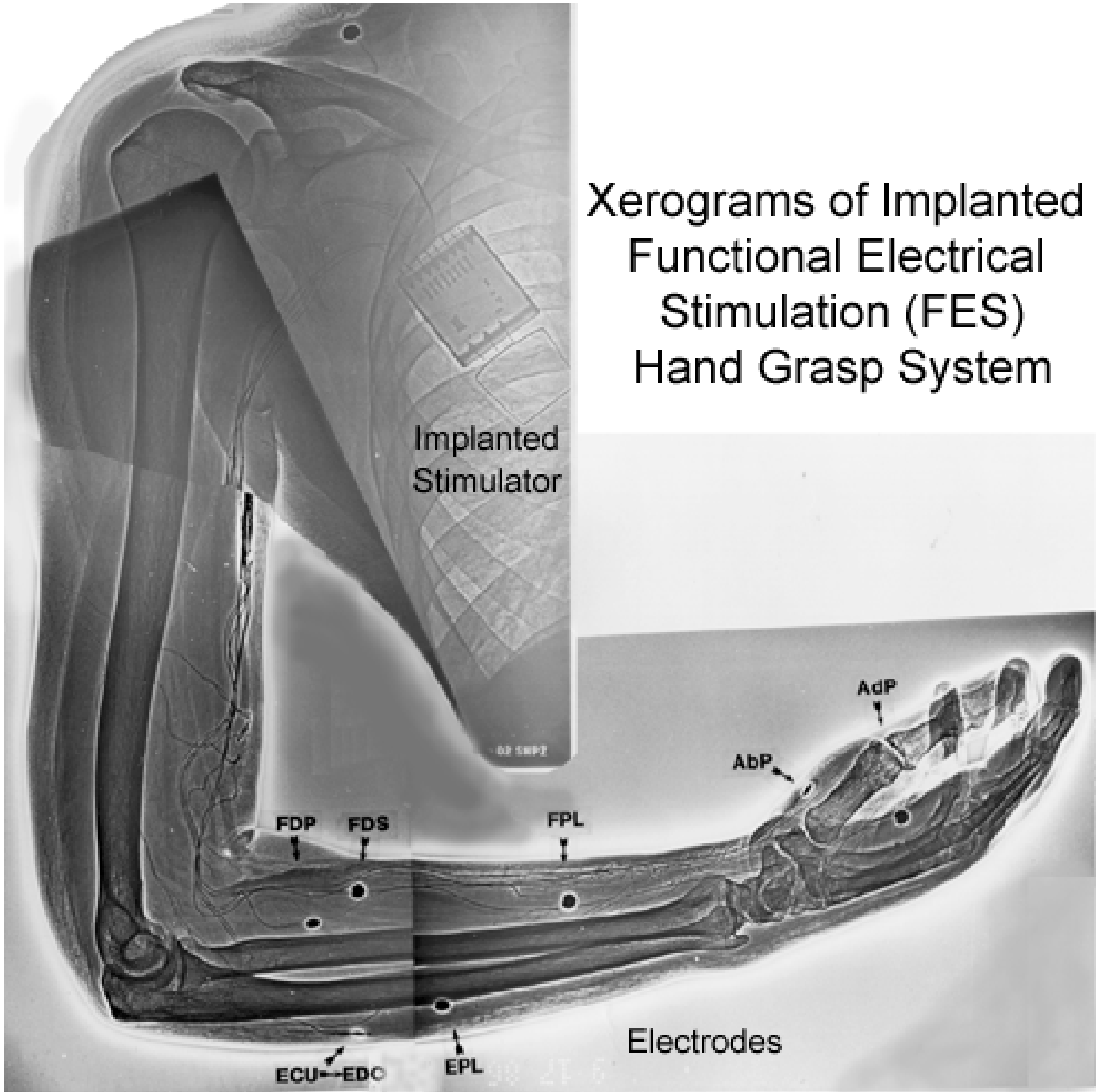


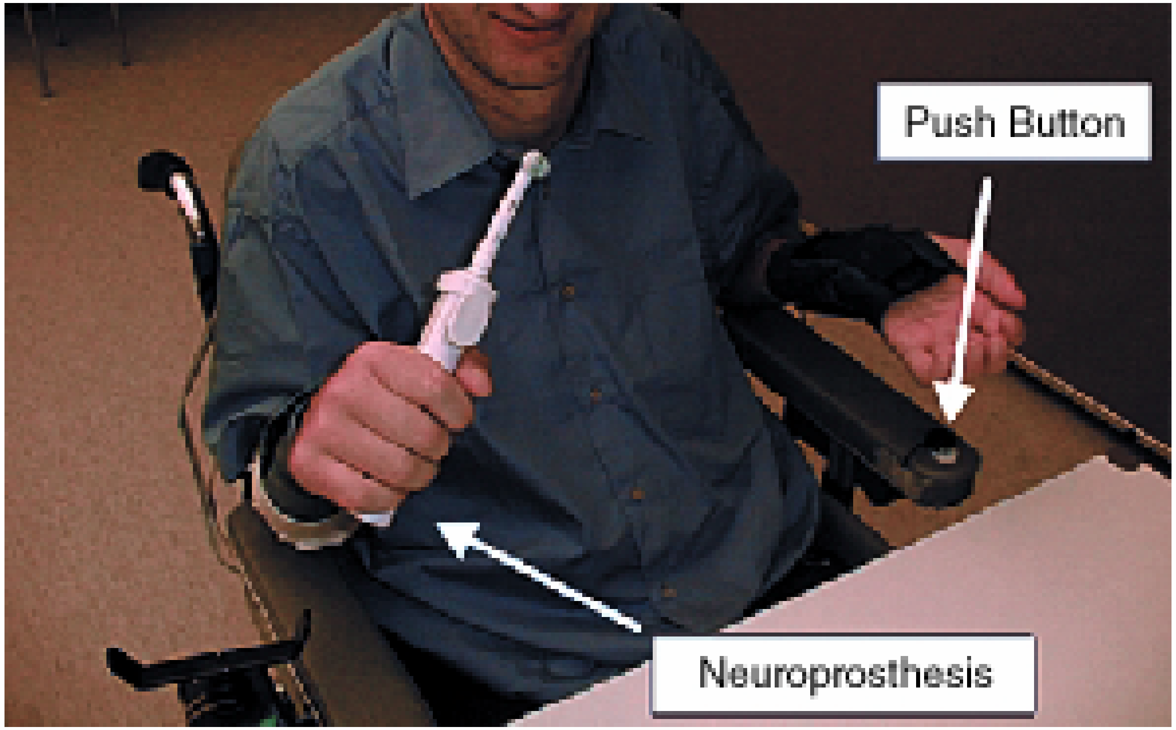
For quadriplegic patients from spinal cord injury

Implanted Joint Angle Transducer (IJAT)

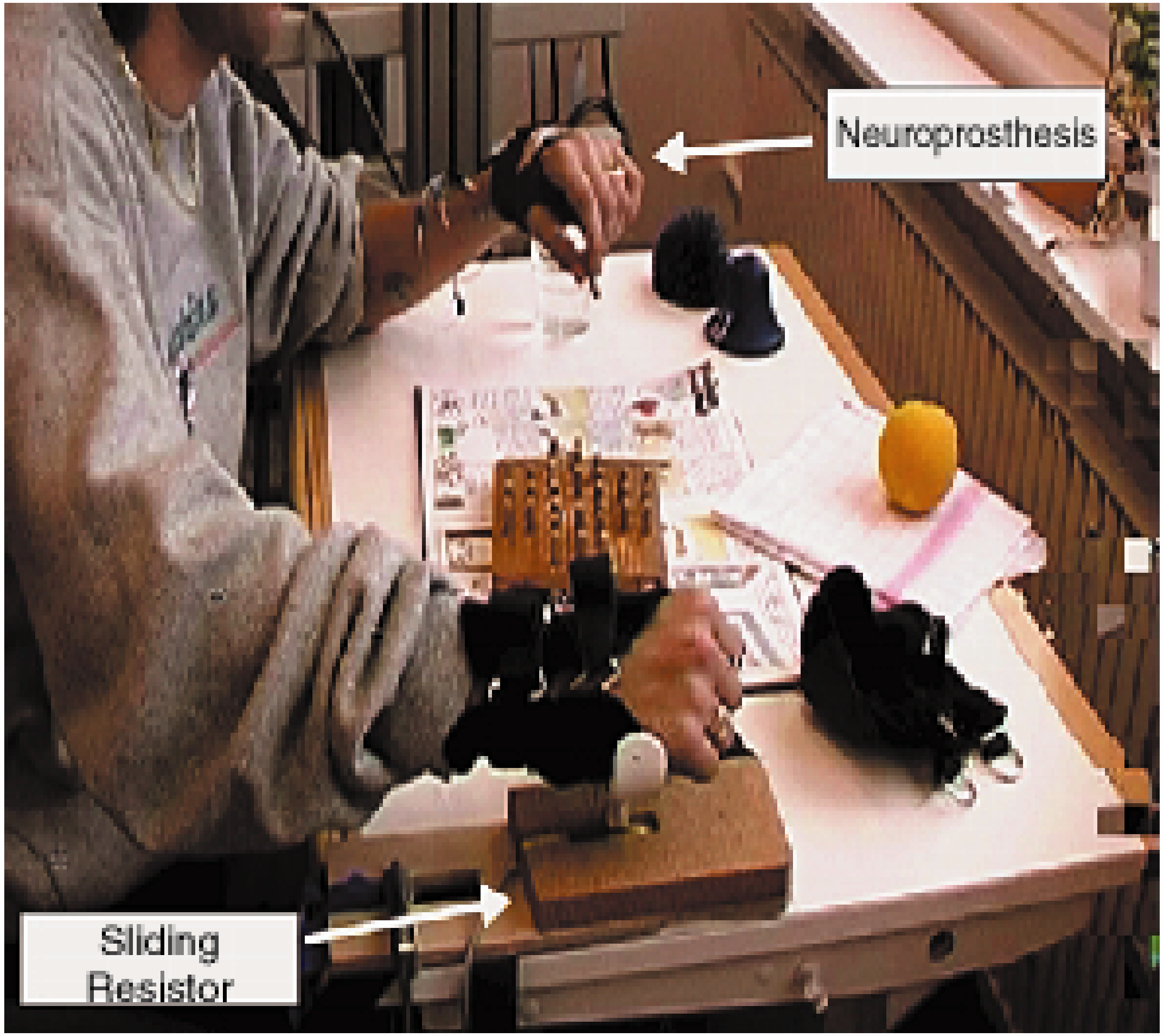


Xerograms of Implanted Functional Electrical Stimulation (FES) Hand Grasp System





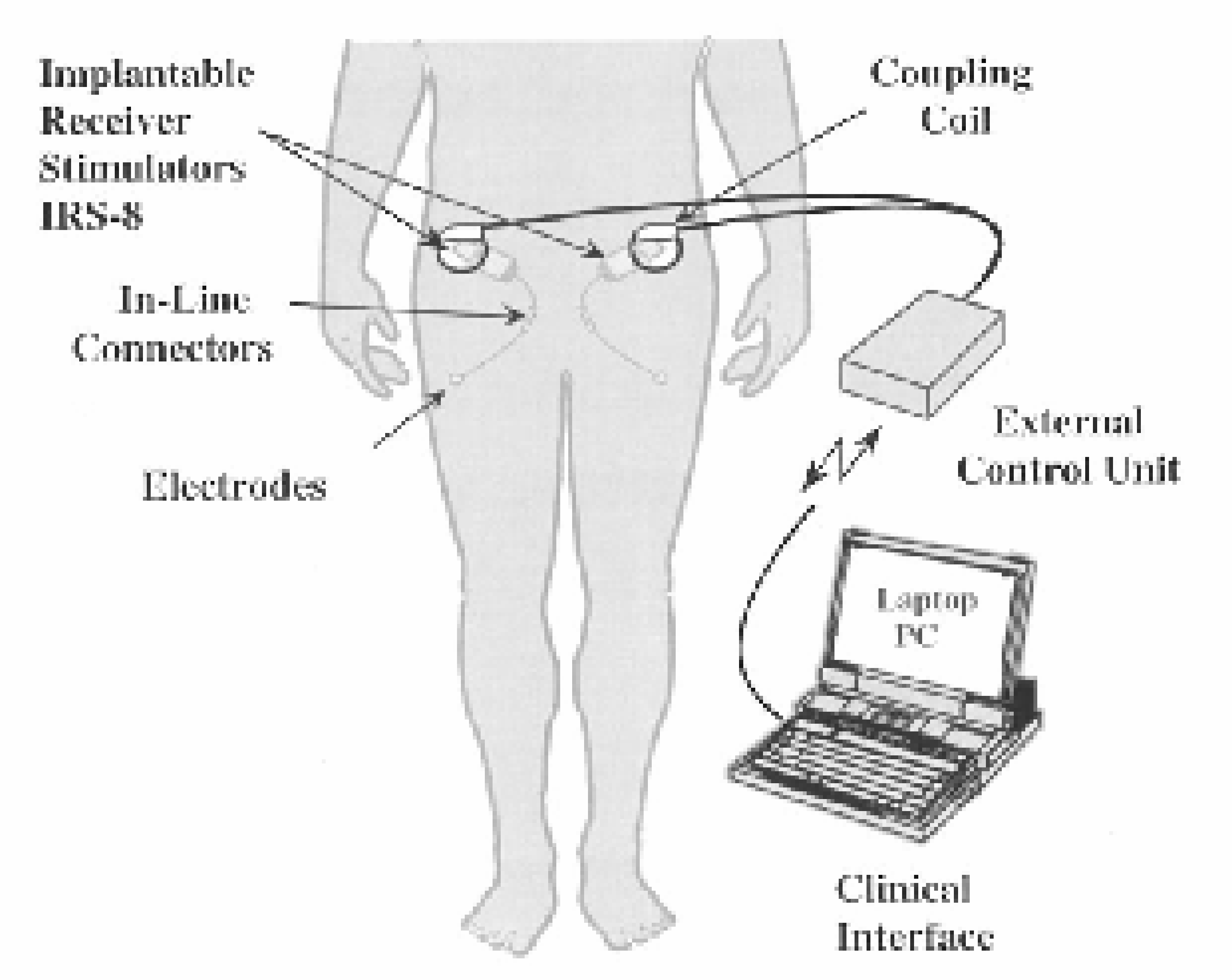
5. Subject S.O. performs a palmar grasp with the grasping neuroprosthesis.

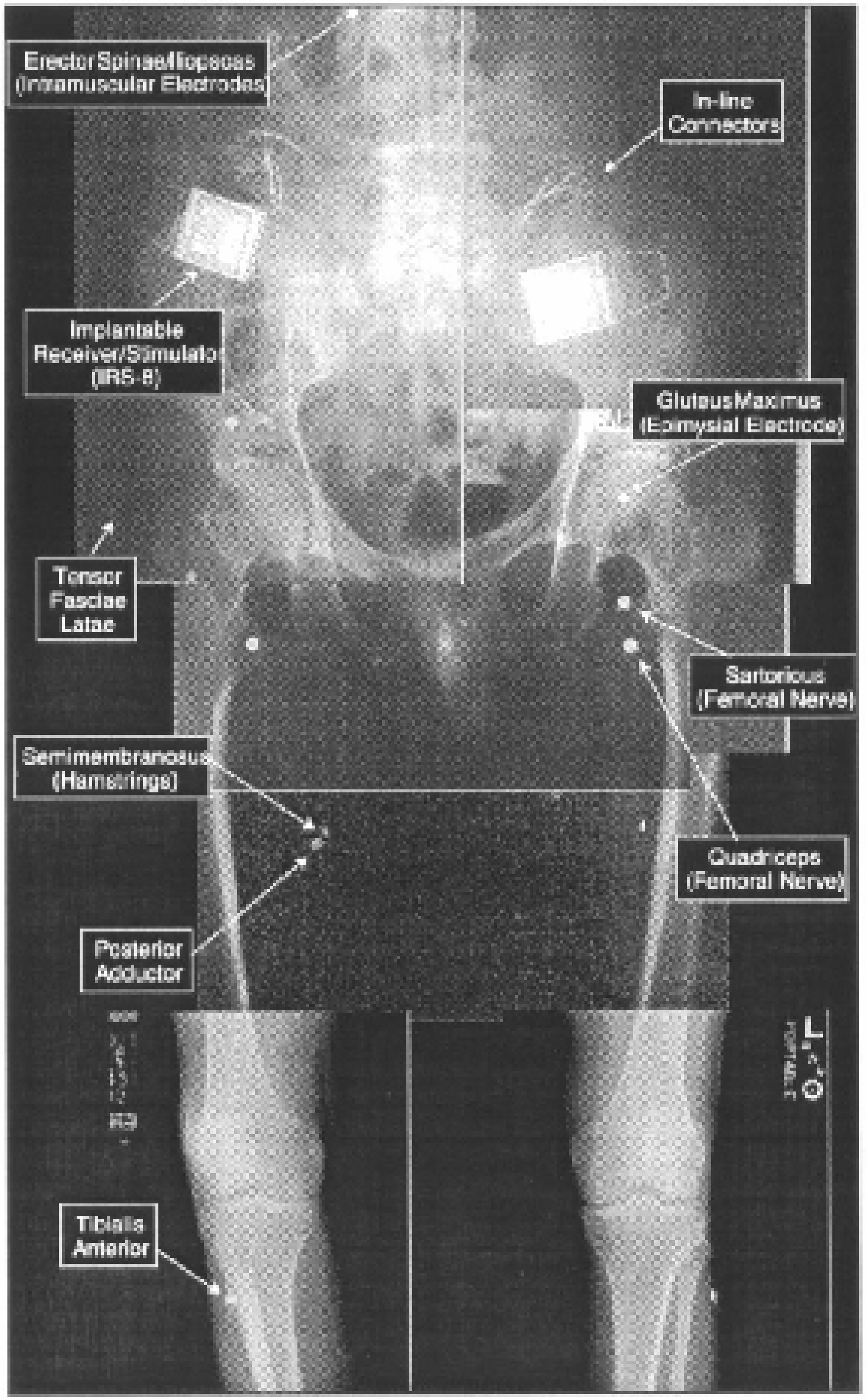


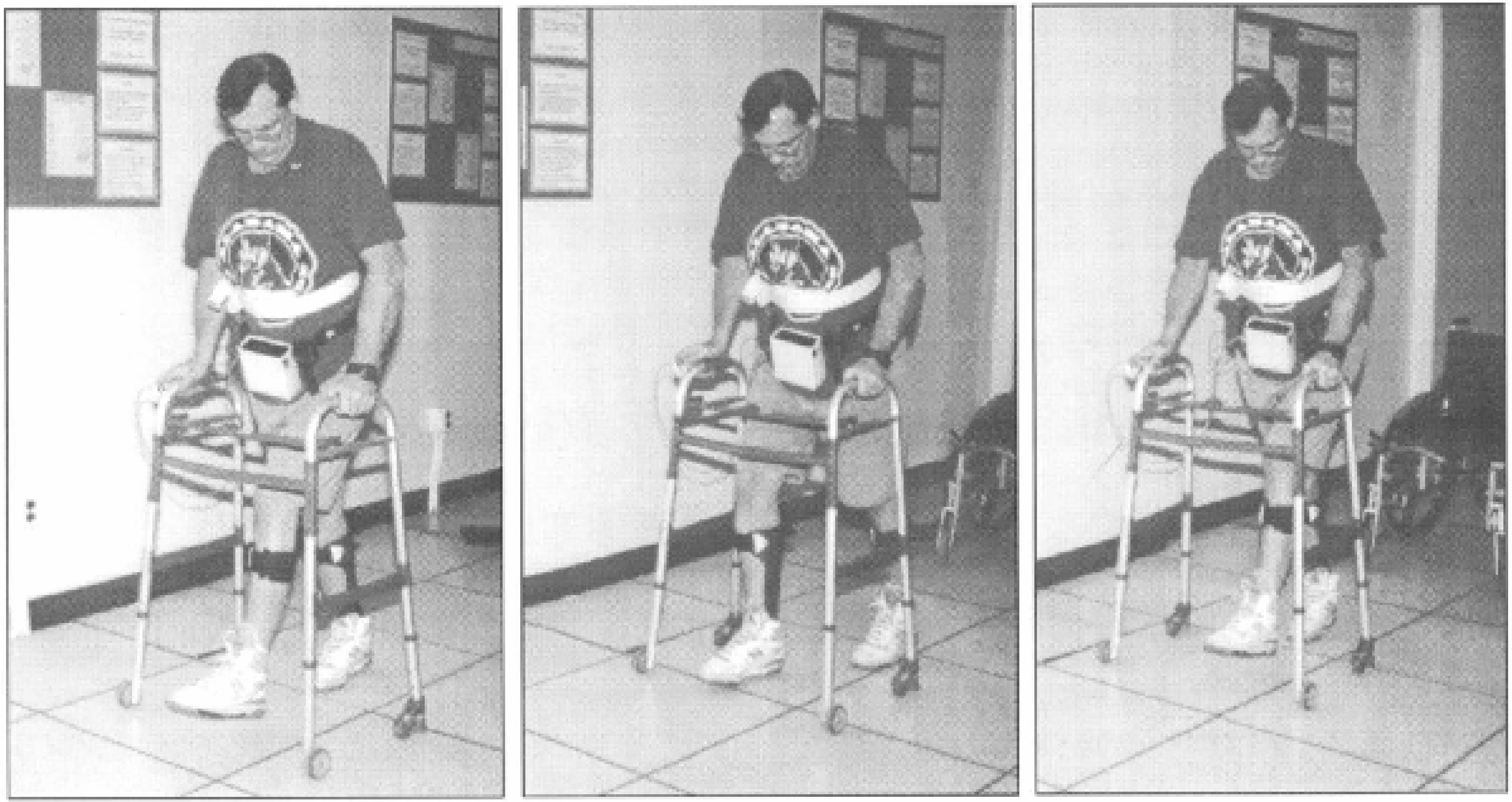
6. Subject D.K. performs a pinch grasp with the grasping neuroprosthesis.

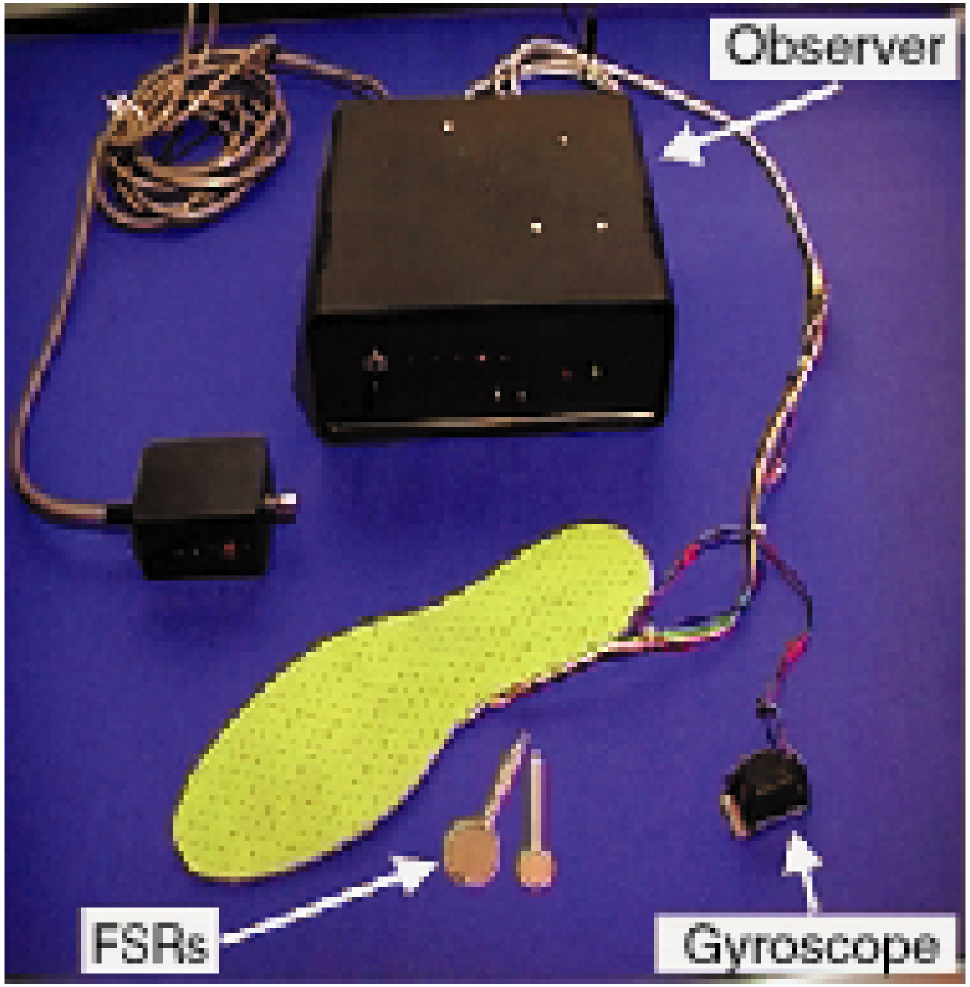
FES FOR LOWER EXTERIMITIES


29P
4/9


Implantable
Receiver
Stimulators
IRS-8
Coupling
Coil
In-Line
Connectors
Electrodes
External
Control Unit
Laptop
PC
Clinical
Interface


Erector Spinae/Iliopsoas (Intramuscular Electrodes)
In-line Connectors
Implantable Receiver/Stimulator (IRS-8)
Gluteus Maximus (Epimysial Electrode)
Tensor Fasciae Latae
Sartorious (Femoral Nerve)
Semimembranosus (Hamstrings)
Quadriceps (Femoral Nerve)
Posterior Adductor
Tibialis Anterior





8. Gait phase identification sensor.

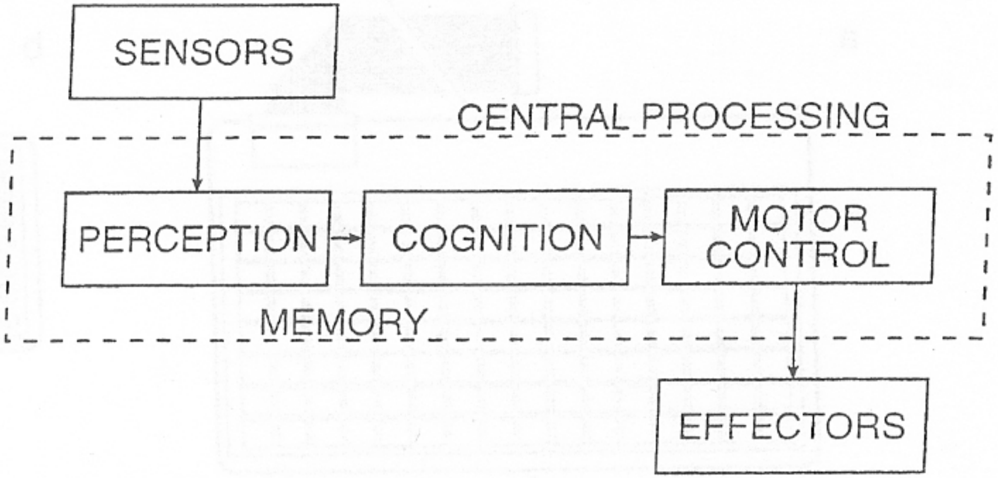
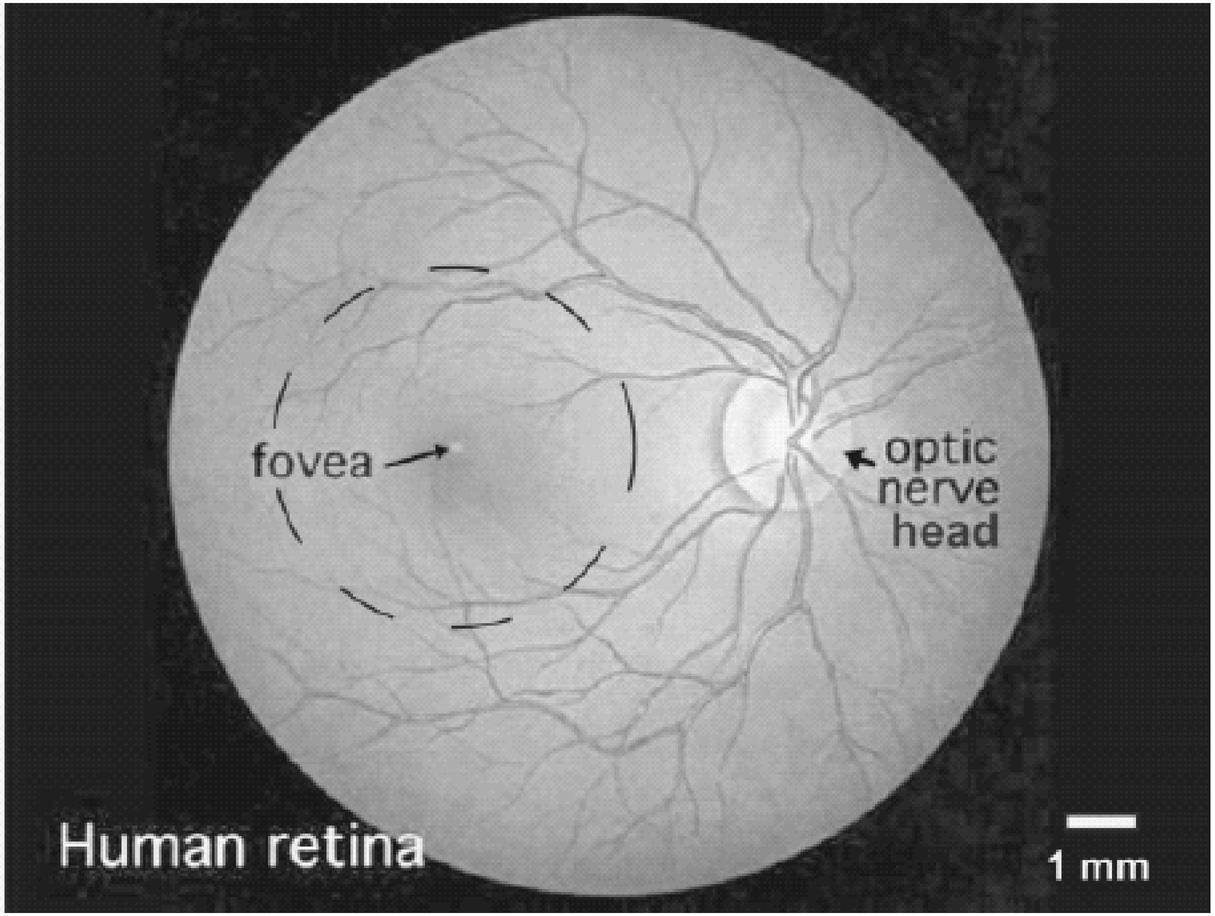


Figure 5.5 An information processing model of the human operator of assistive technologies. Each block represents a group of functions related to the use of technology.

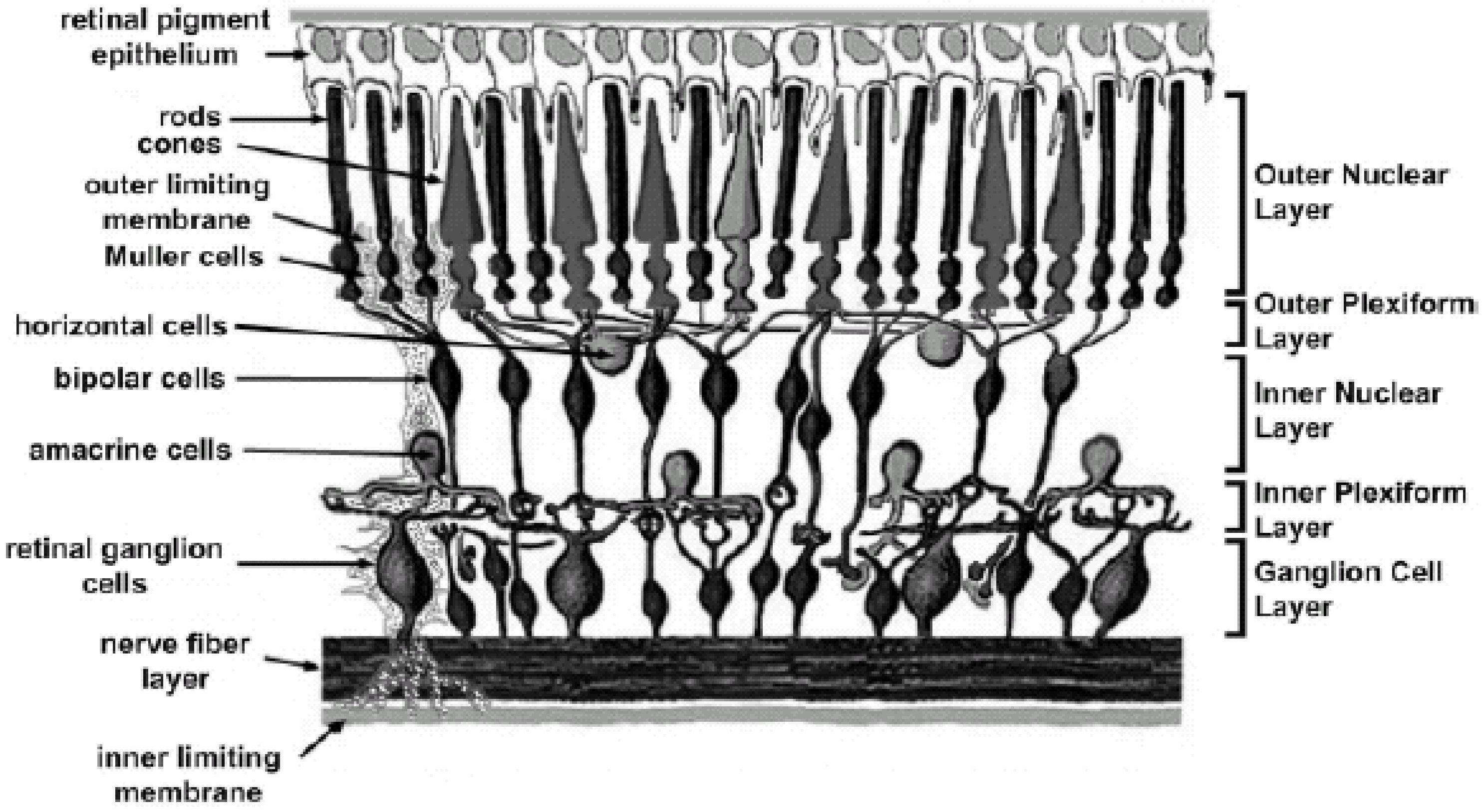
Assistive devices for Persons with Severe Visual Impairments

- Devices to aid reading and writing
- Devices to aid independent mobility

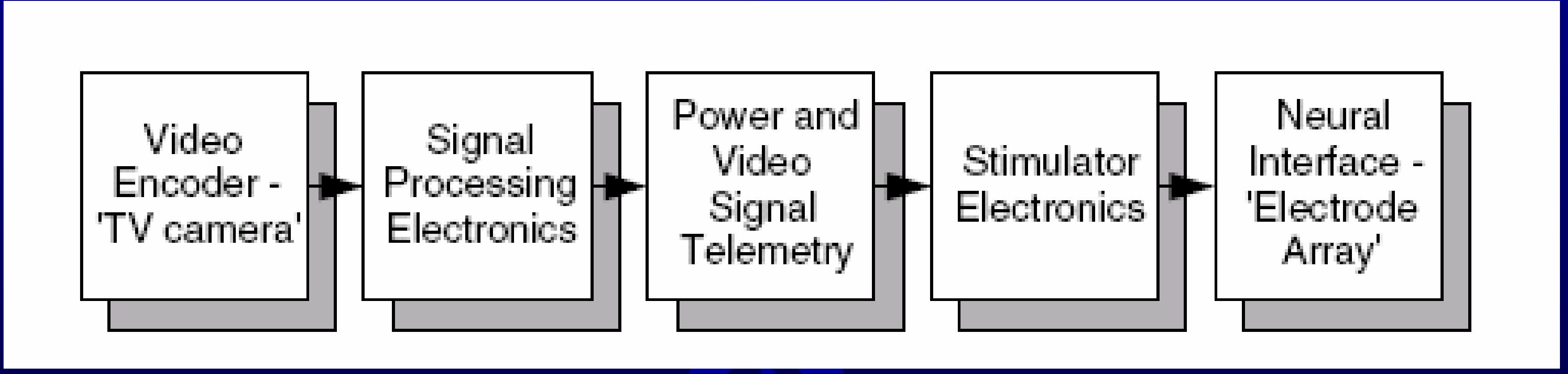
Retina

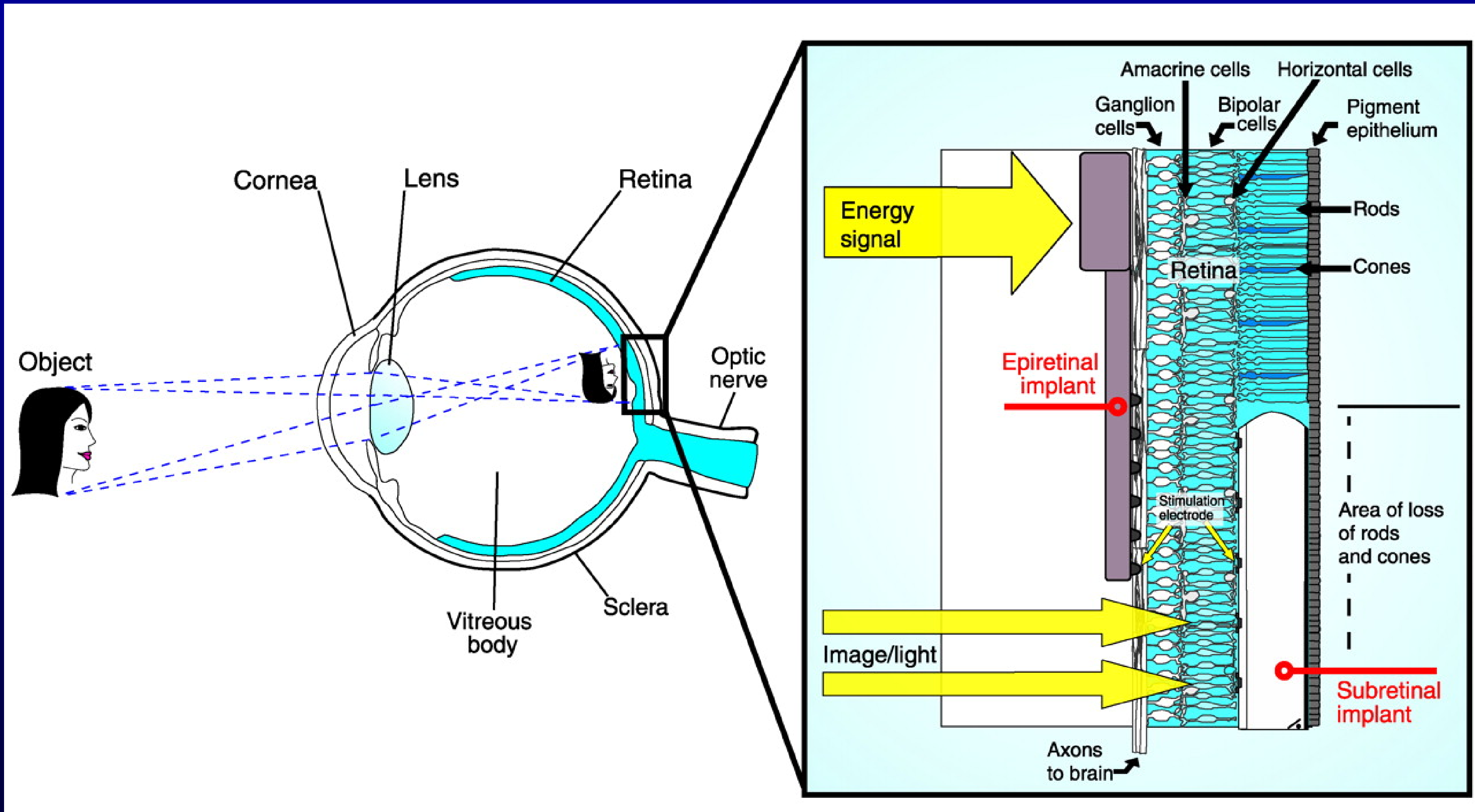


Retina

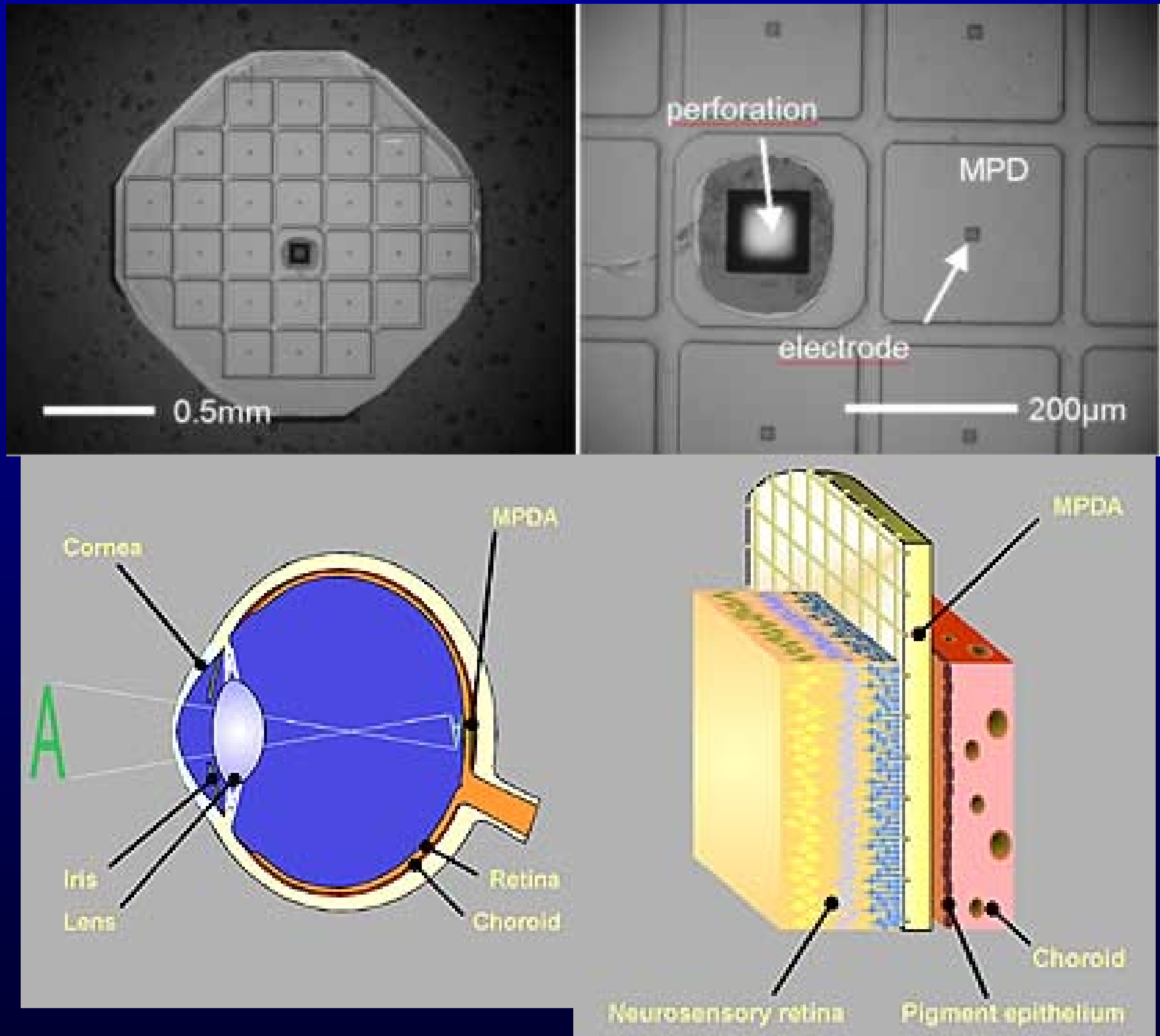

retinal pigment epithelium
rods
cones
outer limiting membrane
Muller cells
horizontal cells
bipolar cells
amacrine cells
retinal ganglion cells
nerve fiber layer
inner limiting membrane
Outer Nuclear Layer
Outer Plexiform Layer
Inner Nuclear Layer
Inner Plexiform Layer
Ganglion Cell Layer

Schematic representation of the elements of a visual neuroprosthesis



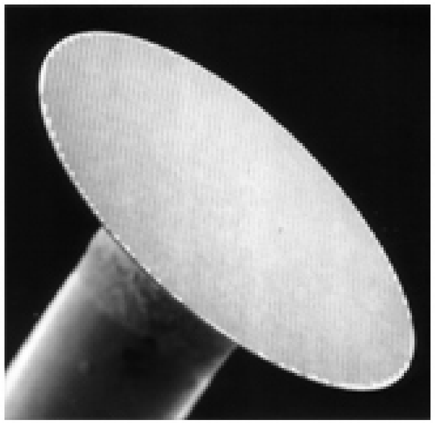

Object
Cornea
Lens
Retina
Optic nerve
Vitreous body
Sclera
Amacrine cells
Horizontal cells
Ganglion cells
Bipolar cells
Pigment epithelium
Energy signal
Rods
Retina
Cones
Epiretinal implant
Stimulation electrode
Area of loss of rods and cones
Image/light
Subretinal implant
Axons to brain

Subretinal neuroprosthetis

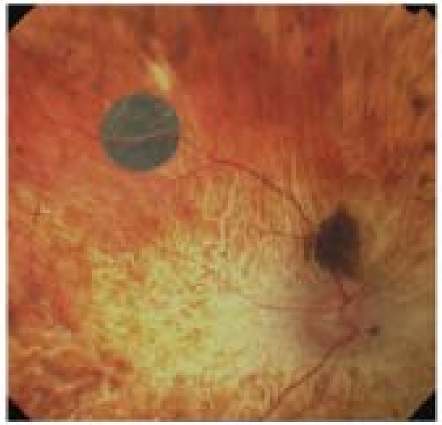


MPDA: Micro-Photodiode Array

2mm ASR® device lying on a penny



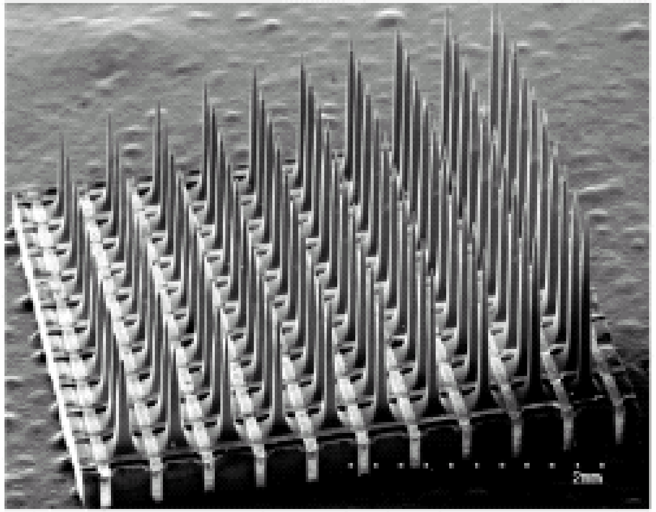
Magnified image of an ASR® device

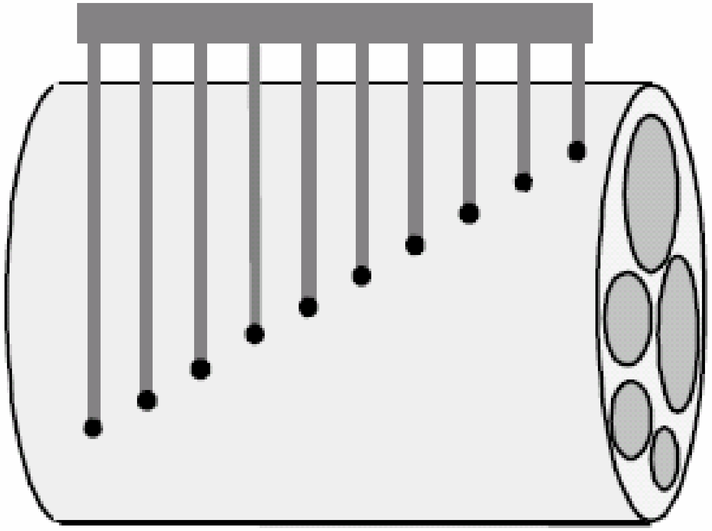


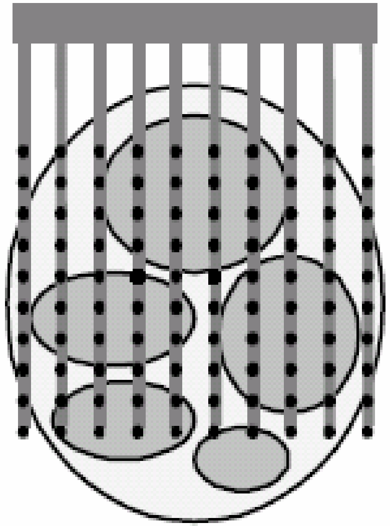
ASR® device implanted in the human eye

The **ASR (artificial silicon retina)** microchip is a silicon chip 2mm in diameter and 25 microns thick. It contains approximately 5,000 microscopic solar cells called "microphotodiodes," each with its own stimulating electrode. These microphotodiodes are designed to convert the light energy from images into electricalchemical impulses that stimulate the remaining functional cells of the retina.

Epiretinal implant







Epiretinal implant has no light-sensitive areas but receives electrical signals from a distant camera and processing unit outside of the body. Electrodes in the epiretinal implant (small black knobs) then directly stimulate the axons of the inner-layer ganglion cells that form the optic nerve

Cortical Stimulation

Assistive Devices for Persons with Severe Auditory Impairments

- Digital hearing aids
- Telephone aids (e.g., TDD and TTY)
- Lipreading aids
- Speech to text converters

Hearing Neuroprosthesis

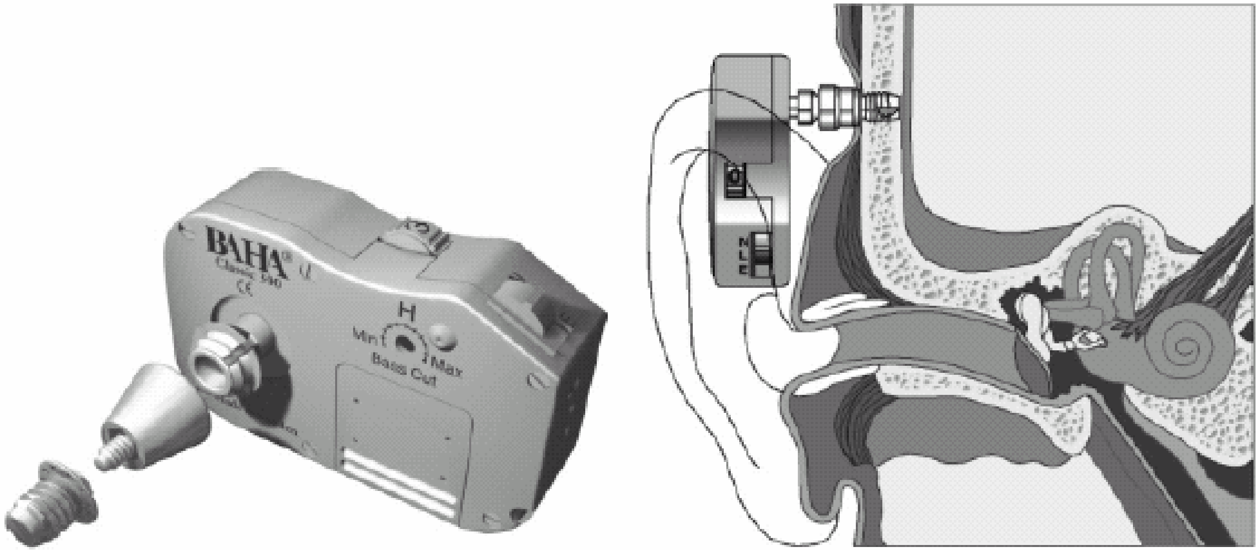


Figure 10.1 Bone-anchored hearing aid (Entific Medical Systems; Gothenberg, Sweden). The external sound processor and percutaneous abutment and titanium implant screw are shown on the left; the abutment screws into an osseointegrated fixture in the temporal bone behind the ear. The diagram on the right shows the sound transfer pathway to the inner ear through the temporal bone. Vibration of the cochlear capsule activates the hair cells.

Hearing Neuroprosthesis

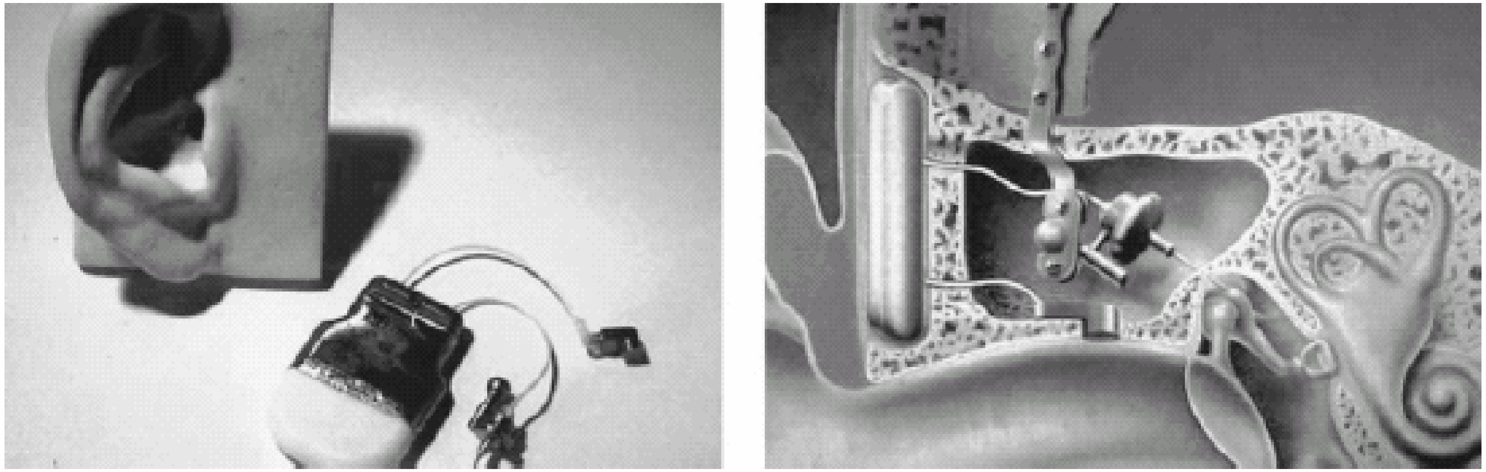
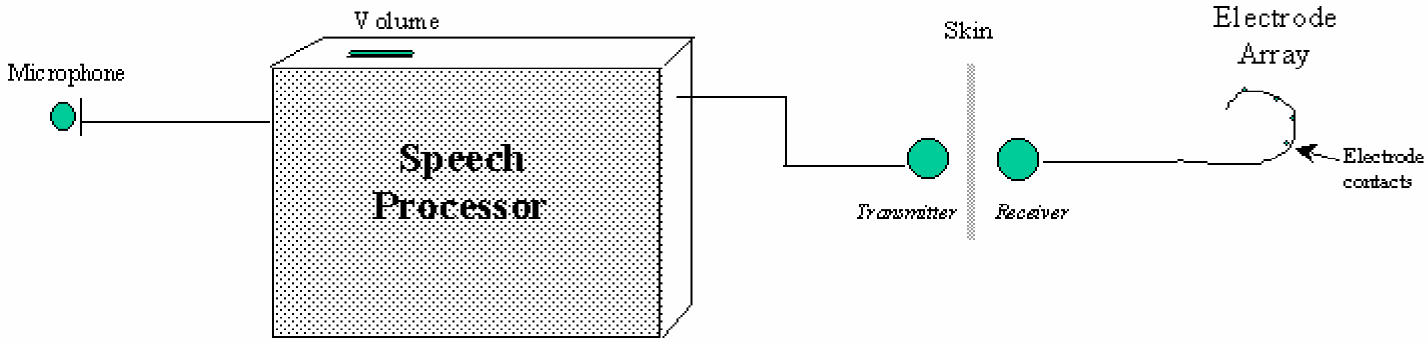
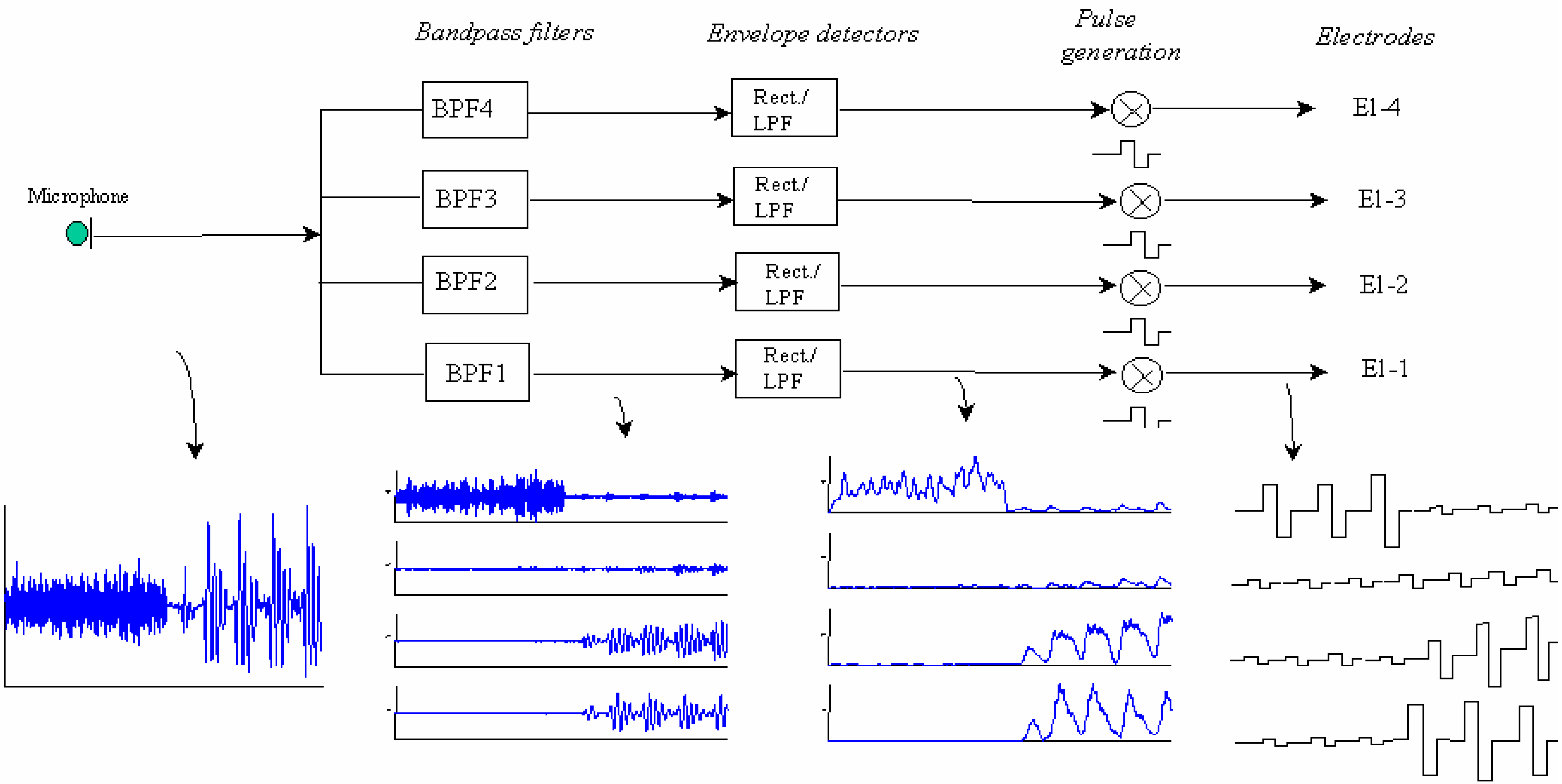


Figure 10.2 Totally integrated cochlear amplifier MEIHD (IMPLEX GmbH; Munich, Germany). On the left is shown the implant portion with implantable microphone and driver. Shown on the right is the implanted device with the microphone above the ear canal and piezoelectric driver on the incus.



V olume
Microphone
Speech
Processor
Skin
Electrode
Array
Electrode
contacts
Transmitter
Receiver



Bandpass filters
Envelope detectors
Pulse
generation
Electrodes
Microphone
BPF4
BPF3
BPF2
BPF1
Rect./
LPF
Rect./
LPF
Rect./
LPF
Rect./
LPF
El-4
El-3
El-2
El-1

How does it work?

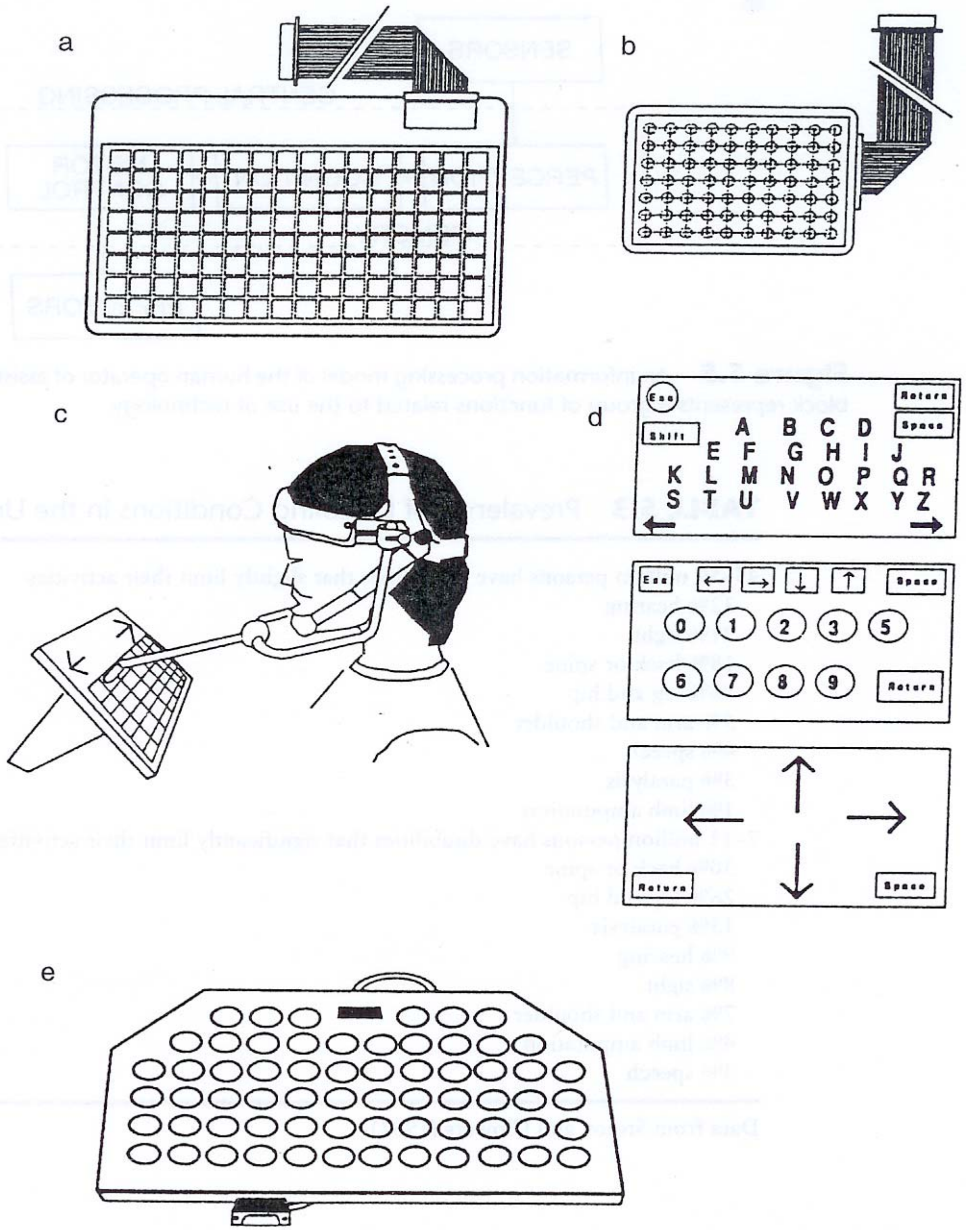
Assistive Devices for Tactile Impairments

- Cushions
- Customized seating
- Sensory substitution
- Pressure relief pumps and alarms


the ROHO group
shape fitting technology®

Alternative and Augmentative Communication Devices

- Interface and keyboard emulation
- Specialized switches, sensors, and transducers
- Computer-based communication devices
- Linguistic tools and software



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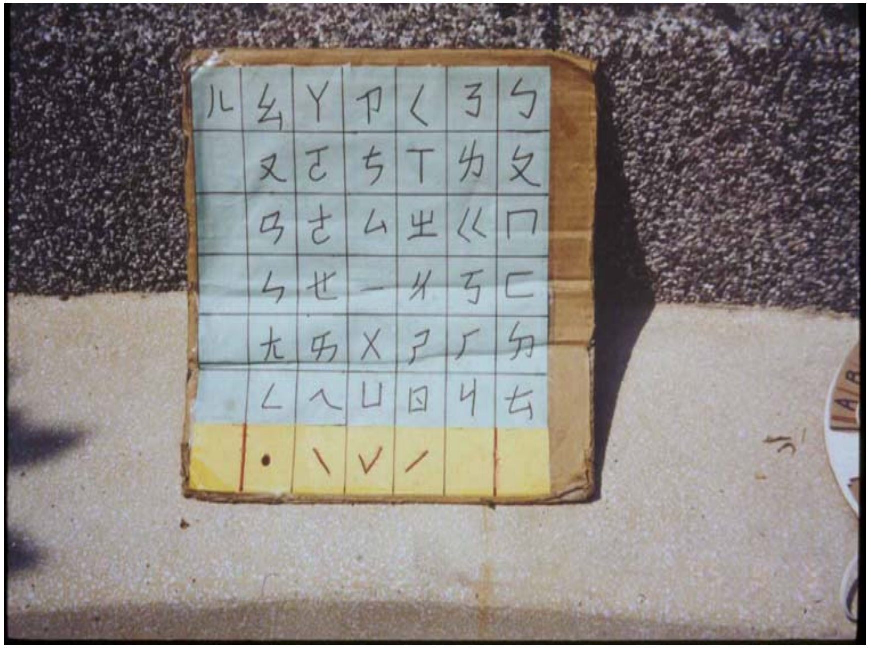
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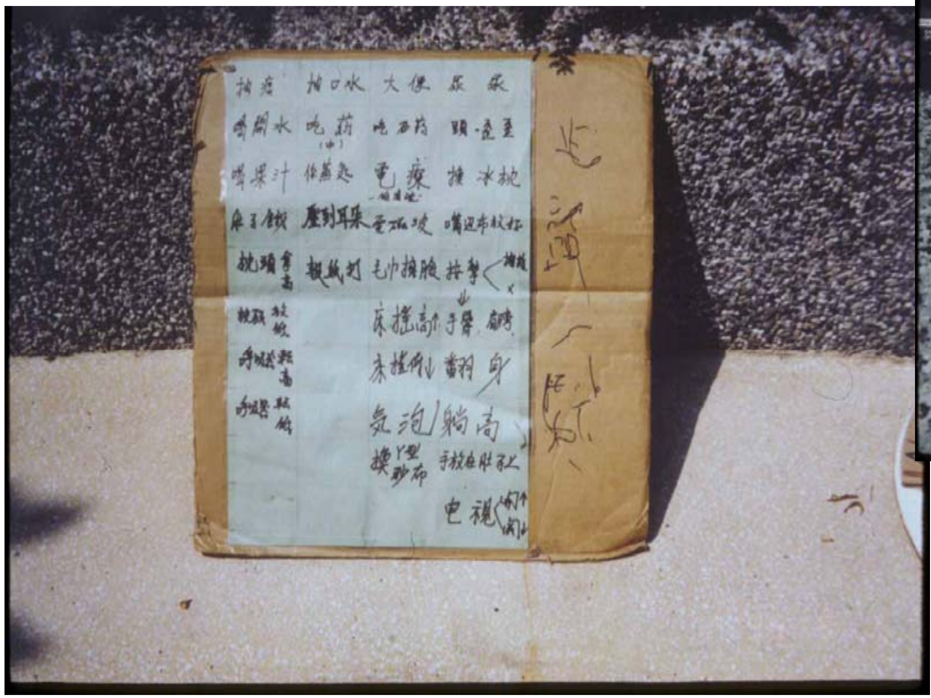

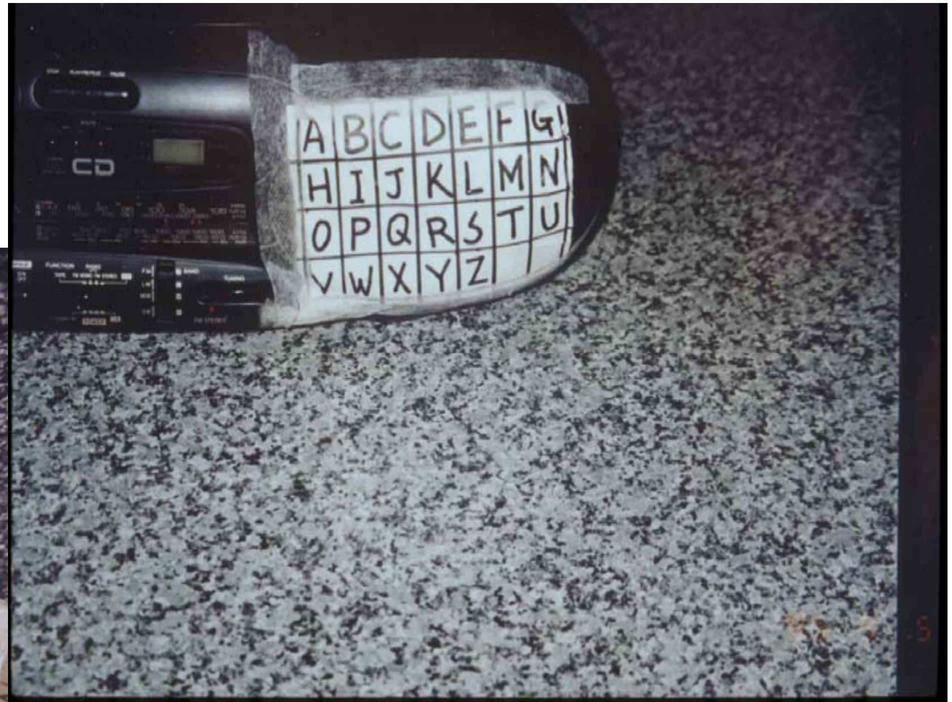
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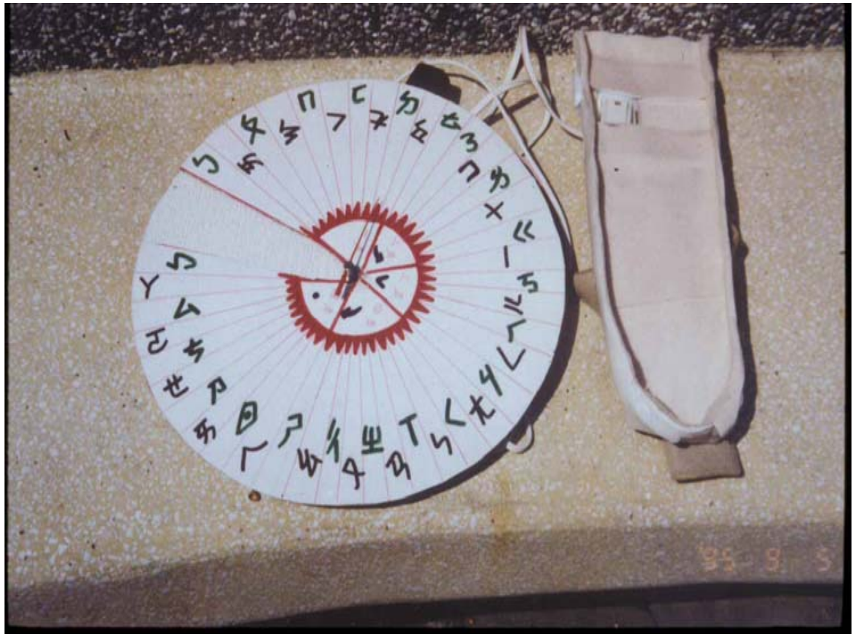
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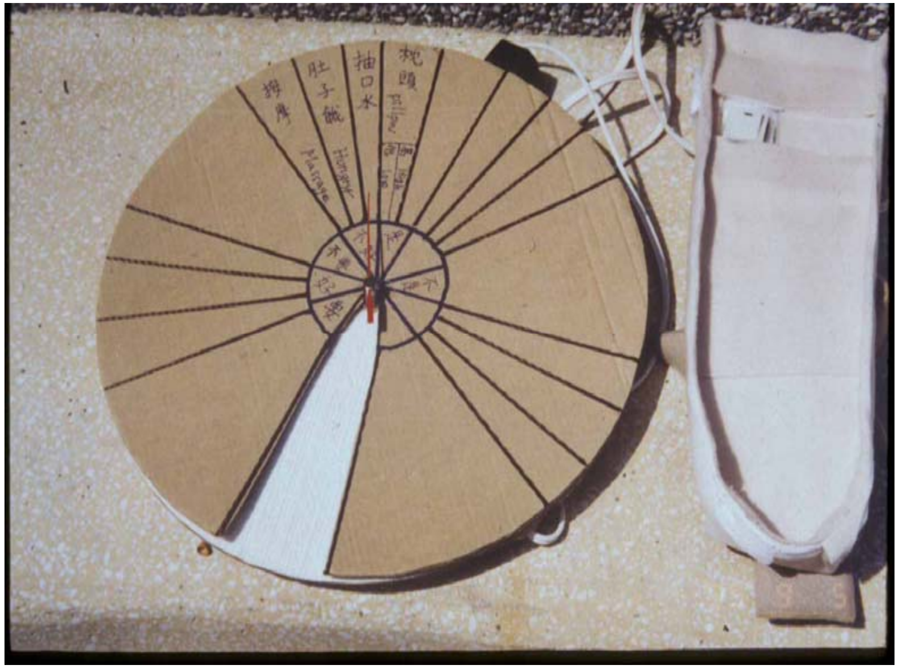

枕頭
抽口水
肚子餓
Hungry


'95 9 2


'95 9 6

Manipulation and Mobility Aids

- Grabbers, feeders, mounting systems, and page turners
- Environmental controllers
- Robotic aids
- Manual and special-purpose wheelchairs
- Powered wheelchairs, scooters, and recliners
- Adaptive driving aids
- Modified personal licensed vehicles

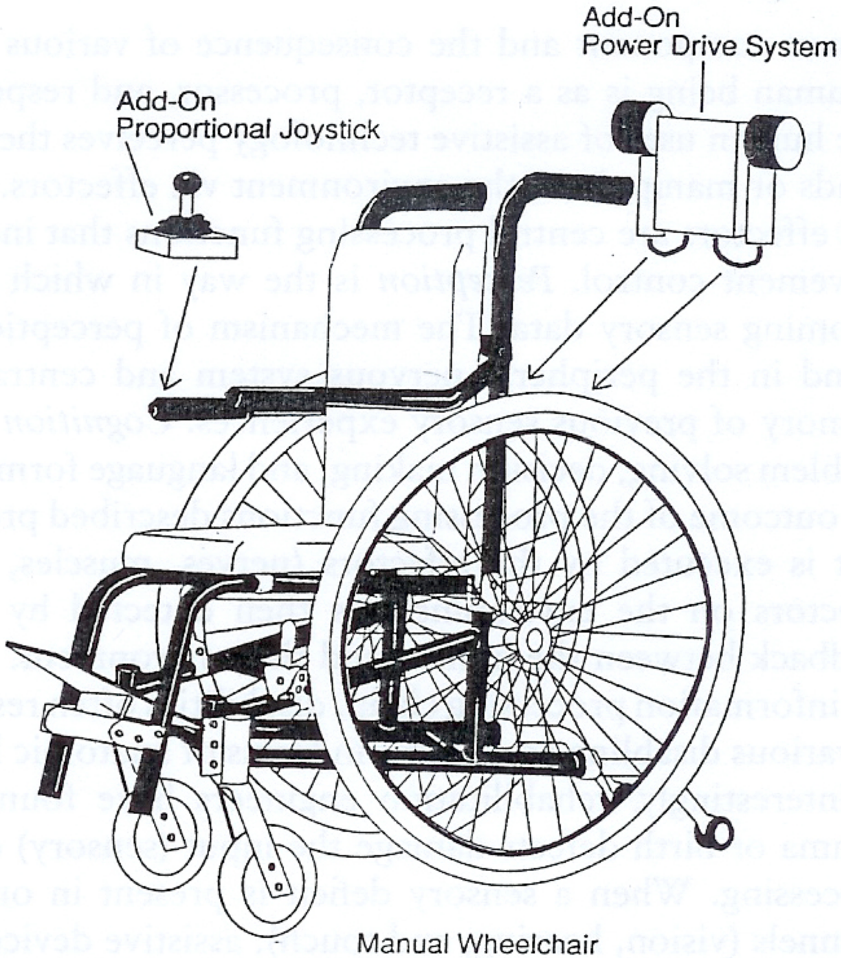
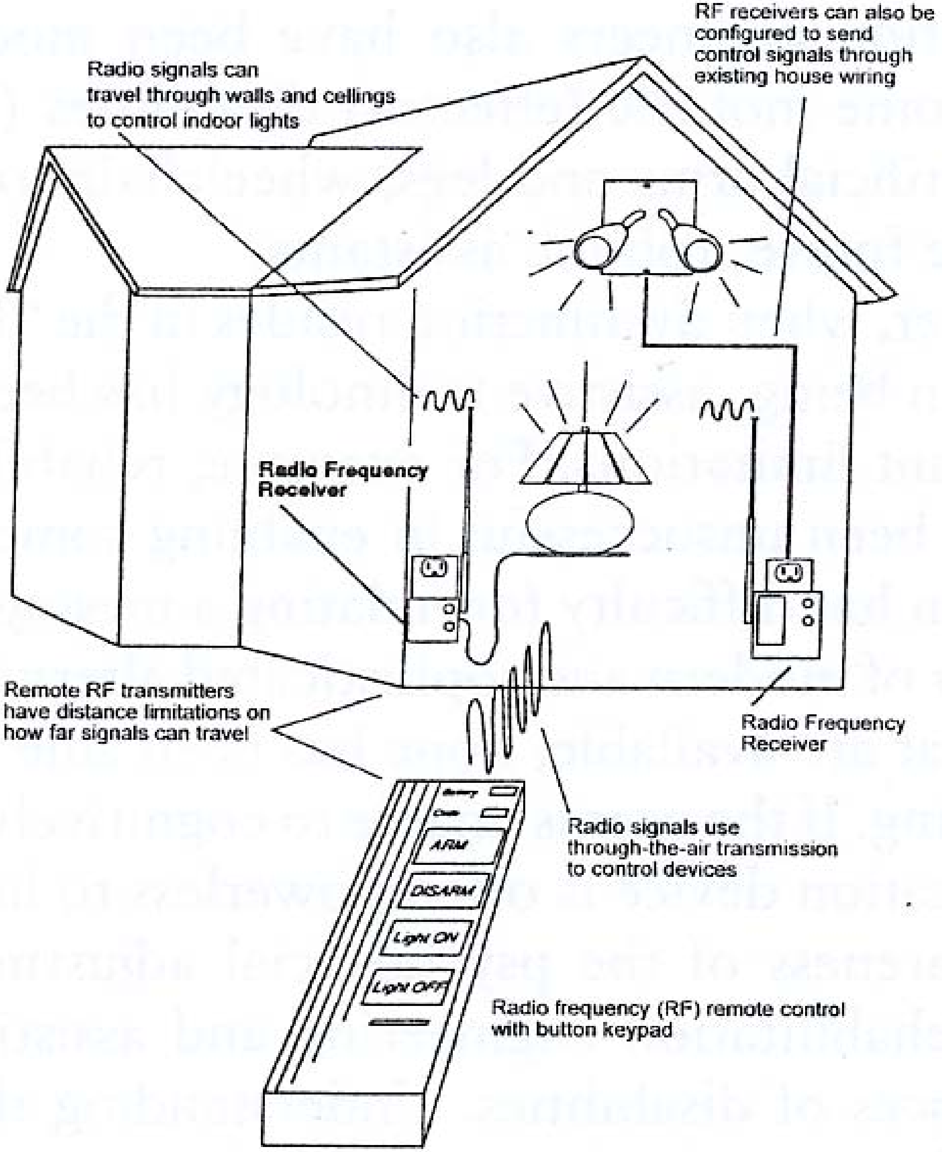


Figure 5.2 Add-on wheelchair system (from Church and Glennen, 1992).


RF receivers can also be configured to send control signals through existing house wiring
Radio signals can travel through walls and ceilings to control indoor lights
Radio Frequency Receiver
Radio Frequency Receiver
Remote RF transmitters have distance limitations on how far signals can travel
Radio signals use through-the-air transmission to control devices
ARM
DISARM
Light ON
Light OFF
Radio frequency (RF) remote control with button keypad

Recreational Assistive Devices

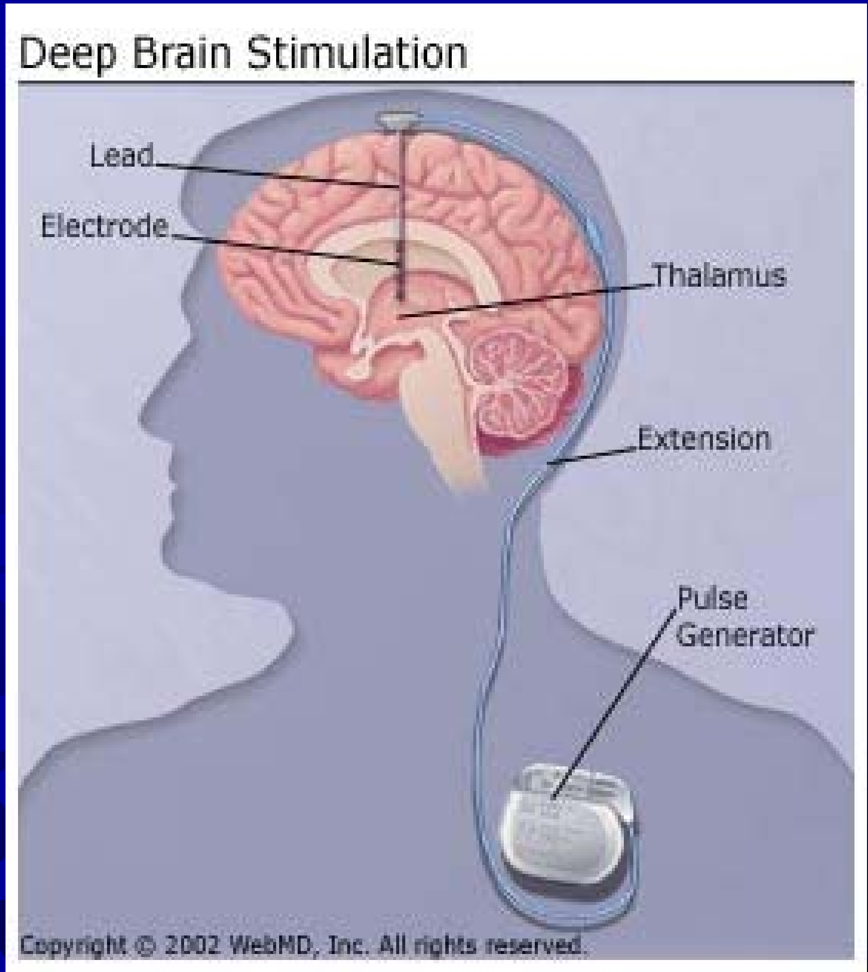
- Arm-powered cycles
- Sports and racing wheelchairs
- Modified sit-down mono-ski

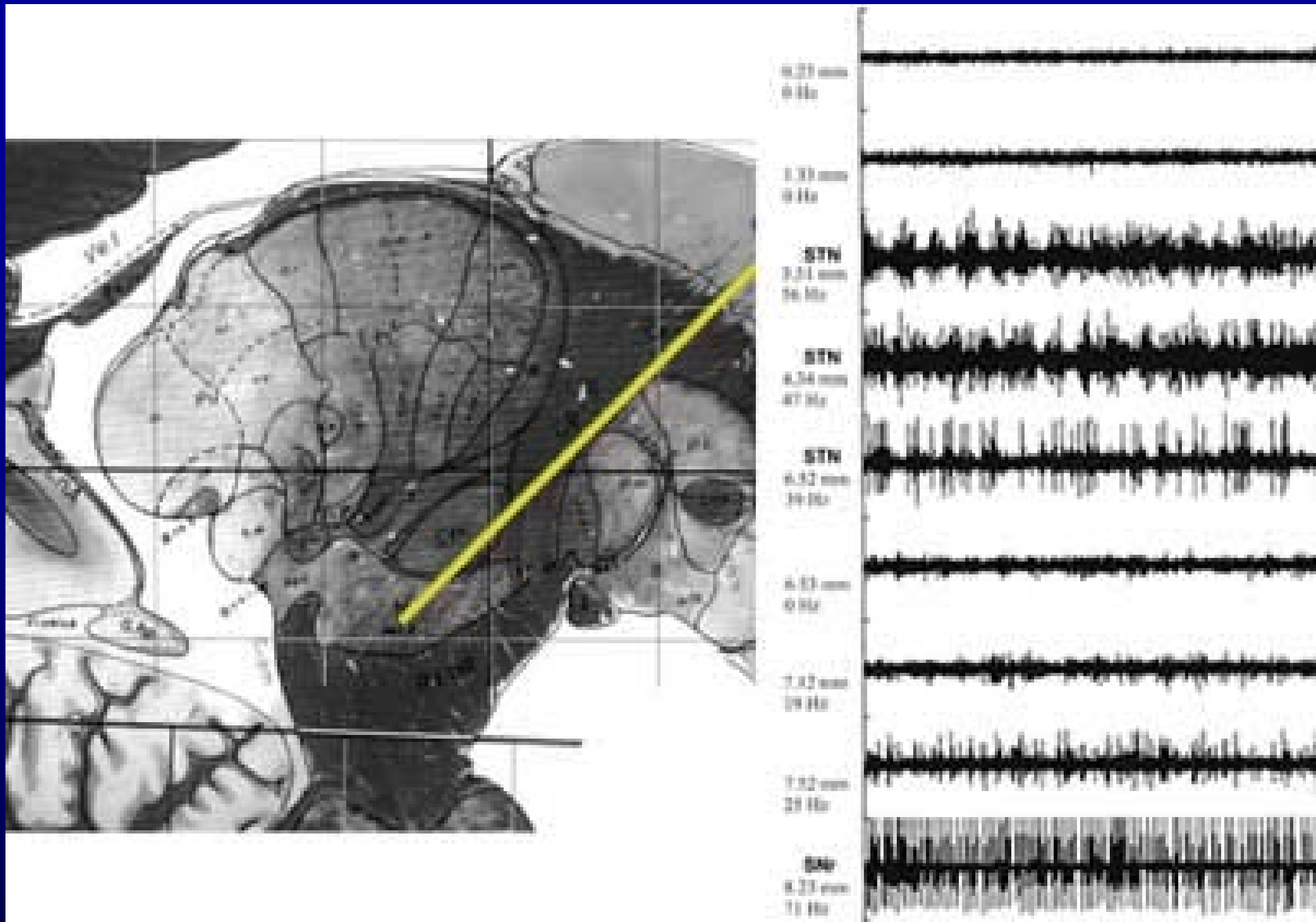
Deep Brain Stimulation

Deep Brain Stimulation for Parknisonism

- Deep brain stimulation (DBS) is a surgical procedure used to treat a variety of disabling neurological symptoms—most commonly the debilitating symptoms of Parkinson's disease, such as tremor, rigidity, stiffness, slowed movement, and walking problems.

- a multi-electrode lead implanted into the ventrointermediate nucleus of the thalamus for tremor, globus pallidus interna (GPi) and subthalamic nucleus for dyskinesias



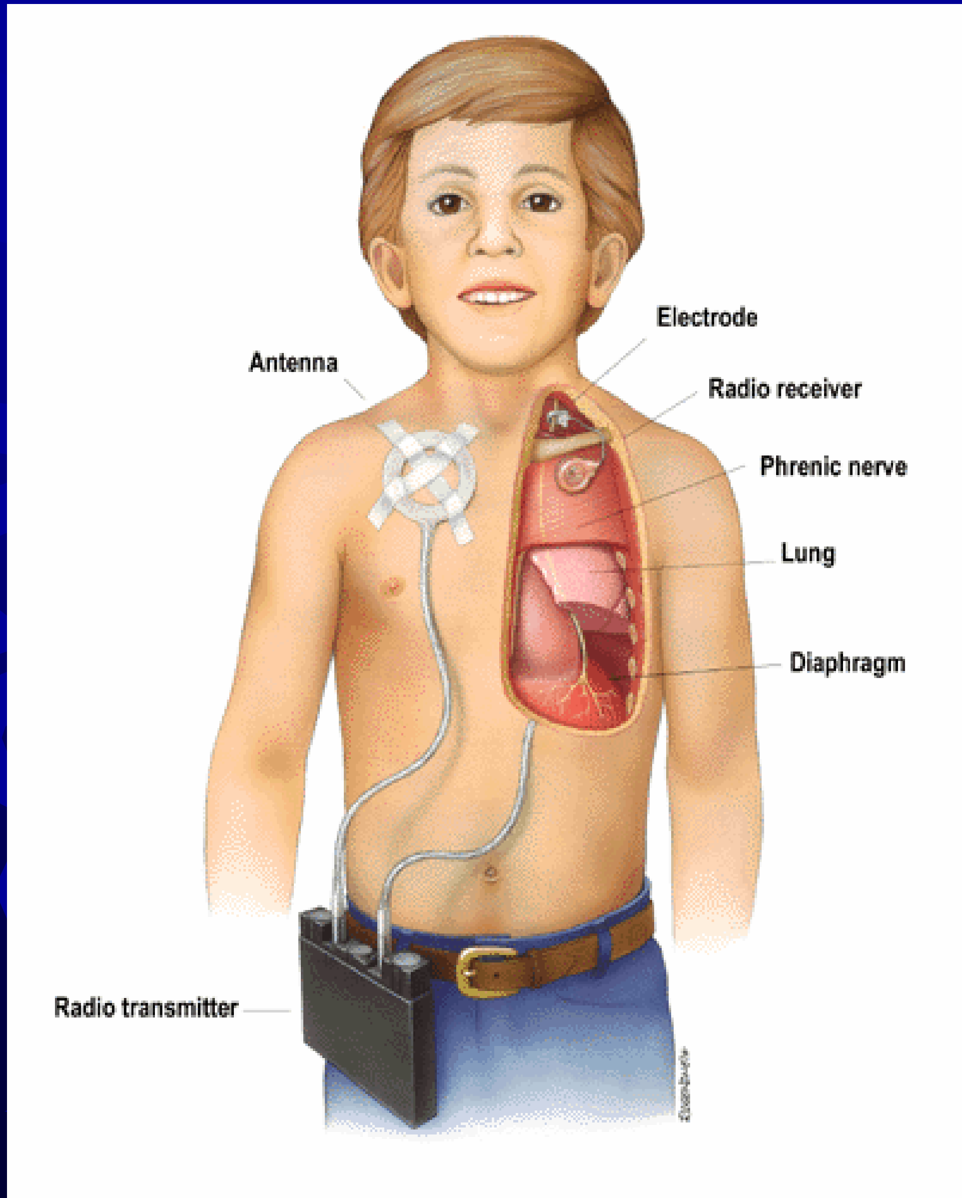


The subthalamus nuclei on both side is stimulated with varying combination of pulse width, frequency and voltage to get the desired effects.

Phrenic Nerve Stimulation

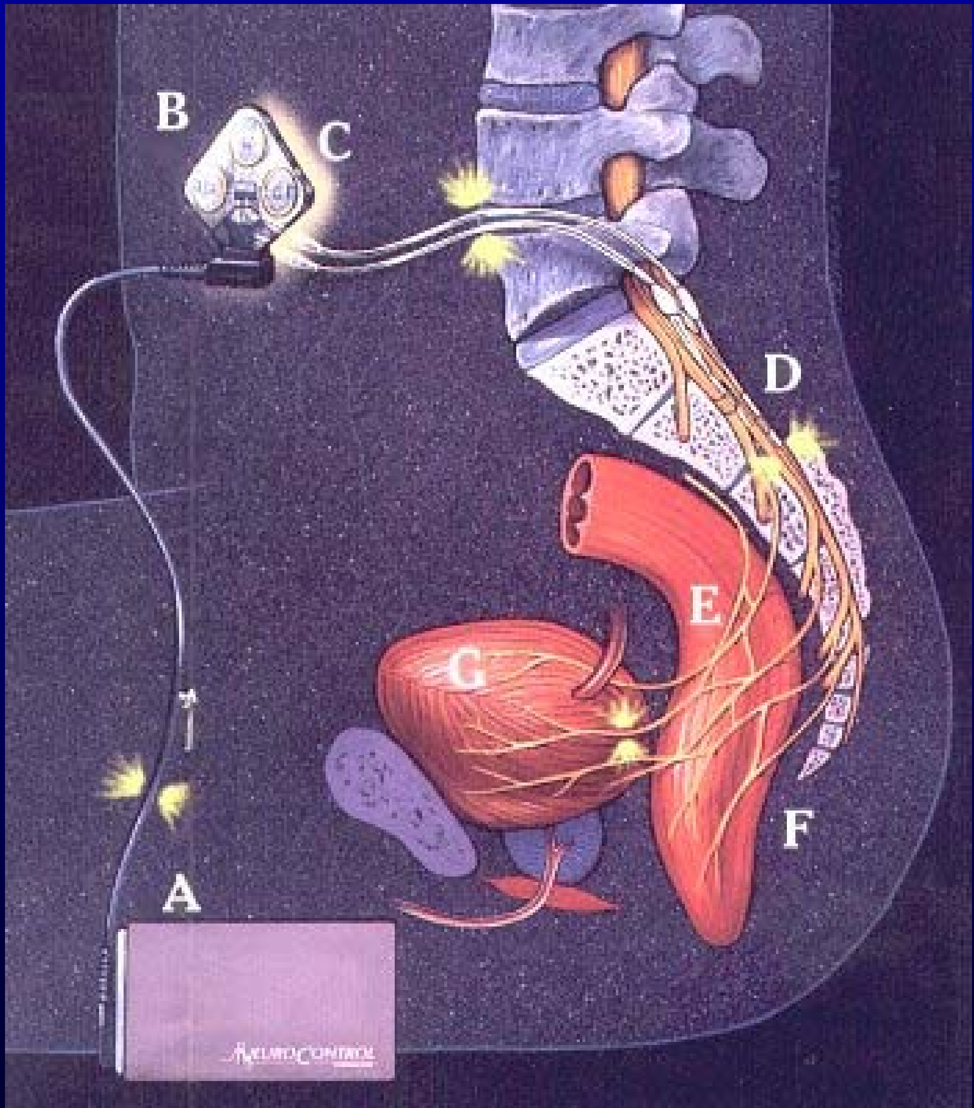
For respiratory failure due to cervical spinal cord injury and damage to the brainstem respiratory center

Mark IV Breathing Pacemaker System – Avery Lab Inc. – FDA approved



VOCARE Bladder System

NeuroControl Vocare Bladder System



- allow the user to empty the bladder when appropriate and, after voiding the bladder, to have a low residual volume of urine
- secondary benefits of bowel function and penile erection in men

FDA APPROVED

Limits of Current Neural Prosthetic Technology

- Current neural prostheses are mostly limited by the small number of recording/stimulating elements, and by the typically large size of these elements preventing a fine scale nervous system interface.
- Some recent efforts to develop high-density neural prostheses using VLSI integrated circuit technology have still been of limited value because the materials that can be used in VLSI are not optimal for neural interfacing or tissue compatibility.

From Engineers's prospect

Limits of Current Neural Prosthetic Technology

- Spasticity in stroke and SCI victims
- No adequate sensation
- Cosmetics / robot?
- Cost and effective

From patients /physicians/therapeutists' prospect

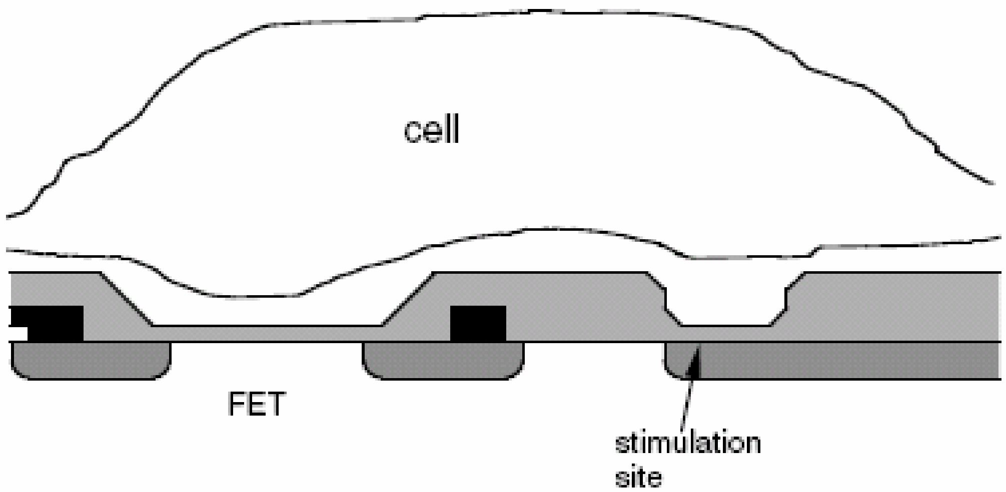


Figure 13.4 Neuron–transistor junction and capacitive stimulation electrode.[44–48] Not to scale.

Requirements of a Practical FES System

- Should be Simple to Don and Doff
- Function must be Relevant to the User
- System must Consistently Provide the Desired Function
- The System must include the User
- User must be Aware of the Limitations of the System
- User must understand the requirement to maximize the benefits
- System should Ideally be Fail Safe

Principles of Assistive Technology Assessment

- 5 misconceptions:
  - Assistive technology can solve all the problems
  - Persons with the same disability need the same assistive devices
  - Assistive technology is necessarily complicated and expensive
  - Assistive technology prescriptions are always accurate and optimal
  - Assistive technology will always be used

Eight Principles

1. The user's goals, needs, and tasks must be clearly defined, listed, and incorporated as early as possible in the intervention process
2. Involvement of rehabilitation professionals with differing skills and know-how will maximize the probability for a successful outcome.

3. The user’s preferences, cognitive and physical abilities and limitations, living situation, tolerance for technology, and probable changes in the future must be thoroughly assessed, analyzed, and quantified.
4. Careful and thorough consideration of available technology for meeting the user’s needs must be carried out to avoid overlooking potentially useful solutions.
5. The user’s preferences and choice must be considered in the selection of the assistive technology device.

6. The assistive technology device must be customized and installed in the location and setting where it primarily will be used.
7. Not only must the user be trained to use the assistive device, but also the attendants or family members must be made aware of the device's intended purpose, benefits, and limitations
8. Follow-up, readjustment, and reassessment of the user's usage patterns and needs are necessary at periodic intervals

TABLE 5.5 Conditions That Require Consideration of Seating and Positioning

Condition	**Description and Characteristics**	**Seating Considerations**
Cerebral palsy	Nonprogressive neuromuscular	
Increased tone (high tone)	Fixed deformity, decreased movements, abnormal patterns	Correct deformities, improve alignment, decrease tone
Decreased tone (low tone)	Subluxations, decreased active movement, hypermobility	Provide support for upright positioning, promote development of muscular control
Athetoid (mixed tone)	Excessive active movement, decreased stability	Provide stability, but allow controlled mobility for function
Muscular dystrophies	Degenerative neuromuscular	
Duchenne	Loss of muscular control proximal to distal	Provide stable seating base, allow person to find balance point
Multiple sclerosis	Series of exacerbations and remissions	Prepare for flexibility of system to follow needs
Spina bifida	Congenital anomaly consisting of a deficit in one or more of the vertebral arches, decreased or absent sensation	Reduce high risk for pressure concerns, allow for typically good upper extremity and head control
Spinal cord injury	Insult to spinal cord, partial or complete loss of function below level of injury, nonprogressive once stabilized, decreased or absent sensation, possible scoliosis/kyphosis	Reduce high risk for pressure concerns, allow for trunk movements used for function
Osteogenesis imperfecta	Connective tissue disorder, brittle bone disease, limited functional range, multiple fractures	Provide protection
Orthopedic impairments	Fixed or flexible	If fixed, support, if flexible, correct

(continued)

TABLE 5.5 Conditions That Require Consideration of Seating and Positioning (Continued)

Condition	Description and Characteristics	Seating Considerations
Traumatic brain injury	Severity dependent on extent of central nervous system damage, may have cognitive component, nonprogressive once stabilized	Allow for functional improvement as rehabilitation progresses, establish a system that is flexible to changing needs
Elderly		
Typical aged	Often, fixed kyphosis, decreased bone mass, and decreased strength, incontinence	Provide comfort and visual orientation, moisture-proof, accommodate kyphosis
Aged secondary to primary disability	Example—older patients with cerebral palsy may have fixed deformities	Provide comfort, support deformities

Condition	Description and Characteristics	Seating Considerations
Cerebral palsy	Nonprogressive neuromuscular	
Increased tone (high tone)	Fixed deformity, decreased movements, abnormal patterns	Correct deformities, improve alignment, decrease tone
Decreased tone (low tone)	Subluxations, decreased active movement, hypermobility	Provide support for upright positioning, promote development of muscular control
Athetoid (mixed tone)	Excessive active movement, decreased stability	Provide stability, but allow controlled mobility for function

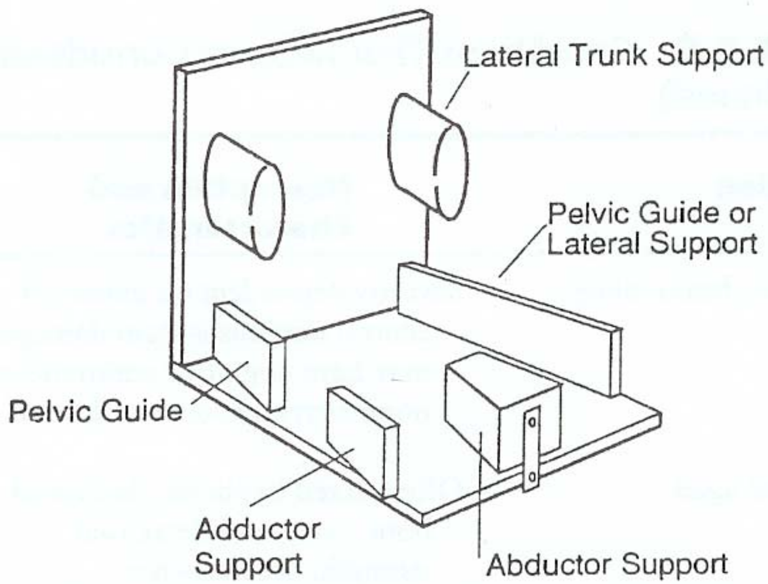
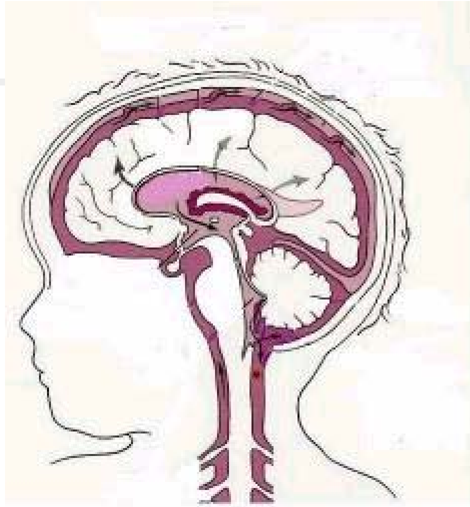


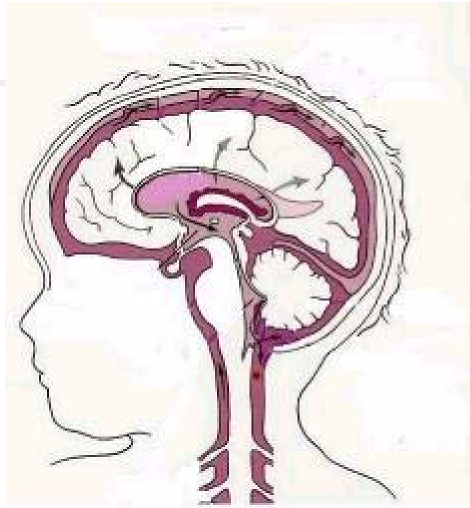
Figure 5.9 Chair adaptations for proper positioning (from Church and Glennen, 1992).

腦性麻痺Cerebral Palsy



- 腦性麻痺是一種
  動作發展障礙。
- 造成腦性麻痺的原因是發展中的腦受到傷害，造成張力、動作及姿態表現異常。

腦性麻痺Cerebral Palsy



- 腦的傷害可以發生在產前、產中或產後。
- 腦性麻痺可以伴隨其他的發展障礙。

腦性麻痺的分類

- Spastic type (痙攣型)
- Dyskinetic type(運動困難型)

  athetoid (徐動型)

  dystonic (肌張力不全型)
- Atonic type (低張型)
- Mixed type (混合型)

Cerebral palsy, spastic type
痙攣型腦性麻痺

- Monoplegia
- Hemiplegia
  半身麻痺
- Diplegia
  雙重麻痺
- Triplegia
- Quadriplegia
  四肢麻痺



Rehabilitation 復健

(1)預防併發症
Preventing complication

(2) 殘存功能的發揮
Maintaining residual function

(3) 促進恢復
Facilitating recovery

(4) 降低功能障礙
Decreasing disability

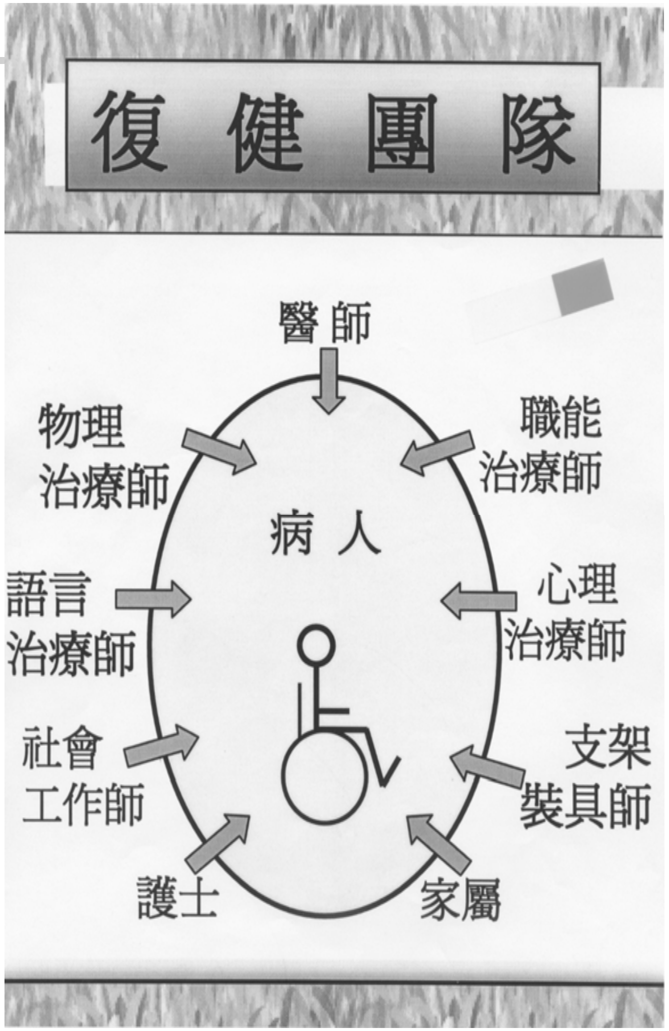
(5) 提高生活品質
Improving quality of life

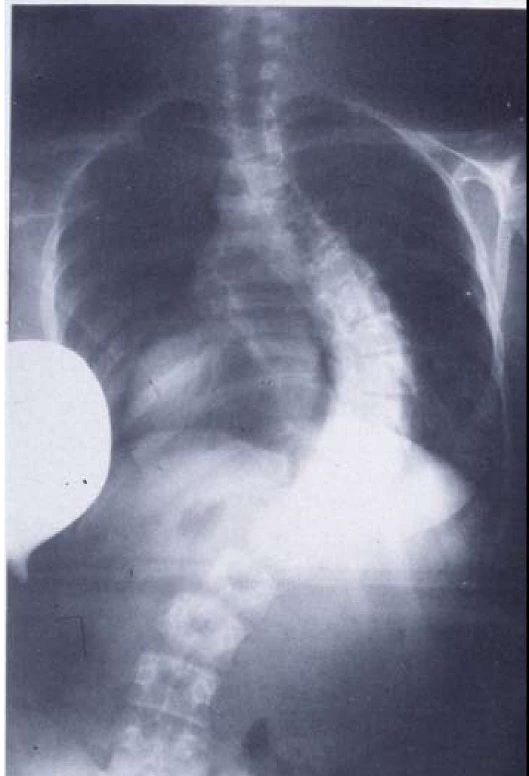
腦性麻痺的復健

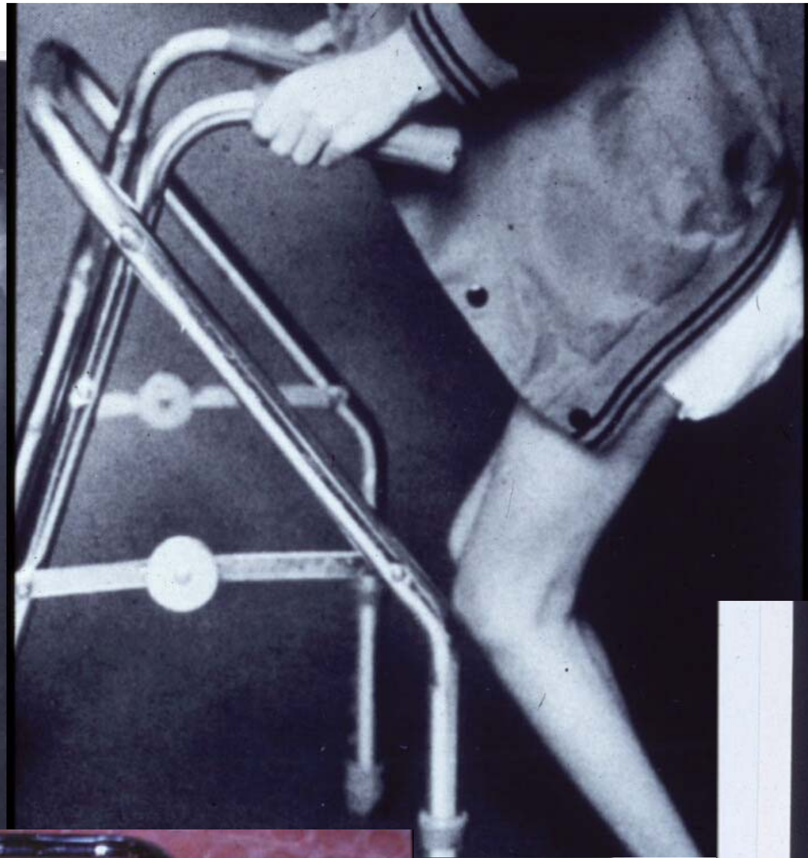
- 增進父母對疾病的認識及了解
- 與其他專業人員共同參與病患之評估及治療
  - 運動治療 **Therapeutic exercise**
  - 藥物治療 **Medication,** 如 Botox
  - 手術治療 **Surgery**
  - 支架 **Orthotics** 與 輔具 **Assistive devices**
- 預防可能發生的併發症
- 依照發展的順序給予復健治療以促進發展或增加功能
- 提供社會與教育資源的諮詢

復健團隊成員

- 醫師
- 治療師
- 裝具師
- 社工
- 心理師
- 營養師
- 護理人員
- 特教老師



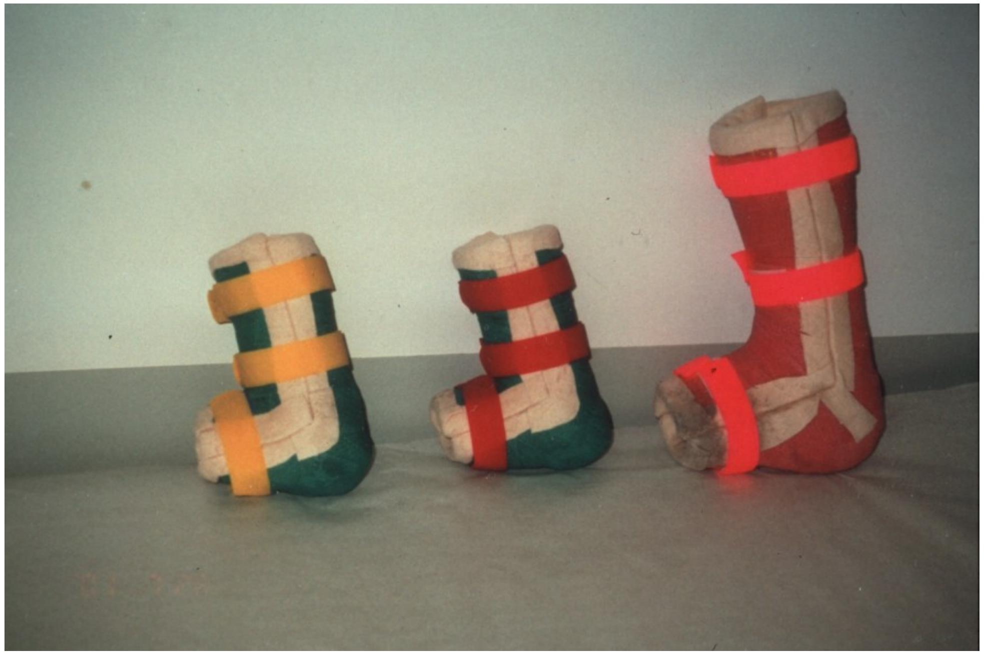




erebral palsy.
osterior view
tersegmental

Fig. 11-47 Patient with spastic quadriparesis. **A,** An-


Genius




'97 3 19



廚房輔具類


'96 3 15


Next Generation Universal Home


Unlimiter
1
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9
10
Blue bird
要
上廁所
吃
喝
買
不要
寫
睡覺
看
去
聽
謝謝
擦
畫
開
關
拿
請幫忙
做
穿
洗
打
帶

Homework

- Search the web space and write a 2-page report about one novel assistant technology I haven't mentioned in class
  - Problem(s) intended to solve
  - Brief introduction of the engineering principles
  - Advantages and disadvantages of this specific device