Artificial organs and implant devices

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Liver Support Systems

- The liver fulfills multiple and finely tuned functions that are critical for the homeostasis of the human body
- The liver is also the principal site of biotransformation, activation or inactivation of drugs and synthetic chemicals
- Therefore, this organ displays a unique biologic complexity
- When it fails, functional replacement presents one of he most difficult challenges in substitutive medicine

Liver Support Systems

TABLE 133.1 Liver Functions

Carbohydrate metabolism: Glyconeogenesis and glycogenolysis
Fat and lipid metabolism: Synthesis of lipoproteins and cholesterol
Synthesis of plasma proteins, for example:
- Albumin
- Globulins
- Fibrinogen
- Coagulation factors
- Transferrin
- α-fetoprotein

Conjugation of bile acids; conversion of heme to bilirubin and biliverdin
Detoxification: Transformation of metabolites, toxins, and hormones into water-soluble compounds (e.g., cytochrome P-450 P-450 oxidation, glucuronyl transferase conjugation)
Biotransformation and detoxification of drugs
Metabolism and storage of vitamins
Storage of essential nutrients
Regeneration

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Liver Support Systems

Hepatic Failure

- More than any other organ, the liver has the property of regeneration after tissue damage
- Removal or destruction of a large mass of hepatic parenchyma stimulates controlled growth to replace the missing tissue
- Hepatic failure may be *fulminant hepatic failure* (FHF) as s the result of massive necrosis of hepatocytes or *chronic hepatic failure*, the more common and progressive form of the disease, is often associated with morphologic liver changes known as cirrhosis

Liver Support Systems

Hepatic Failure

TABLE 133.2 Metabolic Products with Potential Effects in Acute Liver Failure

Substance	Mode of action
Ammonia	Neurotoxic interaction with other neurotransmitters Contributes to brain edema
Benziodiazepinelike substances	Neural inhibition
GABA	Neural inhibition
Mercaptans	Inhibition of Na-K ATPase
Octopamine	Acts as a false neurotransmitter

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Liver Support Systems

- The concept of artificial liver support is predicated on the therapeutic benefit of removing toxic substances accumulating in the circulation of liver failure patients
- Technologies for temporary liver support focus on the detoxifying function, since this appears to be the most urgent problem in liver failure
- The procedures and devices which have been considered for this purpose include several procedures

Liver Support Systems

Hemodialysis

- Hemodialysis with conventional cellulosic membranes or more permeable polysulfone or polyacrylonitrile
- Helps to restore electrolyte and acid-base balance and may decrease the blood ammonia levels but cannot remove large molecules and plasma protein-bound toxins
- Improvement of the patient's clinical condition is temporary
- The treatment appears to have no lasting value and no demonstrated effect on patient survival

Liver Support Systems

Hemofiltration

- Hemofiltration with high cut-off point membranes clears natural or abnormal compounds within limits imposed by convective transport across the exchange membranes
- These procedures again have a temporary favorable effect on hepatic encephalopathy (perhaps because of the correction of toxic levels of certain amino acids) with reversal of coma, but they do not clearly improve survival rates.

Liver Support Systems

Hemoperfusion

- Hemoperfusion, i.e., extracorporeal circulation of blood over nonspecific sorbents (e.g., activated charcoal) or more complex biochemical reactors
- These reactors allow the chemical processing of specific biologic products, such as ammonia
- Direct blood or plasma contact with the sorbent material is avoided by polymer coating of the sorbent particles using either albumin, cellulose nitrate, or similar thin films, but hemocompatibility remains a concern

Liver Support Systems

Lipophilic Membrane Systems

- Because lipophilic toxins dominate in fulminant hepatic failure, it is conceibable to eliminate such compounds with a hydrophobic (e.g., polysulfone) membrane featuring large voids filled with a nontoxic oil

- After diffusion, the toxins can be made water-soluble through reaction with a NaOH-based acceptor solution, thereby preventing their return to the blood stream

- Such a system has proved effective in removing toxins such as phenol and p-cresol as well as fatty acids without inducing detrimental side effects of its own

Liver Support Systems

Parabiotic Dialysis

- Also referred to as cross-dialysis, parabolic dialysis is a variant of hemodialysis
- The dialysate compartment of a solute exchange device is perfused continuously with blood from a living donor
- Because of membrane separation of the two blood streams, the procedure can be carried out even if the two subjects belong to different blood groups or different animal species

Liver Support Systems

Combined Therapy

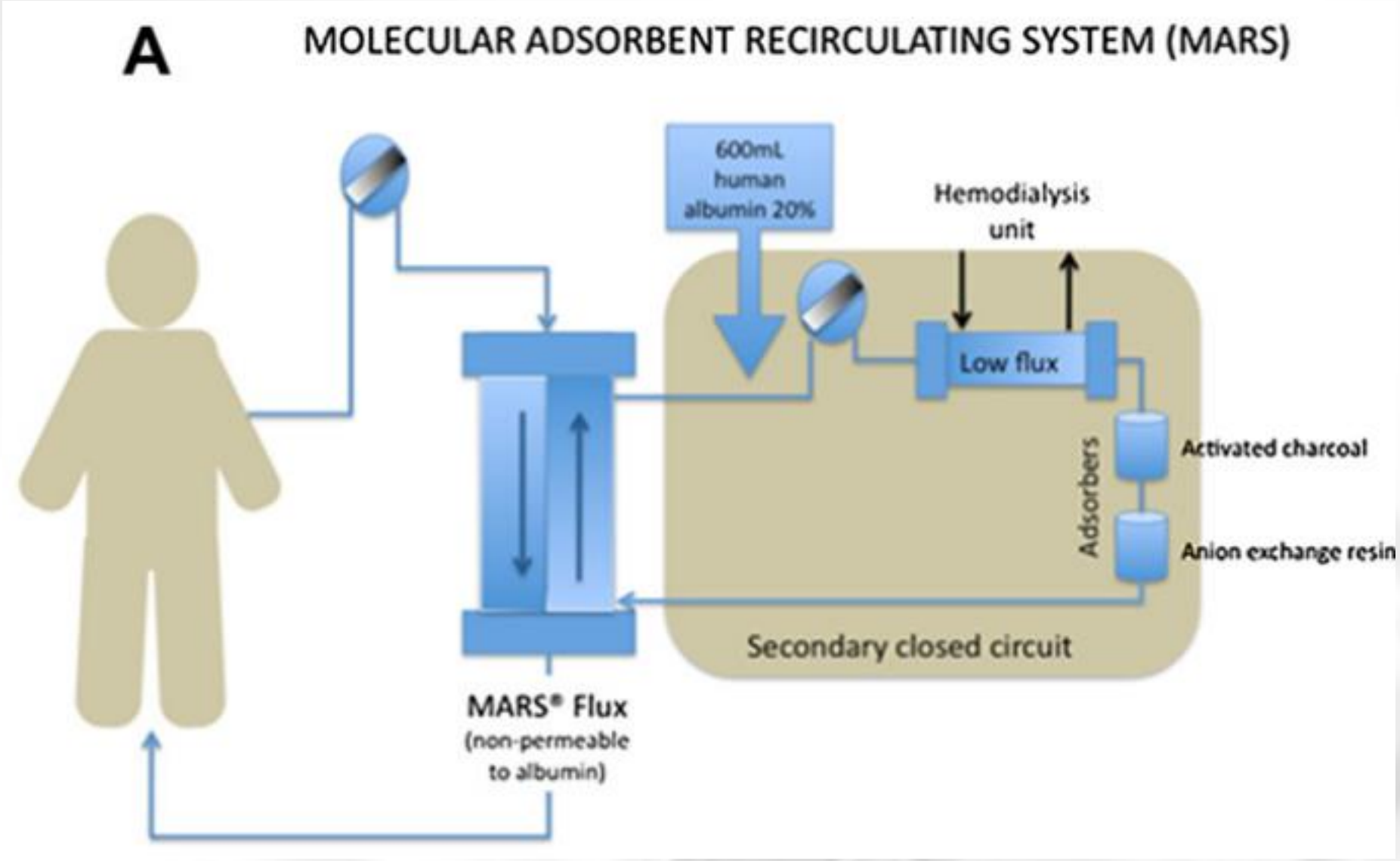
- Endotoxins and cytokines can be removed by hemoperfusion over activated charcoal and absorbent resins, but it may be more effective to process plasma than whole blood

- This has led to the concept of combining plasmapheresis with continuous plasma treatment for removal of substances such as tumor necrosis factor (TNF), interleukin-6 (IL-6), and bile acids by a resin column, and then ultrafiltration or dialysis for fluid removal

Liver Support Systems

MARS

- The molecular adsorbent recirculating system (MARS) device was developed by Stange and Mitzner in 1993 and applied for the first time in humans in 1996
- The system is based on the dialysis of blood with a membrane separation system coated albumin
- The albumin enables the exchange of water-soluble and protein bound toxins by an albumin-coated membrane and recycled protein containing dialyzate

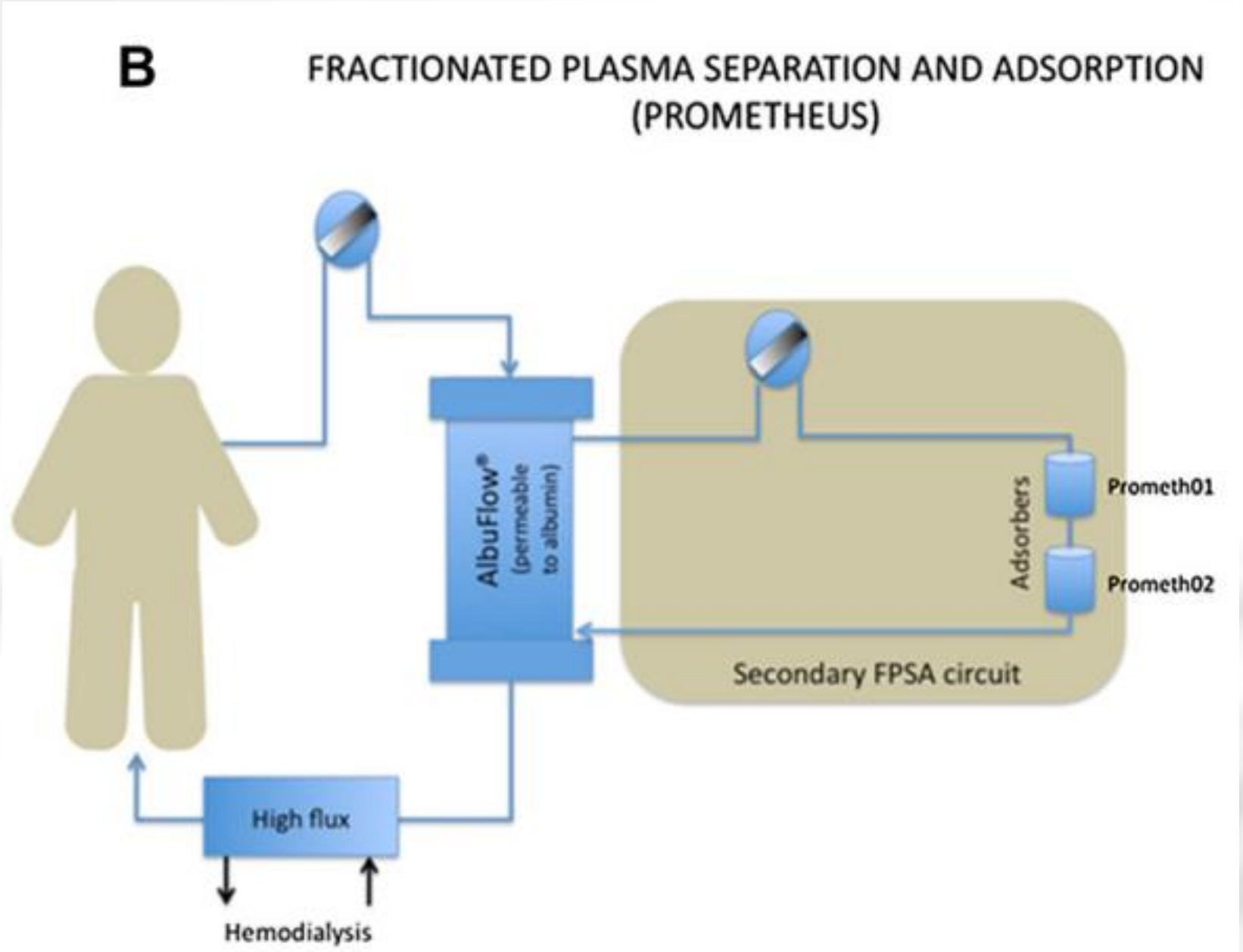


Nevens, W. Laleman, Artificial liver support devices as treatment option for liver failure, Best Practice & Research Clinical Gastroenterology, 2012

Liver Support Systems

Prometheus

- Like MARS, Prometheus combines removal of albumin-bound and watersoluble substances, but works with a different technique
- Prometheus is based on fractionated plasma separation and adsorption
- In this systemfiltration of the native albumin and other plasma proteins with low molecular weight takes place through a specific albumin-permeable polysulfonefilter with a cut-off of >100 kDa into a secondary circuit



Nevens, W. Laleman, Artificial liver support devices as treatment option for liver failure, Best Practice & Research Clinical Gastroenterology, 2012

Liver Support Systems

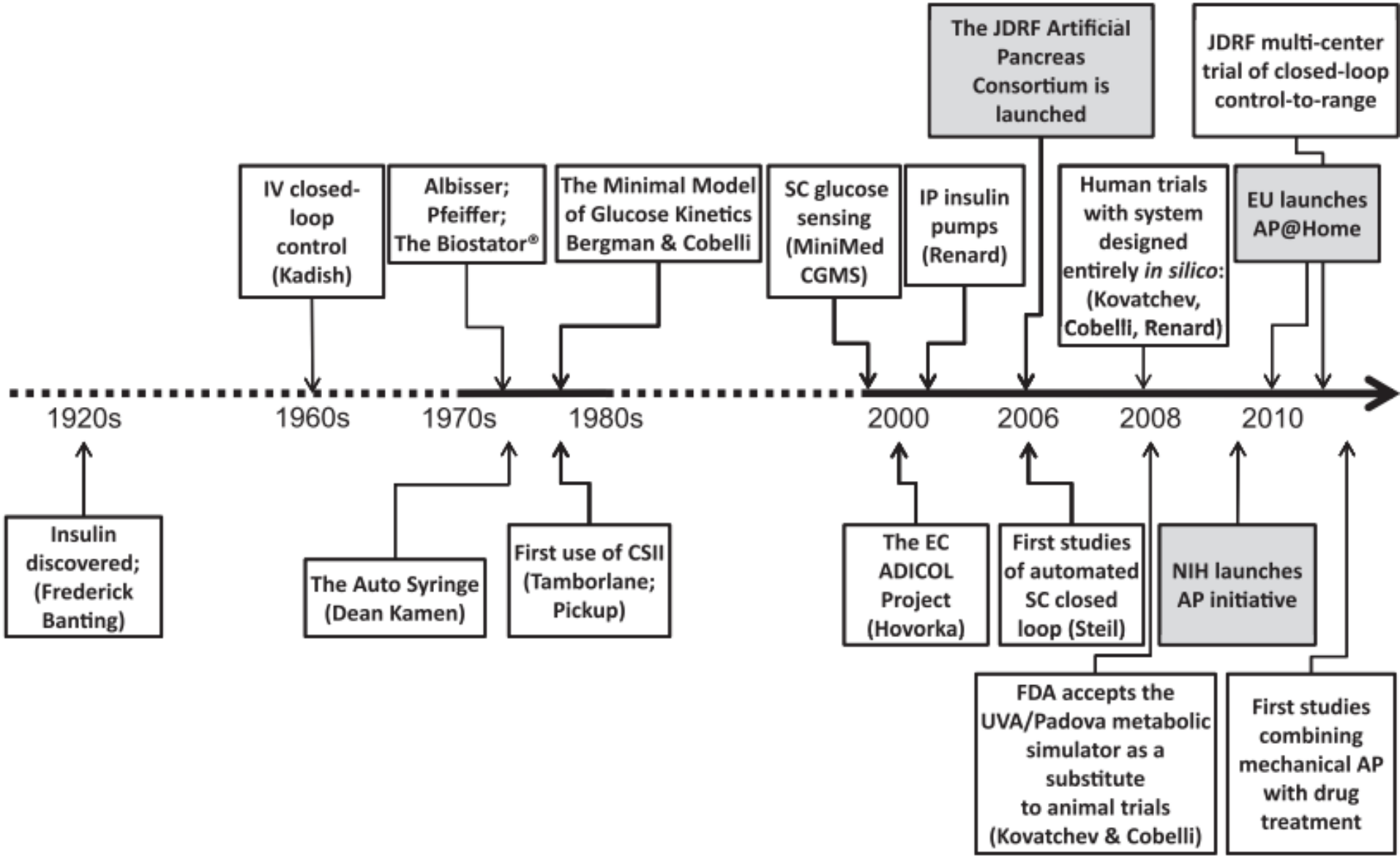
- Non-biological systems are today the most frequent used liver support systems
- Non-biological systems are based, in variable degree, on diffusion (haemodialysis), filtration (plasmaphaeresis), adsorption (haemoperfusion) and/or convection (haemofiltration)
- Non-biological liver support systems are safe and they improve jaundice, haemodynamic instability, portal hypertension, intracranial pressure and hepatic encephalopathy
- Non-biological liver support does not improve survival and is to be considered as a‘bridging’ tool to transplantation

Artificial Pancreas

- The pancreas is a slender, soft, lobulated gland (ca. 75 g in the adult human), located transversally in the upper abdomen in the space framed by the three portions of the duodenum and the spleen
- Most of the pancreas is an *exocrine* gland which secretes proteolytic and lipolytic enzymes, conveying more than 1 L per day of digestive juices to the gastrointestinal tract
- Blood is supplied to the islets by the pancreatic artery and drained into the portal vein
- Therefore the entire output of pancreatic hormones is first delivered to the liver

Artificial Pancreas

- The term artificial pancreas is used exclusively for systems aimed at replacing the endocrine function of that organ
- Although the total loss of exocrine function can be quite debilitating, no device has yet been designed to replace the digestive component of the pancreas
- Since insulin deficiency is the life-threatening consequence of the loss of endocrine function, the artificial pancreas focuses almost exclusively on insulin supply systems



Key milestones in the timeline of AP progress

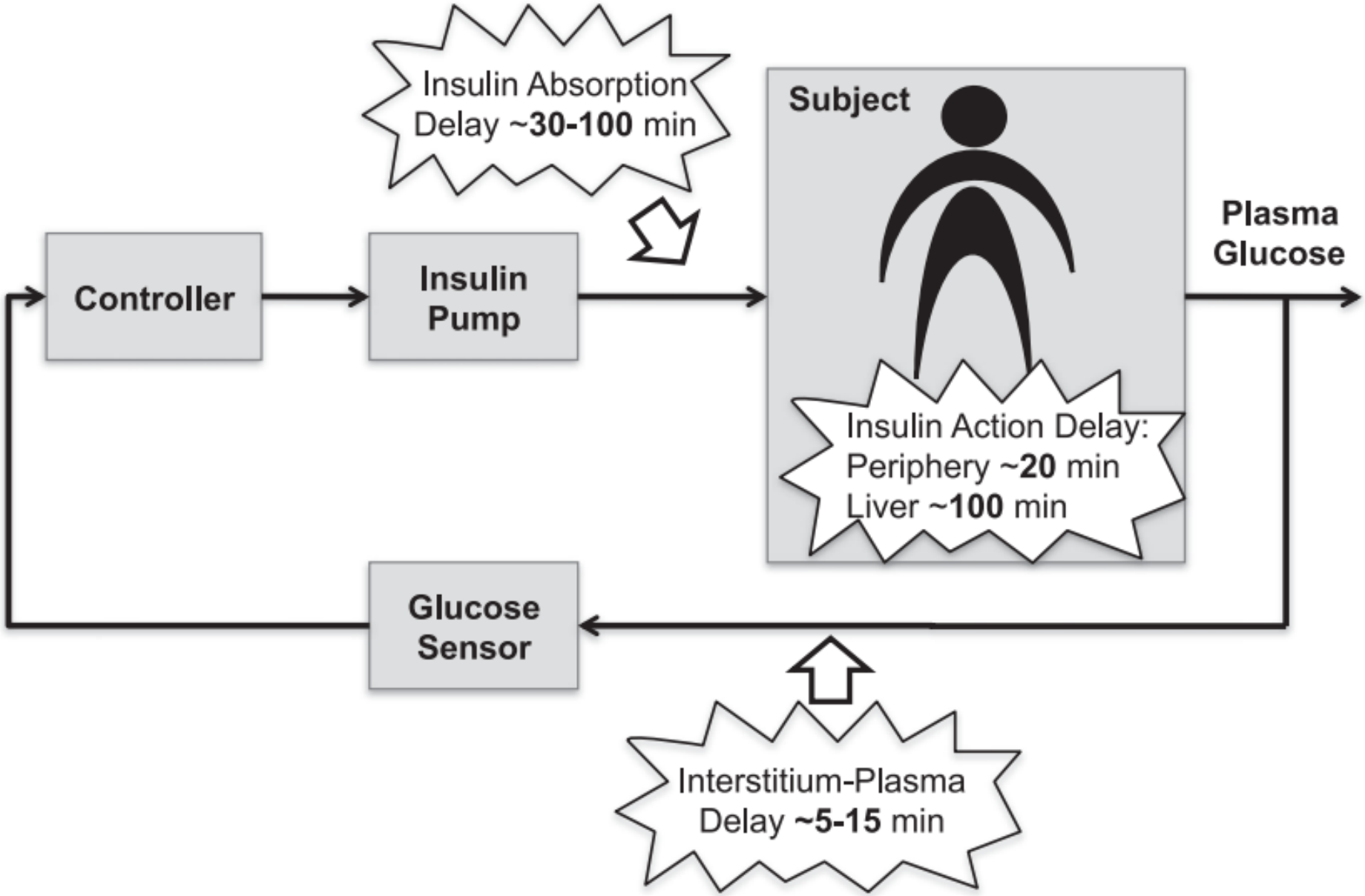
Cobelli et. al, Artificial Pancreas: Past, Present, Future, Diabetes , 2011

Artificial Pancreas

- Despite important developments in sensor and pump technology, the Artificial Pancreas (AP) must cope with the delays and inaccuracies in both glucose sensing and insulin delivery
- This is particularly difficult when a system disturbance, e.g., a meal, occurs and triggers a rapid glucose rise that is substantially faster than the time needed for insulin absorption and action
- The principal AP control dilemma?

Artificial Pancreas

- AP control dilemma: find a trade-off between slow-pace regulation well suited to mild control actions applicable to quasi-steady state (e.g., overnight), and postprandial regulation calling for prompt and energetic corrections
- In a glucose control three major delays are indicated:
  - insulin absorption (regular and ultrafast insulin),
  - insulin action on peripheral tissues and on the liver,
  - and sensing in the interstitium

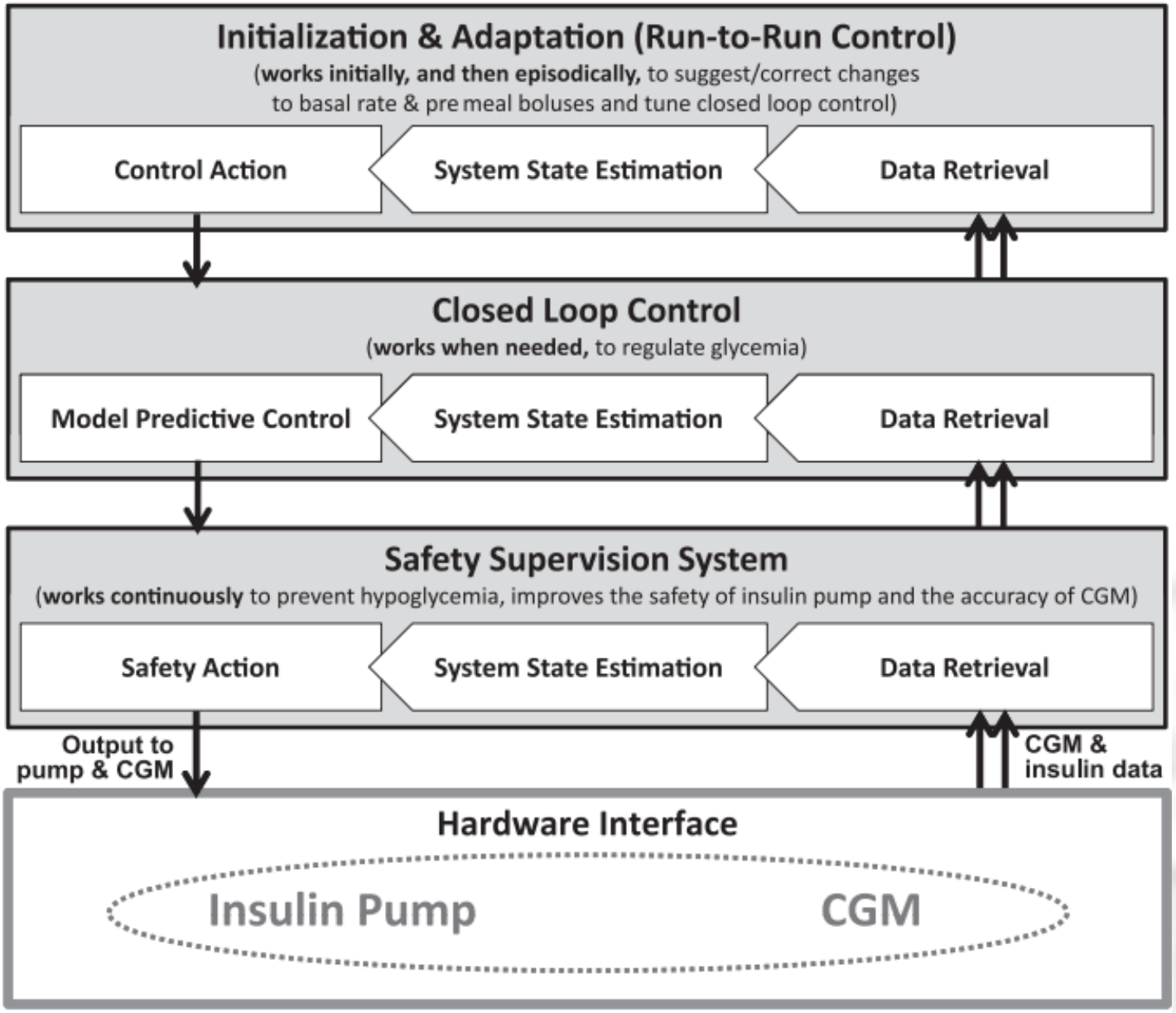


Block diagram of closed-loop glucose control

Cobelli et. al, Artificial Pancreas: Past, Present, Future, Diabetes , 2011

Artificial Pancreas

- Today's technological advancements open the possibility for ambulatory AP
- To account for the multitude of available possibilities, academic, and industrial developments, we have introduced the concept of modular approach to AP design
- To account for the multitude of available possibilities, academic, and industrial developments, we have introduced the concept of modular approach to AP design



Modular architecture for sequential AP developmen

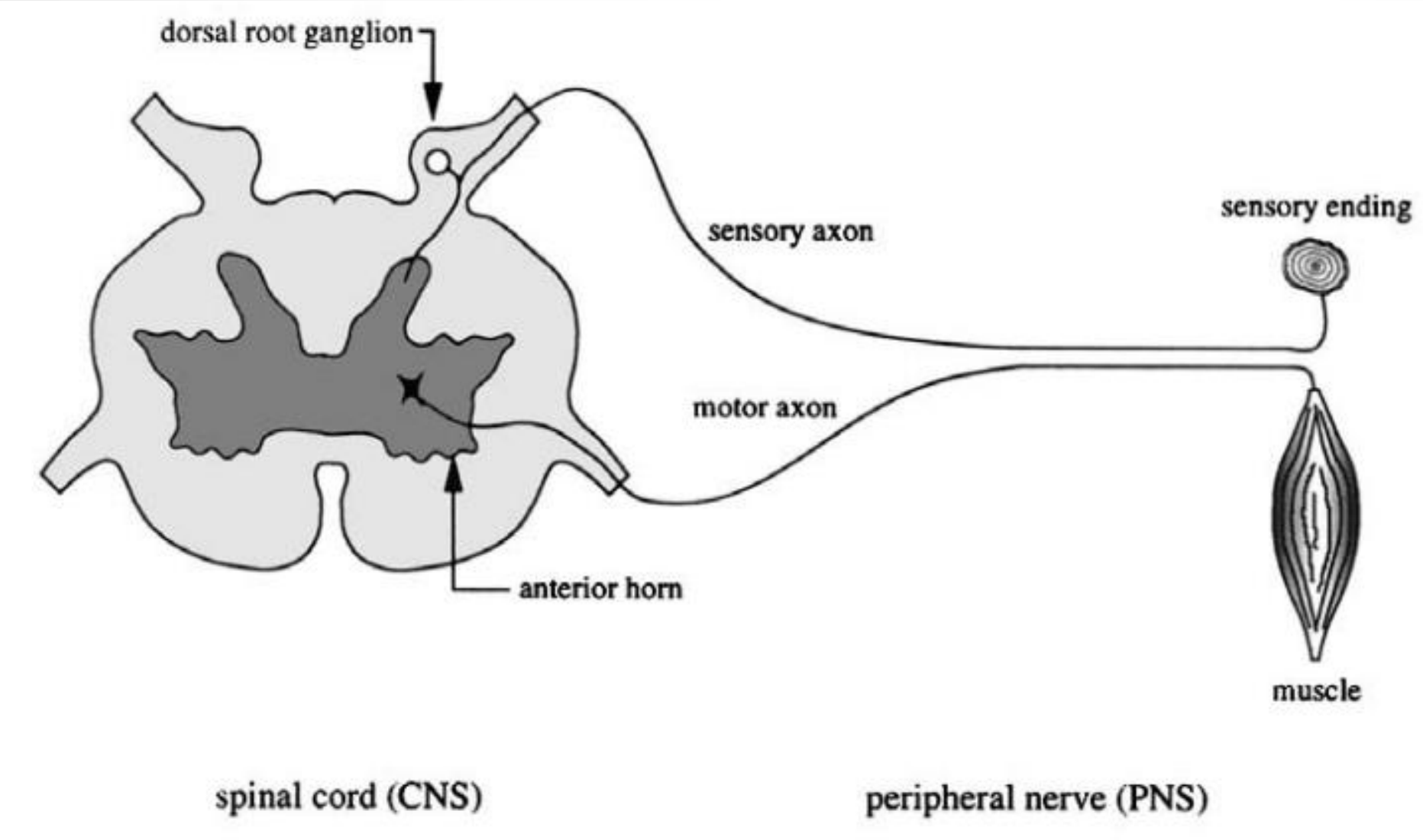
Cobelli et. al, Artificial Pancreas: Past, Present, Future, Diabetes , 2011

Nerve Guidance Channels

- In adult mammals, including humans, the peripheral nervous system (PNS) is capable of regeneration following injury
- The PNS consists of neural structures located outside the central nervous system (CNS), which is comprised of the brain and spinal cord
- Unfortunately, CNS injuries rarely show a return of function, although recent studies suggest a limited capacity for recovery under optimal conditions

Nerve Guidance Channels

- Peripheral nerve trunks are responsible for the innervation of the skin and skeletal muscles and contain electrically conductive fibers termed axons, whose cell bodies reside in or near the spinal cord
- The most severe from of injury results from complete transaction of the nerve
- Injuries close to the nerve cell body are more detrimental than injuries occurring more peripherally



Spinal cord in cross-section

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Nerve Guidance Channels

- In repair procedures using nerve guidance channels, the mobilized ends of a severed nerve are introduced in the lumen of a tube and anchored in place with sutures
- Tubulation repair provides:
  - direct, unbroken path between nerve stumps
  - prevention of scar tissue invasion into the regenerating environment
  - directional guidance for elongation neurites and migrating cells

Nerve Guidance Channels

- In repair procedures using nerve guidance channels, the mobilized ends of a severed nerve are introduced in the lumen of a tube and anchored in place with sutures

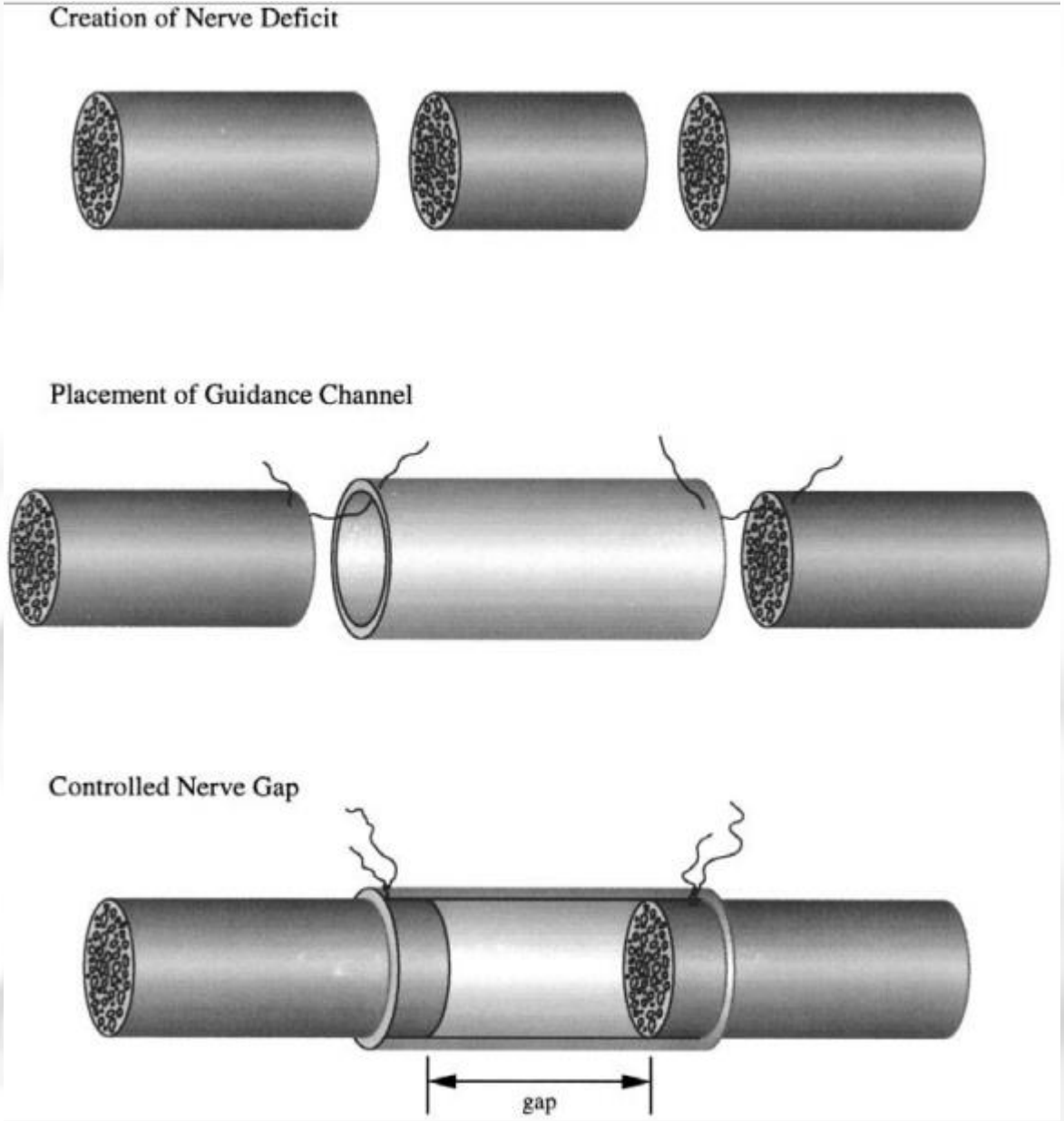
- Tubulation repair provides:

  – proximal-distal stump communication without suture-line tension in cases of extensive nerve deficit

  – minimal number of epineurial stay sutures, which are known to stimulate connective tissue proliferation and

  – preservation, within the guidance channel lumen, of endogenous trophic or growth factors released by the traumatized nerve ends

Tube to repair nerve. Surgical placement of nerve guidance channel.



J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Nerve Guidance Channels

- Guidance channels are also useful from an experimental perspective:
  - the gap distance between the nerve stumps can be precisely controlled
  - the fluid and tissue entering the channel can be evaluated; (3) the properties of the channel can be varied and
  - the channel can be filled with various drugs, gels, and the like

TABLE 135.1 Materials Used for Nerve Guidance Channels

- Synthetic materials
  - Nonresorbable
    - Nonporous
      - Ethylene-Vinyl Acetate Copolymer (EVA)
      - Polytetrafluoroethylene (PTFE)
      - Polyethylene (PE)
      - Silicone elastomers (SE)
      - Polyvinyl chloride (PVC)
      - Polyvinylidene fluoride (PVDF)
    - Microporous
      - Gortex, expanded polytetrafluoroethylene (ePTFE)
      - Millipore (cellulose filter)
    - Semipermeable
      - Polyacrylonitrile (PAN)
      - Polyacrylonitrile/Polyvinyl chloride (PAN/PVC)
      - Polysulfone (PS)
  - Bioresorbable
    - Polyglycolide (PGA)
    - Polylactide (PLLA)
    - PGA/PLLA blends
- Biologic materials
  - Artery
  - Collagen
  - Hyaluronic acid derivatives
  - Mesothelial tubes
  - Vein
- Metals
  - Stainless steel
  - Tantalum

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

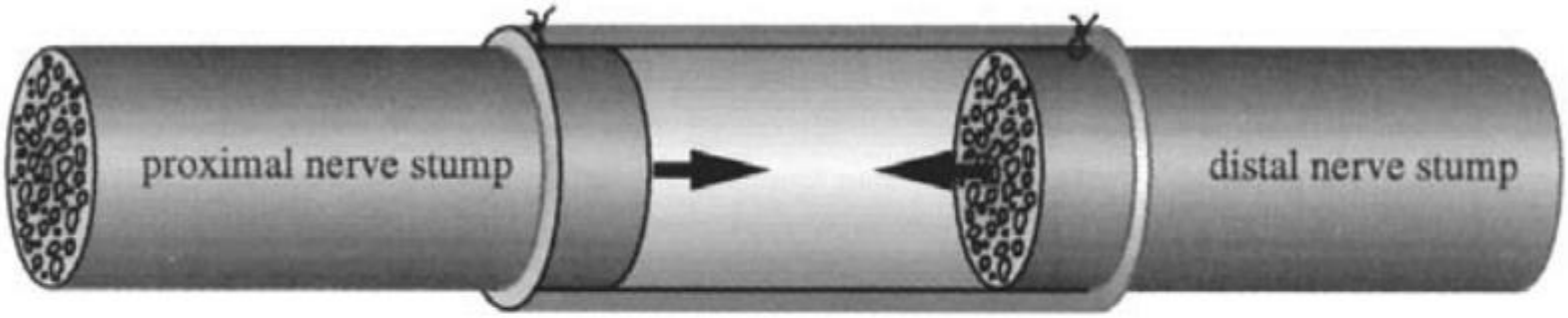
Nerve Guidance Channels

- The availability of a variety of new biomaterials has led to a resurgence of tubulation studies designed to elucidate the mechanisms of nerve regeneration
- The spatial-temporal progress of nerve regeneration across a 10-mm rat sciatic nerve gap repaired with a silicone elastomer tube has been analyzed in detail
- During the first hours following repair, the tube fills with a clear, protein-containing fluid exuded by the cut blood vessels in the nerve ends

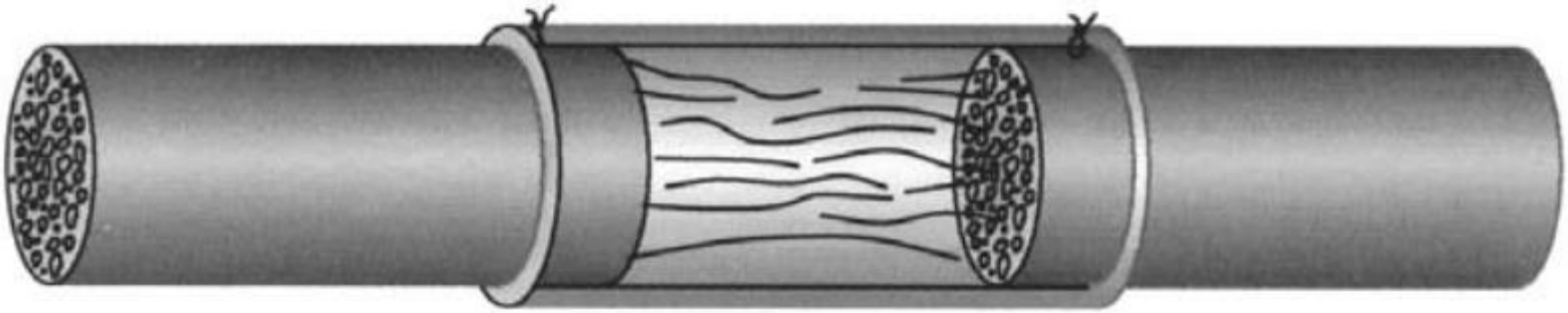
Nerve Guidance Channels

- The fluid contains the clot-forming protein, fibrin, as well as factors known to support nerve survival and outgrowth
- By the end of the first week, the lumen is filled with a longitudinally oriented fibrin matrix which coalesces and undergoes syneresis to form a continuous bridge between the nerve ends
- The fibrin matrix is soon invaded by cellular elements migrating from the proximal and distal nerve stumps

Filling of Tube by Blood Derived Fluid and Proteins (day 1)



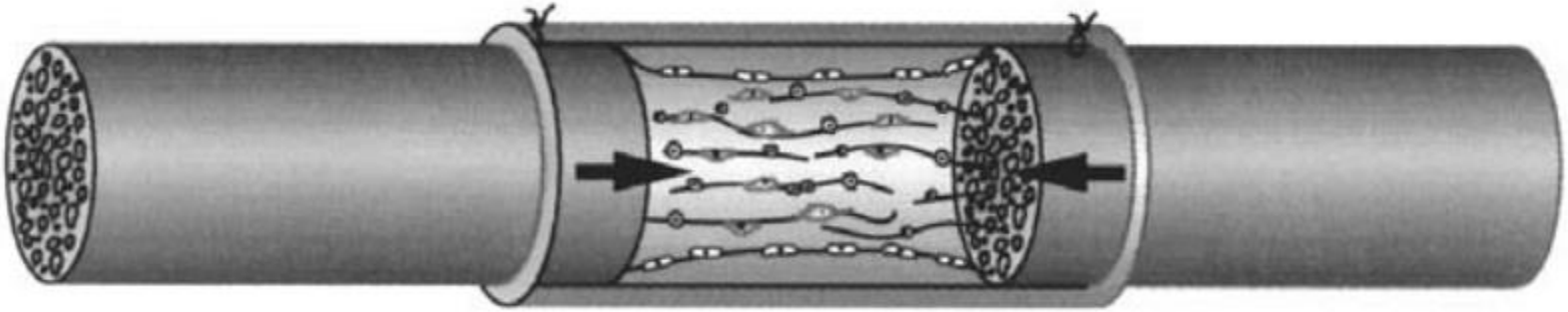
Formation and Coalescence of Fibrin Cable (days 2-6)



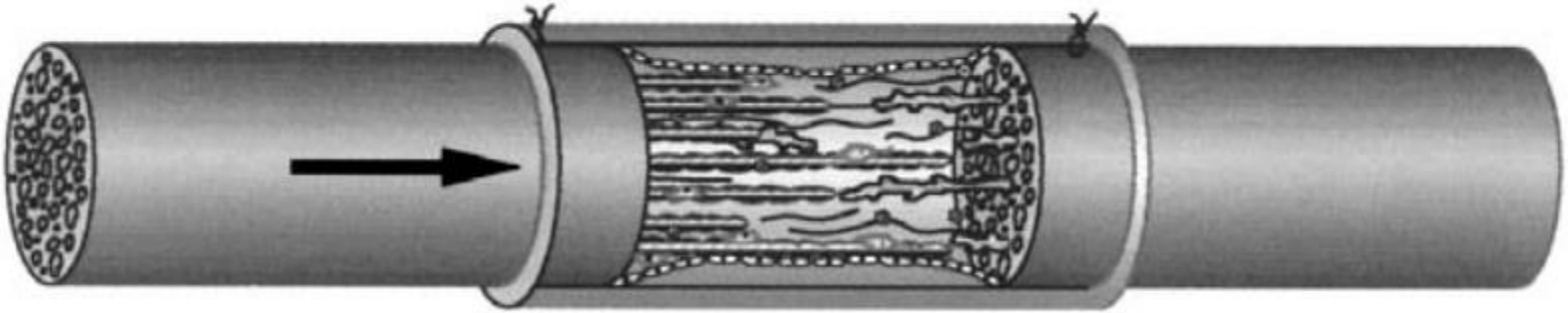
Regeneration process. Nerve regeneration through a guidance channel.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Invasion of Cable by Schwann Cells, Fibroblasts, and Endothelial Cells (days 7-14)



Axonal Elongation and Myelination (days 15-28)



Regeneration process. Nerve regeneration through a guidance channel.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Nerve Guidance Channels

- Growth or neurontrophic factors that ensure the survival and general growth of neurons are produced by support cells (e.g., Schwann cells) or by target organs (e.g., muscle fibers)
- Some factors support neuronal survival, other support nerve outgrowth, and some do both
- Numerous growth factors have been identified, purified, and synthesized through recombinant technologies

TABLE 135.2 Growth Factors Involved in Peripheral Nerve Regeneration

Growth Factor	Possible function
NGF—nerve growth factor	Neuronal survival, axon-Schwann cell interaction
BDNF—brain-derived neurotophic factor	Neuronal survival
CNTF—ciliary neuronotrophic factor	Neuronal survival
NT-3—neuronotrophin 3	Neuronal survival
NT-4—neuronotrophin 4	Neuronal survival
IGF-1—insulinlike growth factor-1	Axonal growth, Schwann cell migration
IGF-2—Insulinlike growth factor-2	Motoneurite sprouting, muscle reinnervation
PDGF—platelet-derived growth factor	Cell proliferation, neuronal survival
aFGF—acidic fibroblast growth factor	Neurite regeneration, cell proliferation
bFGF—basic fibroblast growth factor	Neurite regeneration, neovascularization

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Nerve Guidance Channels

- The permeability, textural, and electrical properties of nerve guidance channels can be optimized to impact favorably on regeneration
- The release of growth factors, addition of growth substrates, and inclusion of neural support cells and genetically engineered cells also enhance regeneration through guidance channels
- The ideal guidance system is a composite device that contains novel synthetic or bioderived materials and incorporates genetically engineered cells and new products from biotechnology

Tracheal, Laryngeal, and Esophageal Replacement Devices

- As the ability to reconstruct parts of the body has increased, so has the potential for complications associated with the replacement devices used to do so
- Some of the most significant complications associated with replacement devices, such as vascular prostheses, cardiac valves, and artificial joints, are caused by infections at the implantation site
- It is well known that the presence of a foreign material impairs host defenses and that prolonged infections cannot be cured unless the foreign material is removed from the site of infection

Tracheal, Laryngeal, and Esophageal Replacement Devices

- As the trachea, larynx, and esophagus are located at sites facing the “external environment,” these prostheses are exposed to a high risk of infections and severe complications
- The development of an artificial trachea, esophagus, and larynx is way behind that of artificial vascular grafts even though they are all tubular organs

Tracheal, Laryngeal, and Esophageal Replacement Devices

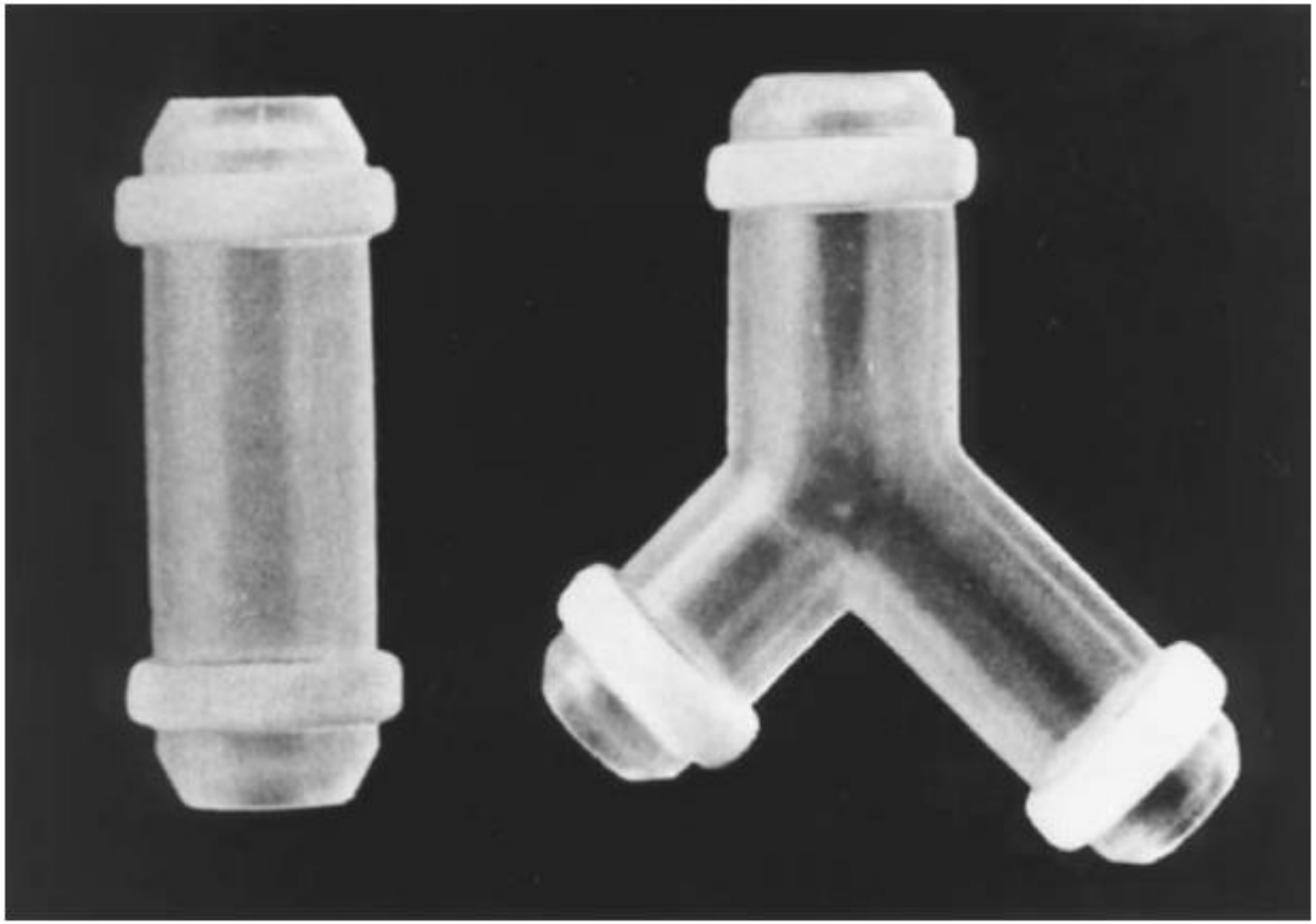
Tracheal Replacement

- When *end-to-end anastomosis* operation for tracheal reconstruction fails alternative methods are required to reconstruct the airway
- Such reconstructive methods can be classified into the following three categories:
  - reconstruction with autologous tissue
  - reconstruction with nonautologous trachea and
  - reconstruction with artificial material

Tracheal, Laryngeal, and Esophageal Replacement Devices

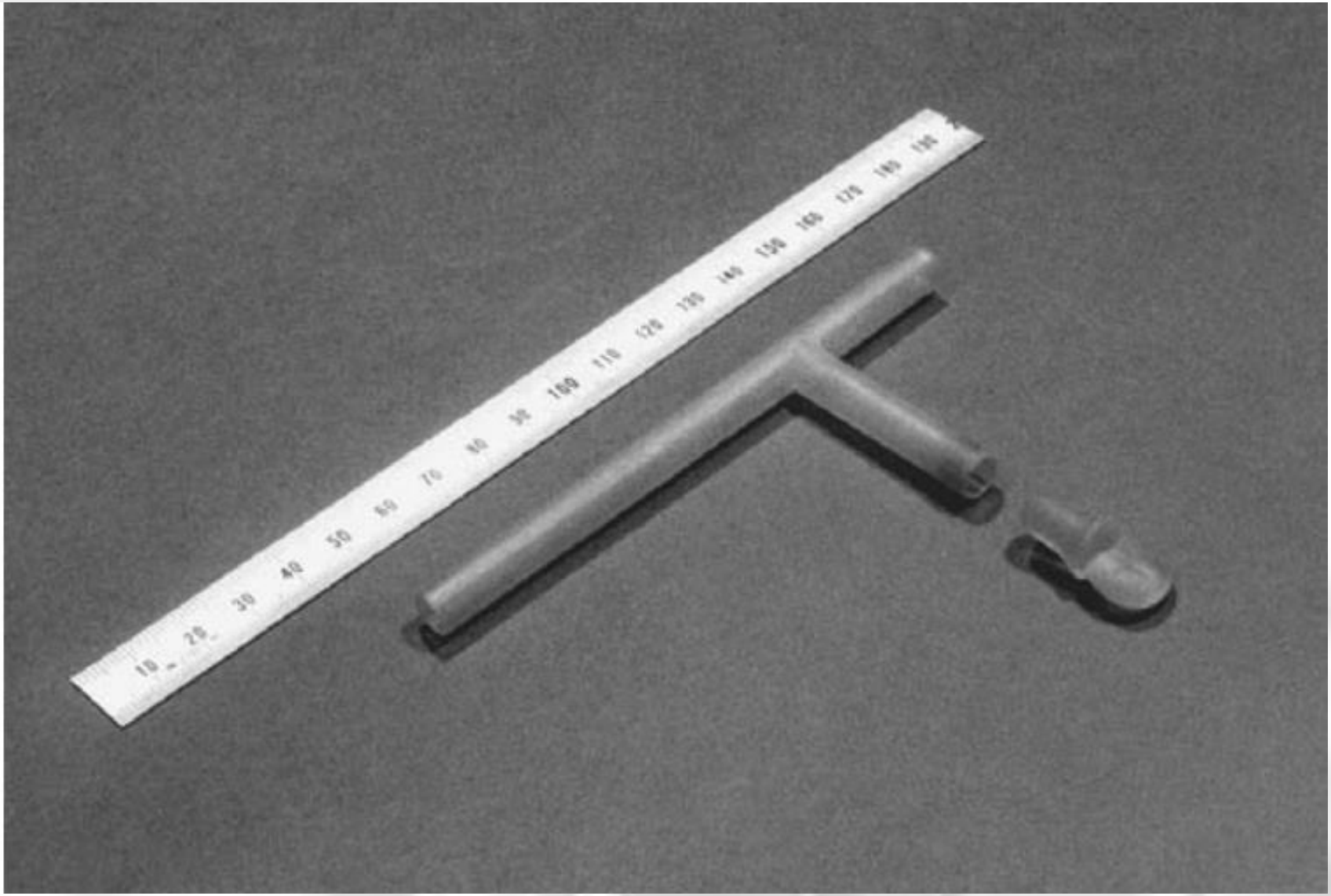
Tracheal Replacement

- The artificial tracheae aredesigned according to one of two concepts:
  - One is that the implanted prosthesis alone replaces the resected area of trachea, and the inner surface of the reconstructed trachea is not endothelialized
  - The other is that the implanted prosthesis is incorporated by the host tissue and its inner surface is endothelialized



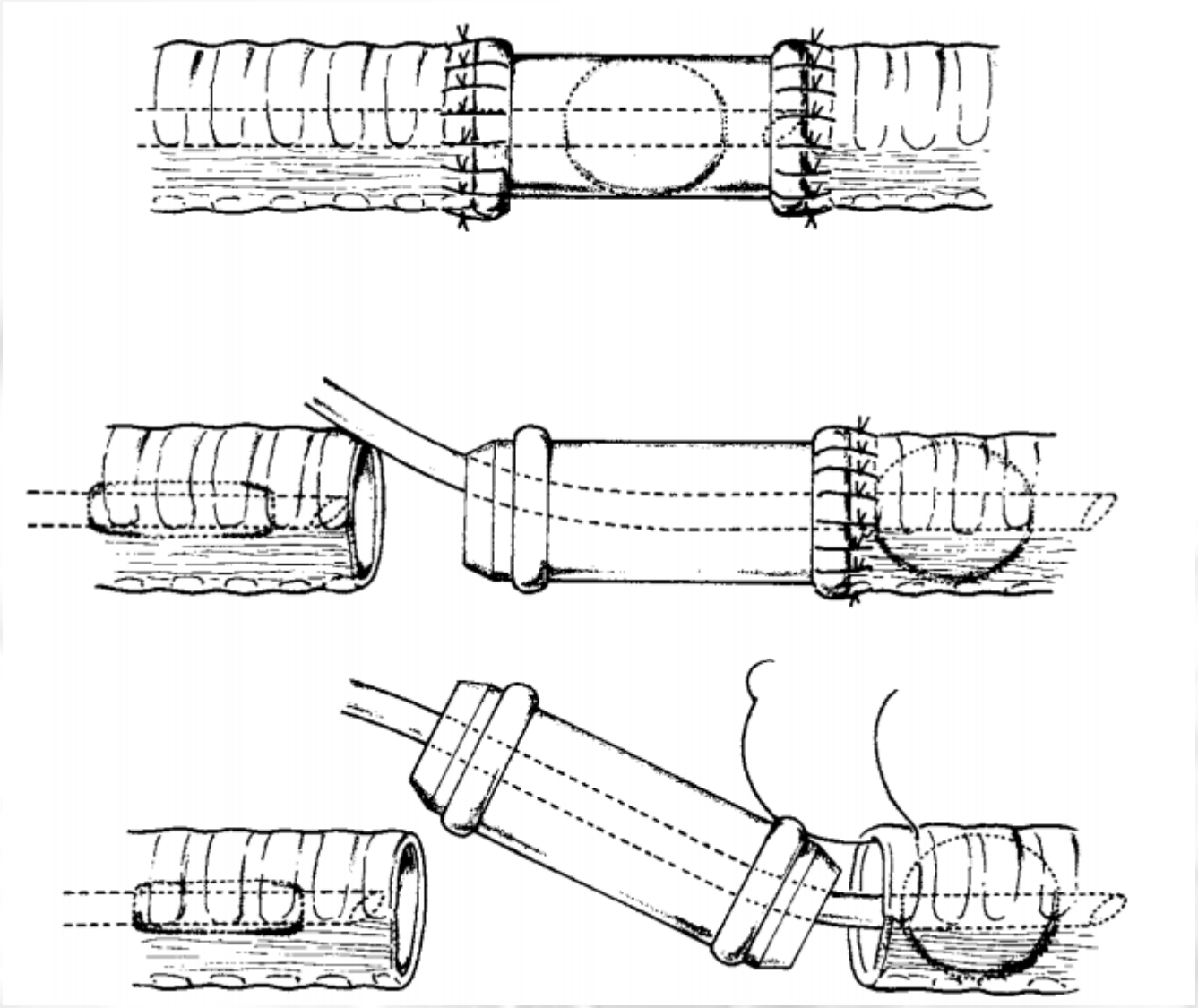
Neville artificial trachea constructed with a nonporous silicone tube with Dacron suture rings.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.



For the alleviation of tracheal stenosis, silicone T-tubes are widely indicated.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.



Operation proceeding of tracheal reconstruction using an artificial trachea.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Tracheal, Laryngeal, and Esophageal Replacement Devices

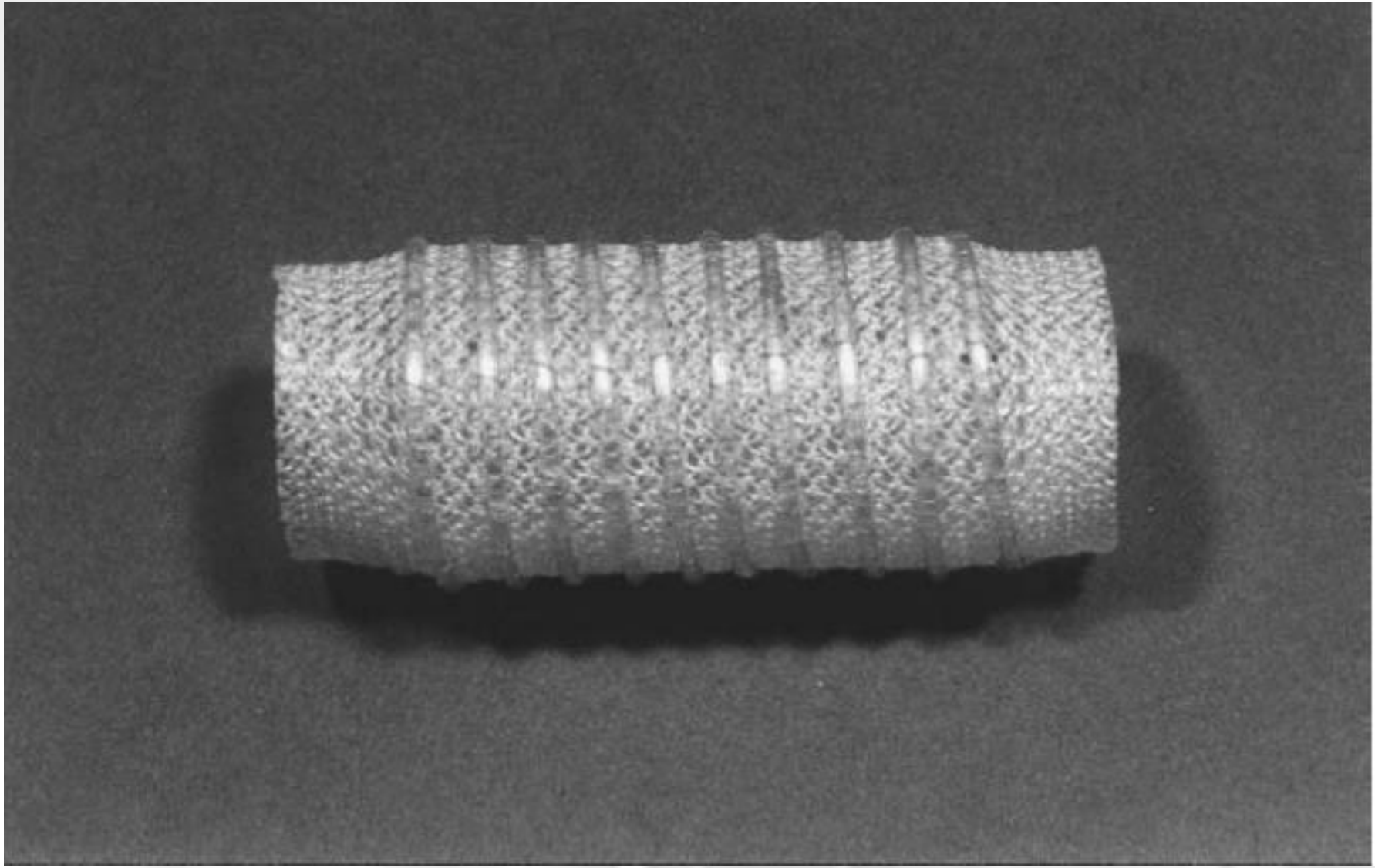
Mesh-Type Artificial Tracheae

- Porous artificial tracheae are called mesh-typebecause the prosthetic trunk is made of mesh
- In the 1950s, several trials of tracheal reconstruction using metallic meshes made of tantalum and stainless steel were conducted
- However, long-term observations showed that this mesh caused rupture of the adjacent graft vessels, which was fatal, so it fell gradually out of use for tracheal reconstruction

Tracheal, Laryngeal, and Esophageal Replacement Devices

Mesh-Type Artificial Tracheae

- Collagen-grafted fine Marlex mesh is air-tight, and clinically, good tissue regeneration is achieved when it is used to patch-graft of the trachea
- The grafted collagen has excellent biocompatibility and promotes connective tissue infiltration into the mesh
- However, the fine mesh alone is too soft to keep the tube open, so a tracheal prosthesis was made of collagen-grafted fine Marlex mesh reinforced with a continuous polypropylene spiral



Artificial trachea made from collagen-conjugated fine Marlex mesh.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Tracheal, Laryngeal, and Esophageal Replacement Devices

Laryngeal Replacement Devices

- Total laryngectomy is one of the standard operations for laryngeal carcinomas
- As radiation therapy and surgery have progressed, the prognosis associated with laryngeal carcinoma has improved
- The curability of total laryngeal carcinoma is now almost 70%, and therefore many patients survive for a long time after surgery

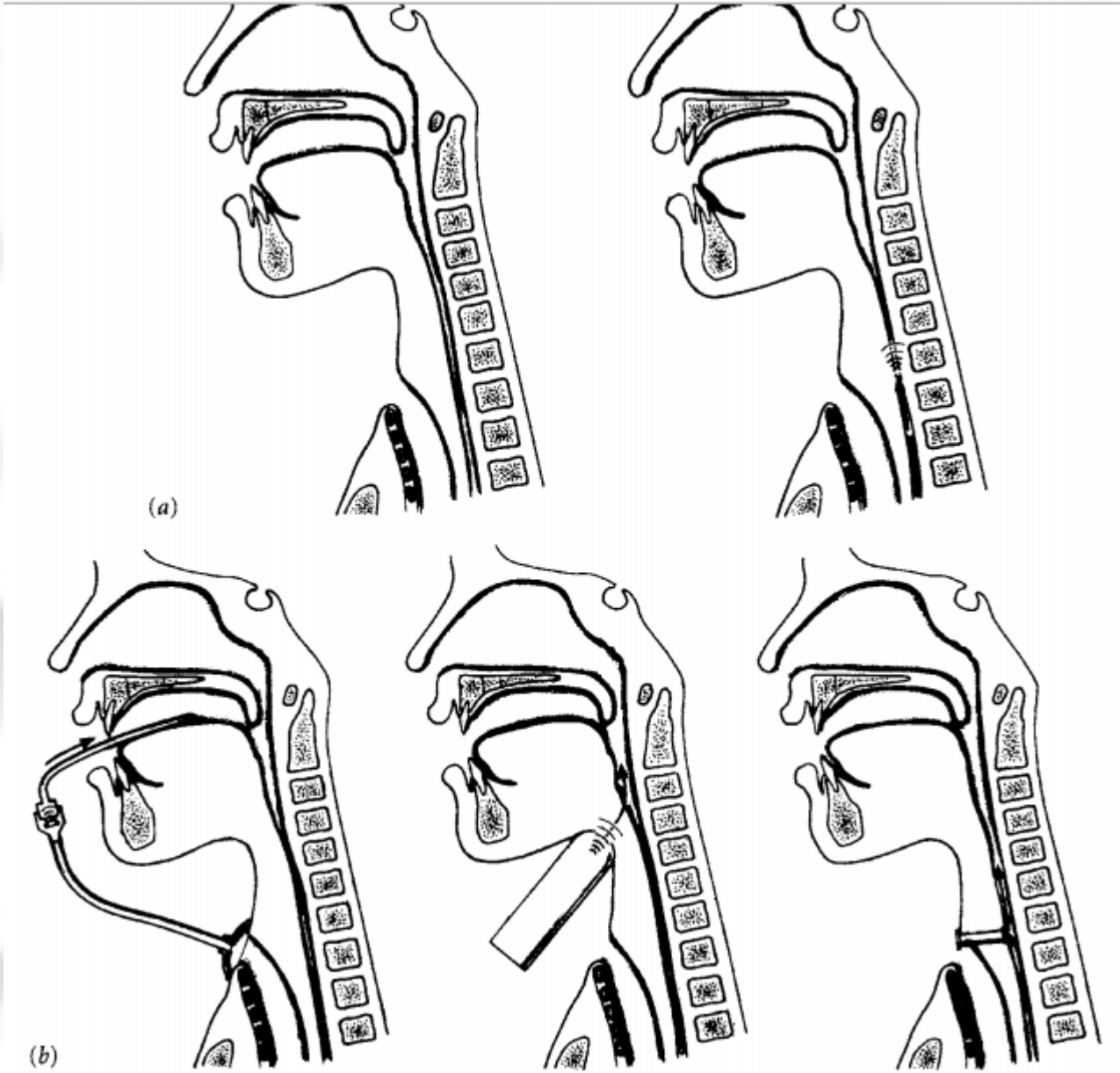
Tracheal, Laryngeal, and Esophageal Replacement Devices

Laryngeal Replacement Devices

- A variety of methods have been developed to recover phonation after total larygectomy, which is called vocal rehabilitation.
- Methods for vocal rehabilitation are classified as:
  - esophageal speech,
  - artificial larynx, and
  - surgical laryngoplasty.

•Sagital views of the laryngectomee (left) and esophageal speech (right). Air flow from the esophagus makes the sound.

•Pneumatic larynx (reed type) (left); electric artificial larynx (transcervical type), (center); voice prosthesis (T-E shut) of Blom & Singer method, right

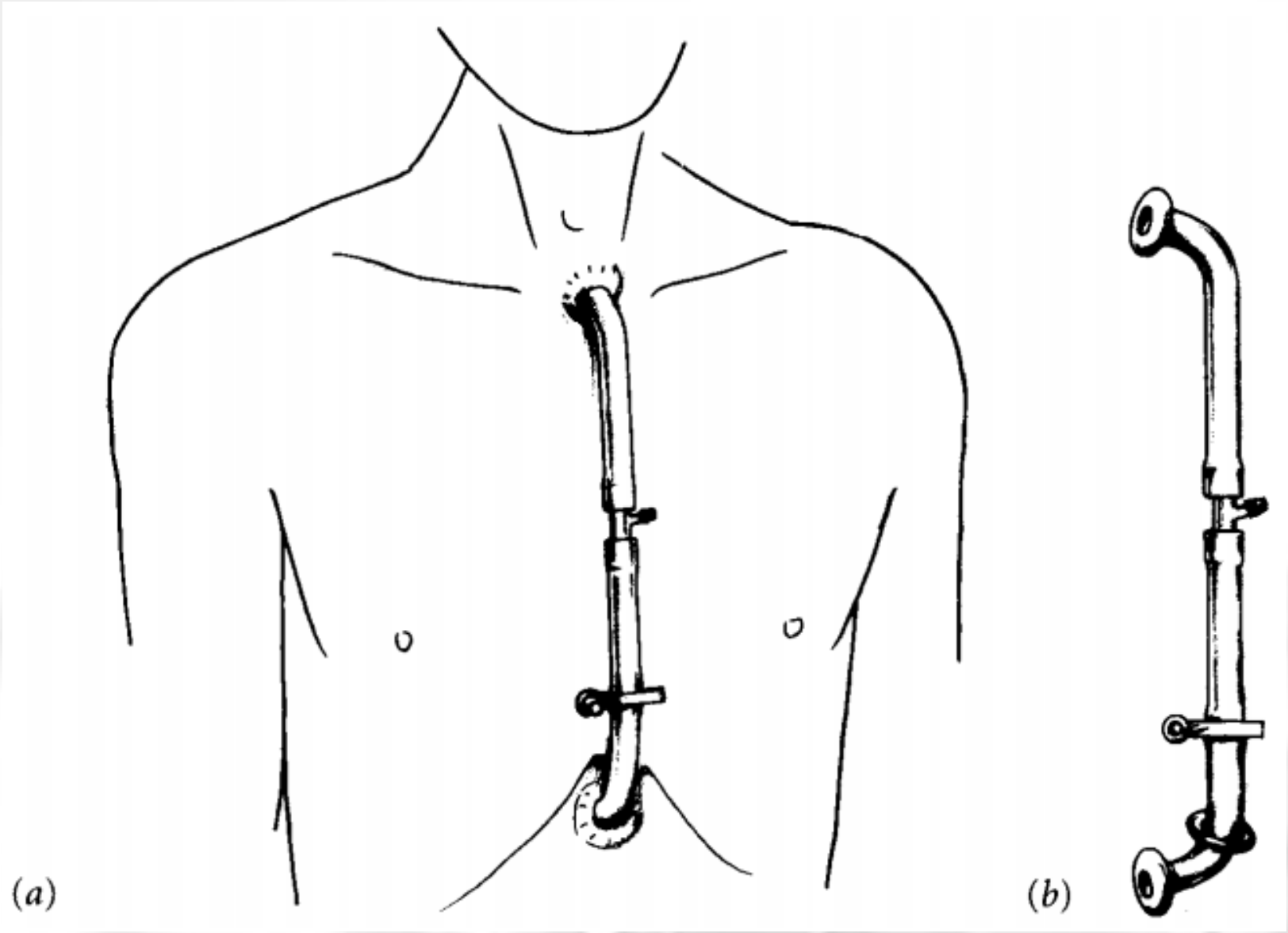


J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Tracheal, Laryngeal, and Esophageal Replacement Devices

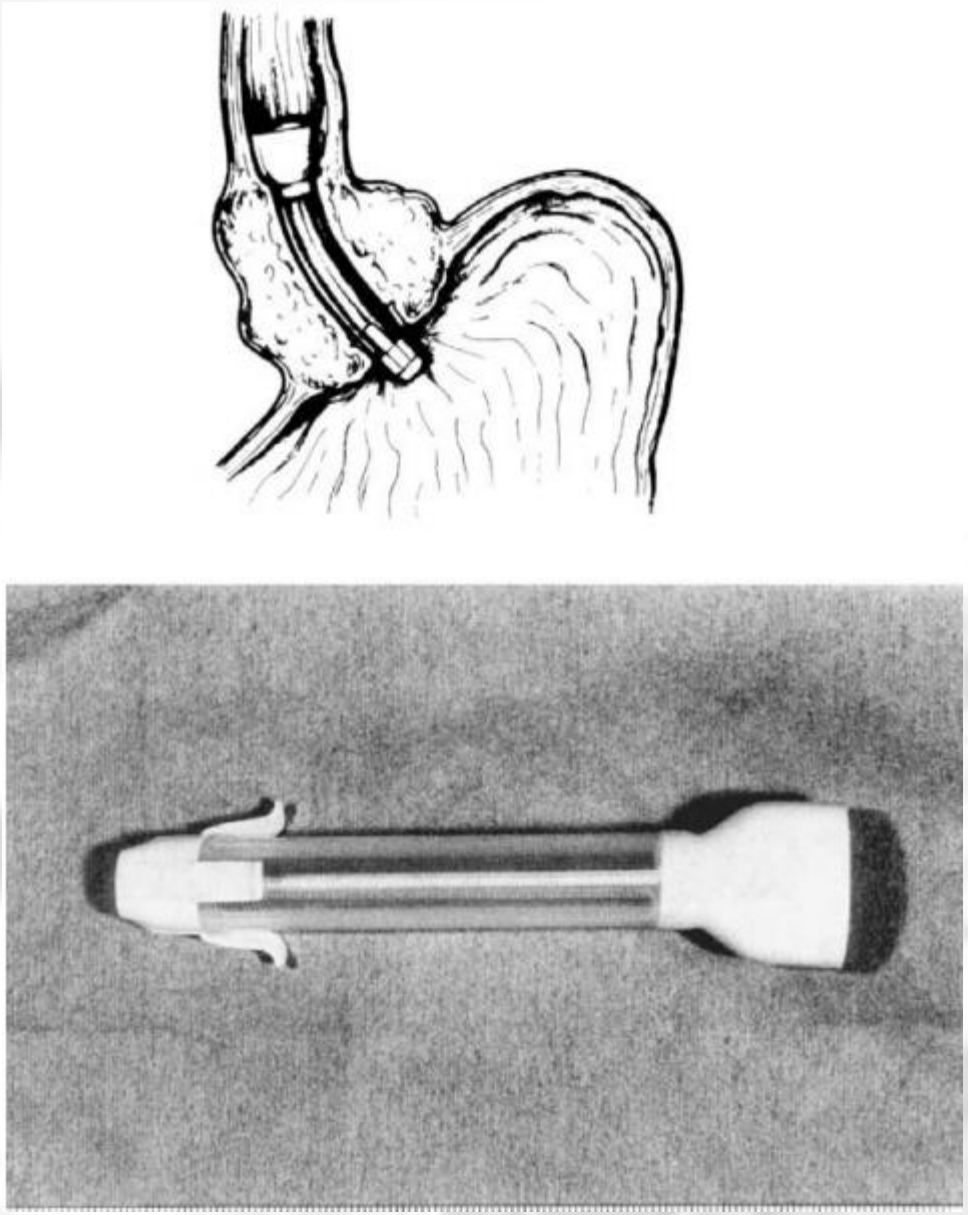
Artificial Esophagi

- In patients with esophageal cancer, the esophagus is resected and reconstructed using a piece of pediculated alimentary tract, such as the gastric conduit, colon, or ileum
- However, in some cases, it is impossible to use autologous alimentary tract, for example, in patients who have undergone gastrectomy
- In such cases, an artificial esophagus is indicated



Extracorporeal artificial esophagus (Tokyo University type).

J.D.Bronzino , Biomedical Engineering Handbook, 2000.



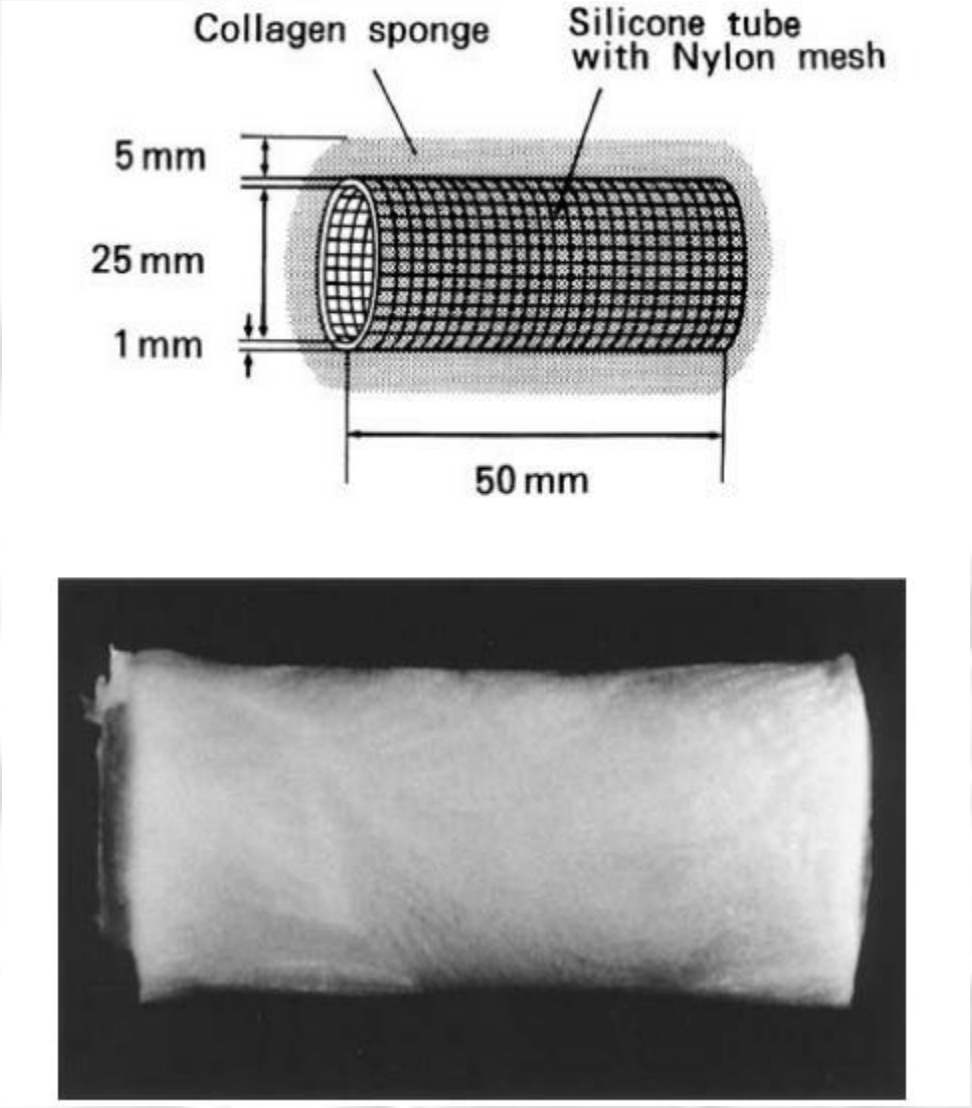
Intraesophageal type of artificial esophagus. (Sumitomo Bakelite Co., Ltd., Tokyo, Japan).

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Tracheal, Laryngeal, and Esophageal Replacement Devices

Artificial Esophagi

- In contrast to the palliative artificial esophagi, the ideal artificial esophagus would replace the resected part of the esophagus by itself
- The artificial esophagi of this type are classified according to the materials from which they are made, namely:
  - natural substances,
  - artificial materials, and
  - their composites (hybrids)



An artificial esophagus made of collagen sponge which is intended to be replaced with host tissue.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Artificial Skin and Dermal Equivalents

- Skin is a vital organ, in the sense that loss of a substantial fraction of its mass immediately threatens the life of the individual

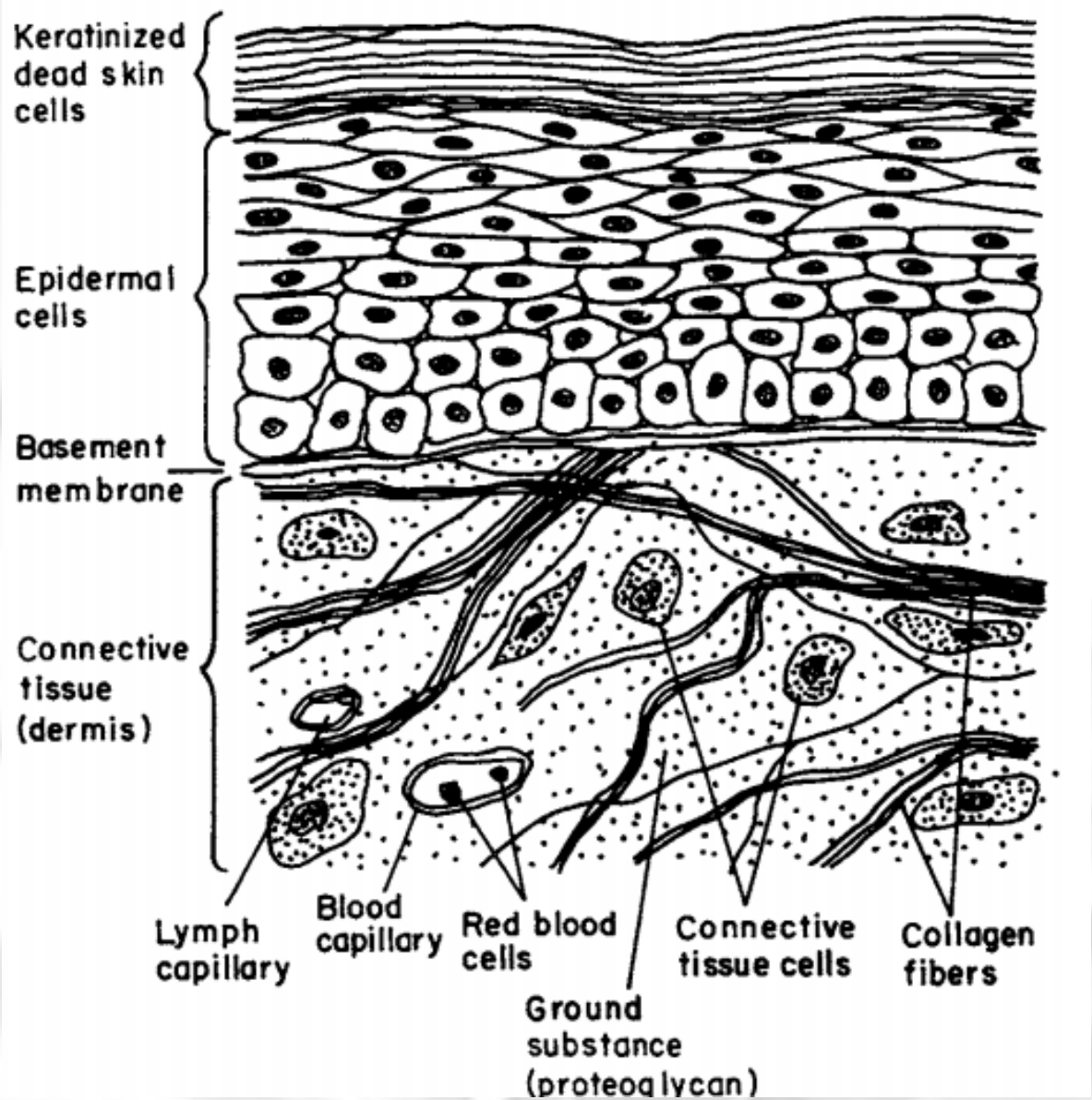
- Four types of tissue can be distinguished clearly in normal skin:

  – The epidermis, outside, is a 0.1-mmthick sheet, comprising about 10 layers of keratinocytes at levels of maturation which increase from the inside out

  – The dermis, inside, is a 2–5-mm-thick layer of vascularized and innervated connective tissue with very few cells, mostly quiescent fibroblasts

Artificial Skin and Dermal Equivalents

- Skin is a vital organ, in the sense that loss of a substantial fraction of its mass immediately threatens the life of the individual
- Four types of tissue can be distinguished clearly in normal skin:
  - Interleaved between the epidermis and the dermis is the basement membrane, an approximately 20–nm-thick multilayered membrane
  - A fourth layer, the subcutis, underneath the dermis and 0.4–4-mm in thickness, comprises primarily fat tissue



Schematic view of skin which highlights the epidermis, the basement membrane interleaved between the epidermis and the dermis, and the dermis underneath.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Artificial Skin and Dermal Equivalents

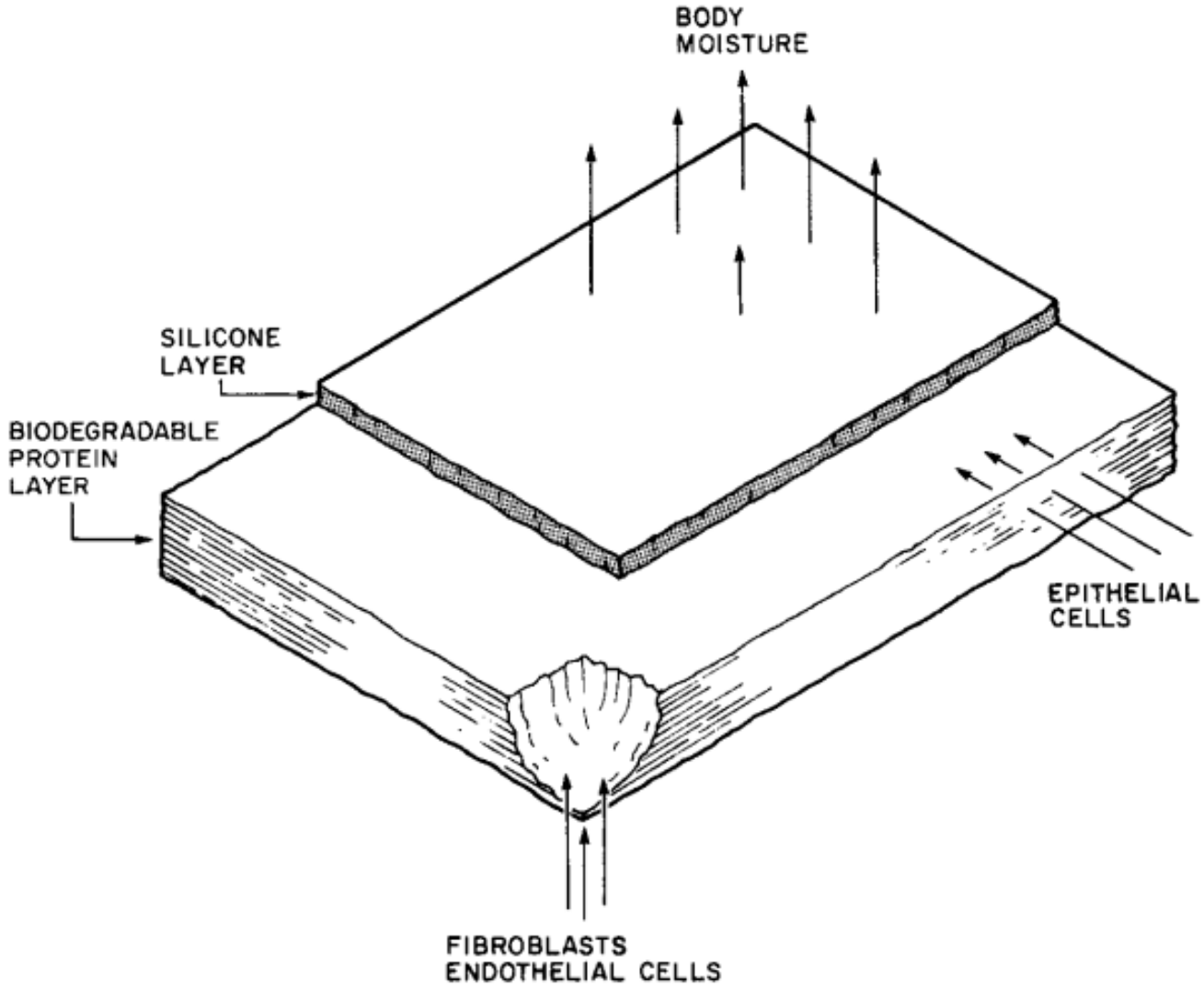
- Loss of the epidermis alone can result from a relatively mild burn, such as an early exposure to the sun.
- Controlled loss of epidermis in a laboratory experiment with an animal can result from the repeated use of adhesive tape to peel off the keratinocyte layers
- In either case, the long-term outcome is an apparently faithful regeneration of the epidermis by migration of epithelial cells from the wound edge, and from roots of hair follicles, over the underlying basement membrane and dermis

Artificial Skin and Dermal Equivalents

- The analysis of the plight of the patient who has suffered extensive skin loss, presented above, leads logically to a wound cover which treats the problem in two stages:
  - Stage 1 is the early phase of the clinical experience, one in which protection against severe fluid loss and against massive infection are defined as the major design objectives
  - Stage 2 is the ensuing phase, one in which the patient needs protection principally against disfiguring scars and crippling contractures

Artificial Skin and Dermal Equivalents

- The sequential utilization of features inherent in stages 1 and 2 in a single device can be ensured by designing the graft as a bilayer membrane
- In this approach, the top layer incorporates the features of a stage 1 device, while the bottom layer delivers the performance expected from a stage 2 device
- The top layer is subject to disposal after a period of about 10–15 days. Following removal of the top layer, the epidermal cover is provided by covering with a thin epidermal graftorso that an epidermis forms spontaneously by about 2 weeks after grafting



Schematic of the bilayer membrane which has become known as the artificial skin.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Artificial Skin and Dermal Equivalents

bilayer membrane

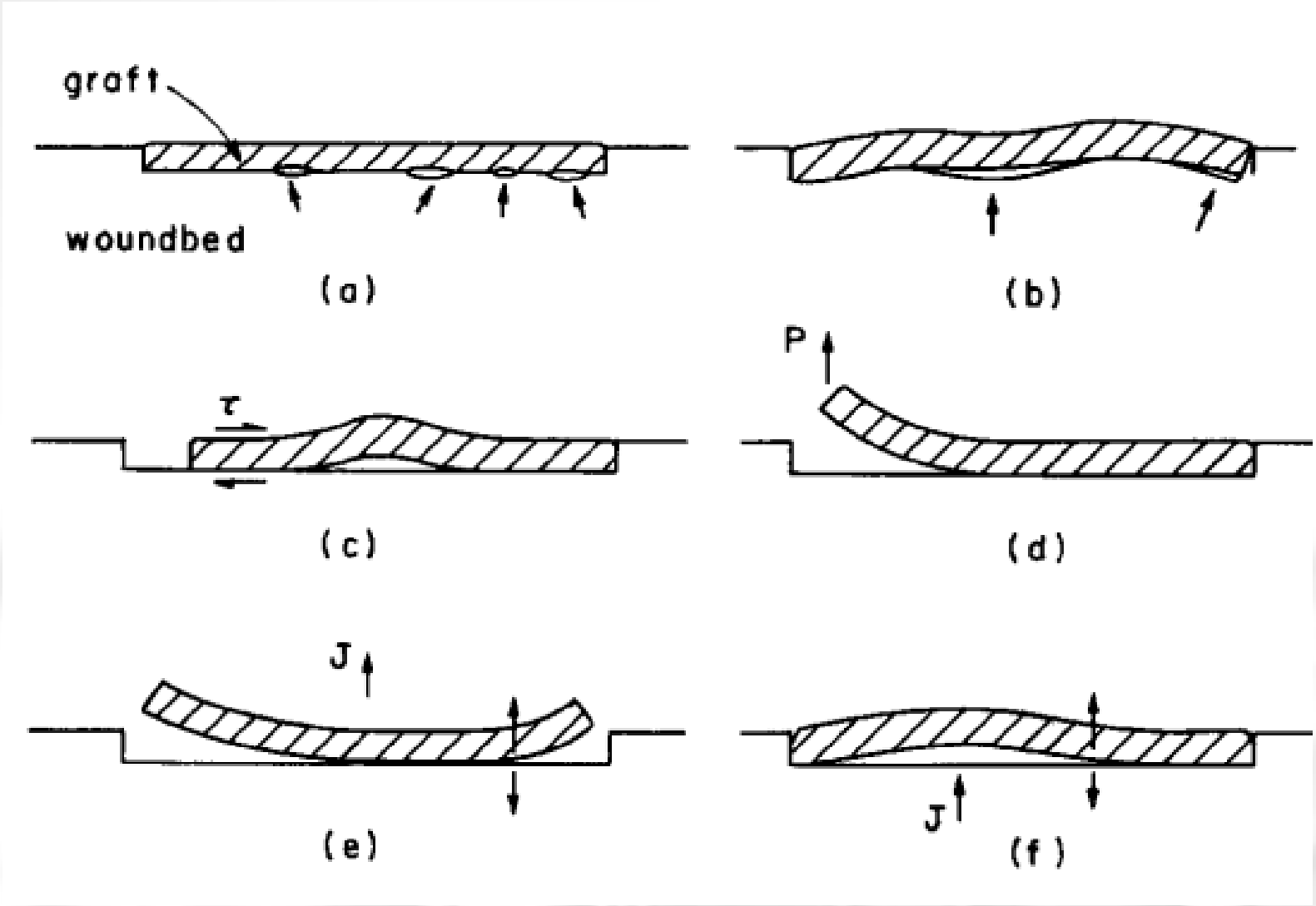
- The top layer is a silicone film which controls moisture flux through the wound bed to nearly physiologic levels, controls infection of the wound bed by airborne bacteria, and is strong enough to be sutured on the wound bed.
- The bottom layer is the skin regeneration template, which consists of a graft copolymer of type I collagen and chondroitin 6-sulfate, with critically controlled porosity and degradation rate

Artificial Skin and Dermal Equivalents

Design Parameters

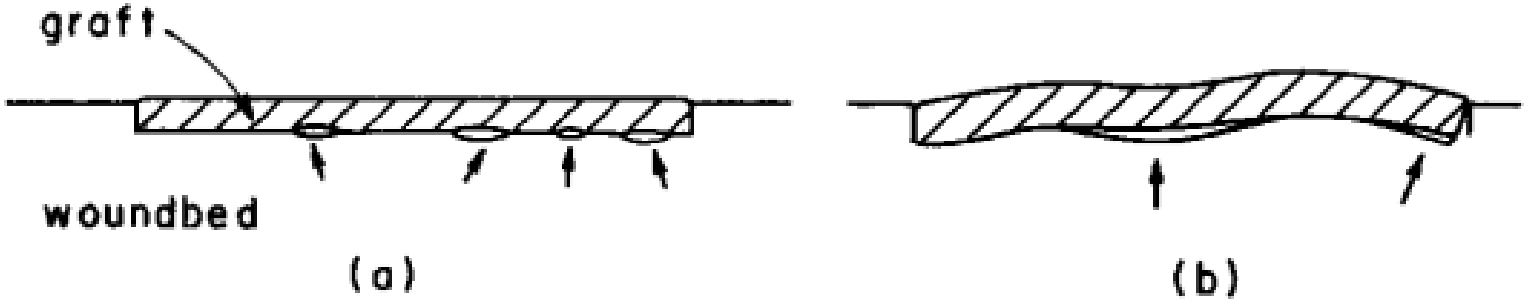
- The overriding design requirement is based on the observation that air pockets (“dead space”) at the graft-wound bed interface readily become sites of bacterial proliferation

- Such sites can be prevented from forming if the graft surface wets, in the physicochemical sense, the surface of the wound bed on contact and thereby displaces the air from the graft-tissue interface



Certain physicochemical and mechanical requirements in the design of an effective closure for a wound bed with full-thickness skin loss.

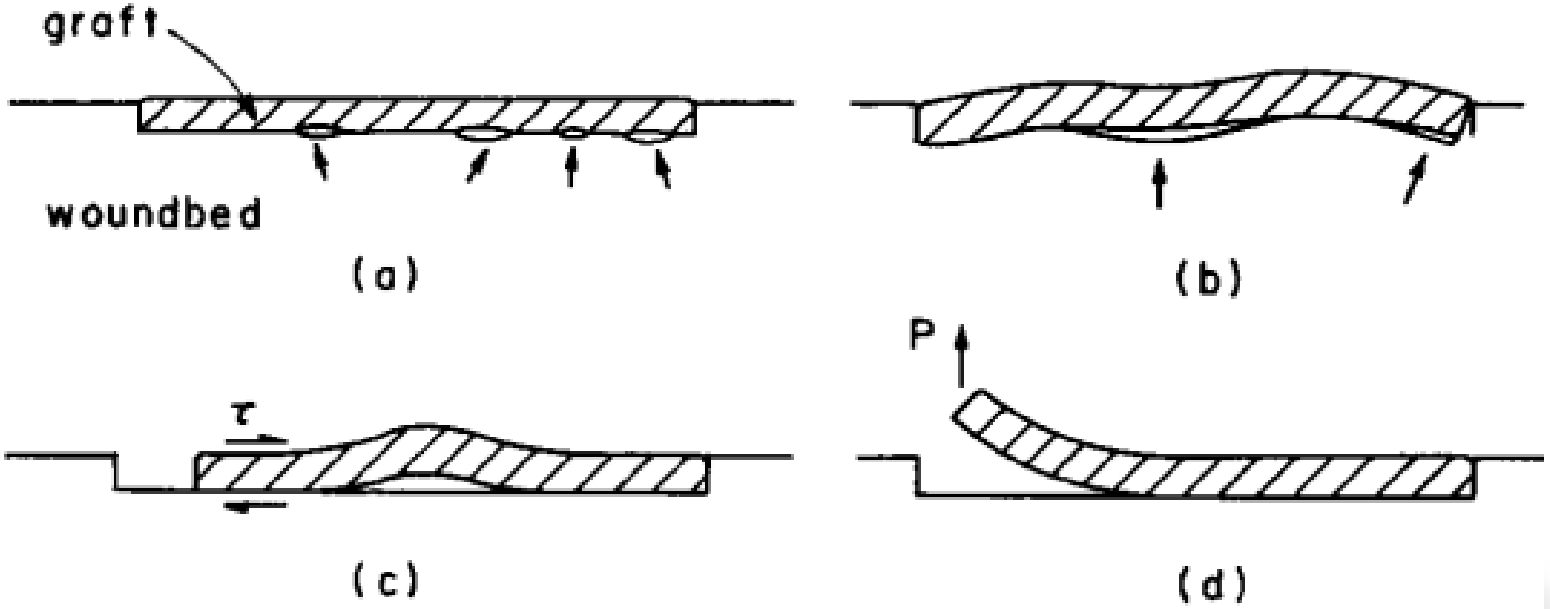
J.D.Bronzino , Biomedical Engineering Handbook, 2000.



- (a) The graft (cross-hatched) does not displace air pockets (arrows) efficientlyfrom the graft-wound bed interface

- b) Flexural rigidity of the graft is excessive. The graft does not deform sufficiently, under its own weight and the action of surface forces, to make good contact with depressions on the surface of the wound bed; as a result, air pockets form (arrows)

J.D.Bronzino , Biomedical Engineering Handbook, 2000.



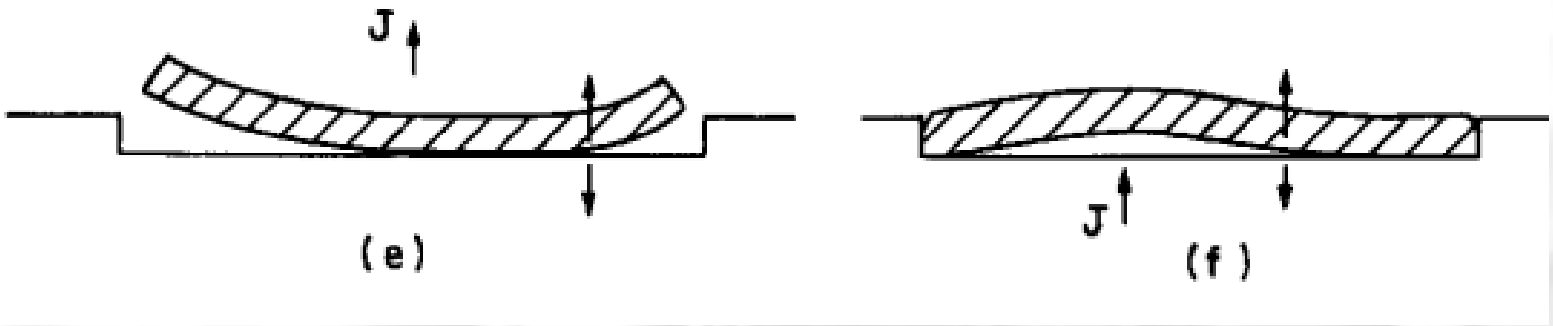
- (c) Shear stresses τ(arrows) cause buckling of the graft, rupture of the graft-wound bed bond and formation of an air pocket

- (d) Peeling force Plifts the graft away from the wound bed.

J.D.Bronzino , Biomedical Engineering Handbook, 2000.

- (e) Excessively high moisture flux rate Jthrough the graft causes dehydration and development of shrinkage stresses at the edges (arrows), which cause lift-off away from the wound bed

- (f) Very low moisture flux Jcauses fluid accumulation (edema) at the graft-wound bed interface and peeling off (arrows)



J.D.Bronzino , Biomedical Engineering Handbook, 2000.

Artificial Skin and Dermal Equivalents

- The artificial skin leads to a new skin which appears closer to the patient's intact skin than does the meshed autograft
- Take of the artificial skin is as good as all comparative materials except for the unmeshed autograft, which is superior in this respect
- In comparison to the allograft, the artificial skin is easier to use, has the same take, does not get rejected, and is free of the risk of viral infection associated with use of allograft

Implant devices issues

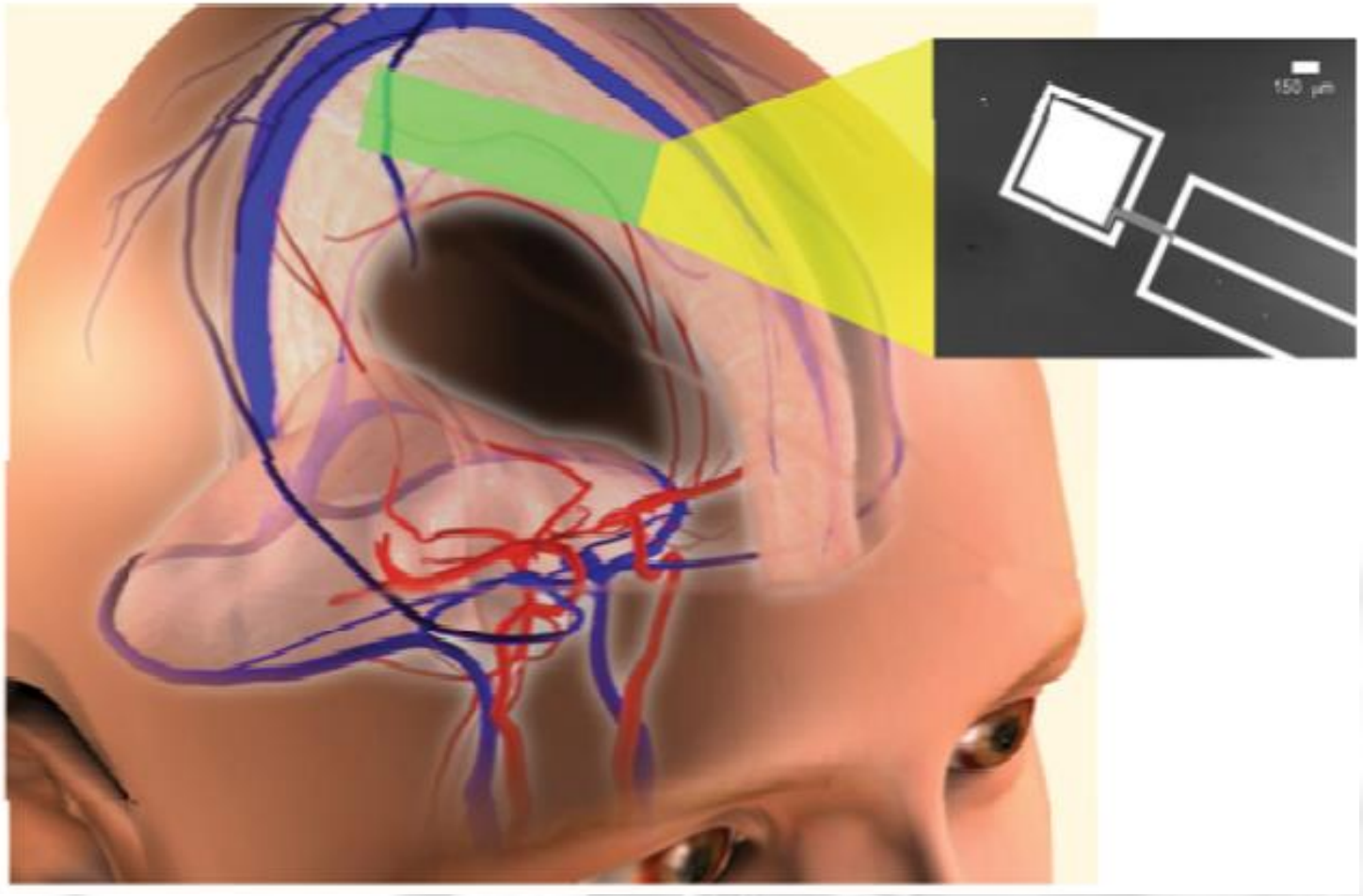
Powering the Implanted Device

- Implanted devices need energy in order to sense or stimulate
- The amount of energy required for the implant to work is small but cannot cease
- Early implanted devices were interfaced with wires through the skin in order to receive energy
- Adding a battery to the implanted device is a prohibitive solution

Implant devices issues

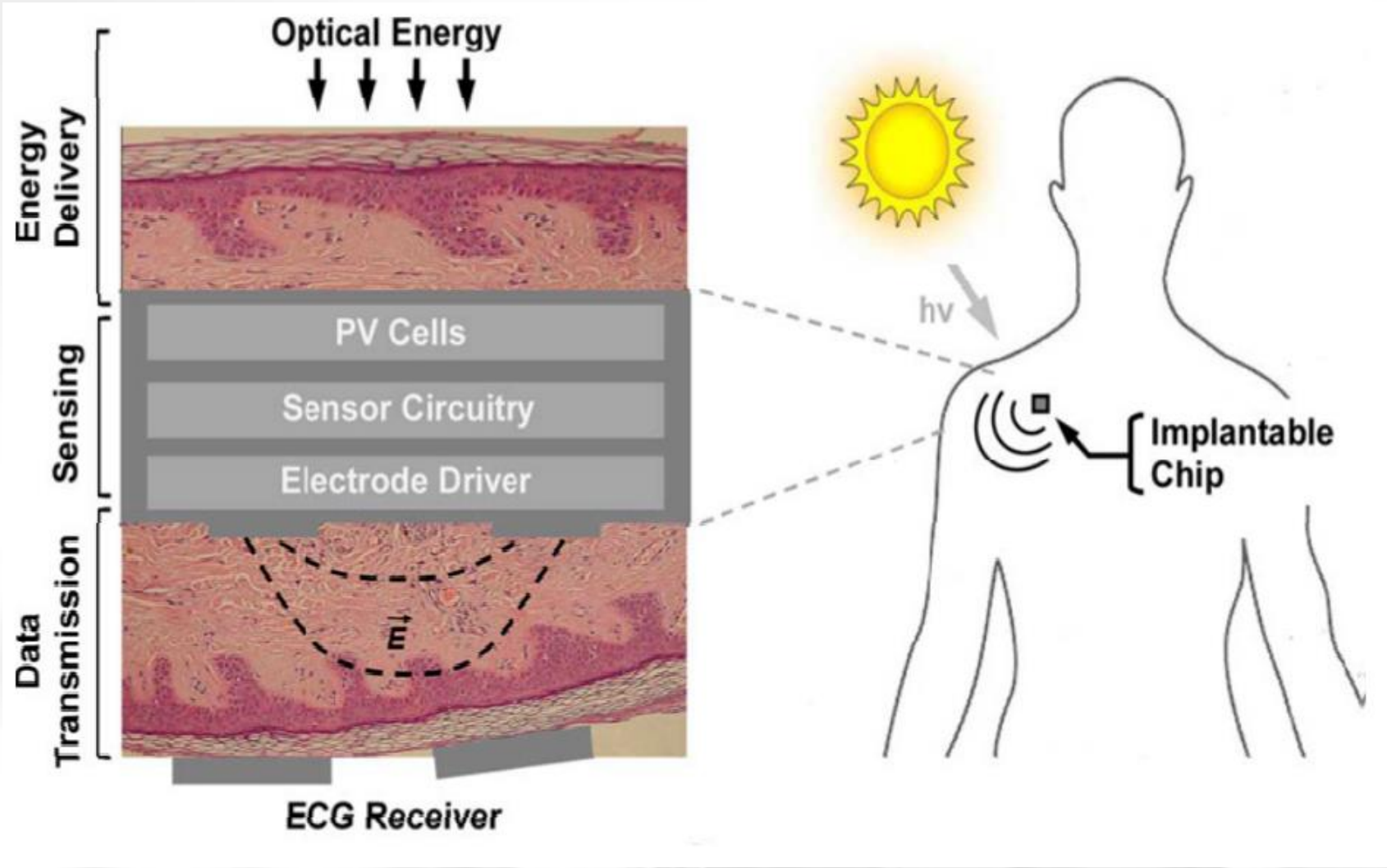
Data Transmission

- Data transmission from the implant to the external device, known as “uplink transmission“, is necessary for both sensors and stimulators
- Sensors measure the biosignals and transmit their measurements to the external world
- Data transmission from the external device to the implant, known as “downlink transmission“
- It is necessary for both sensors and stimulators



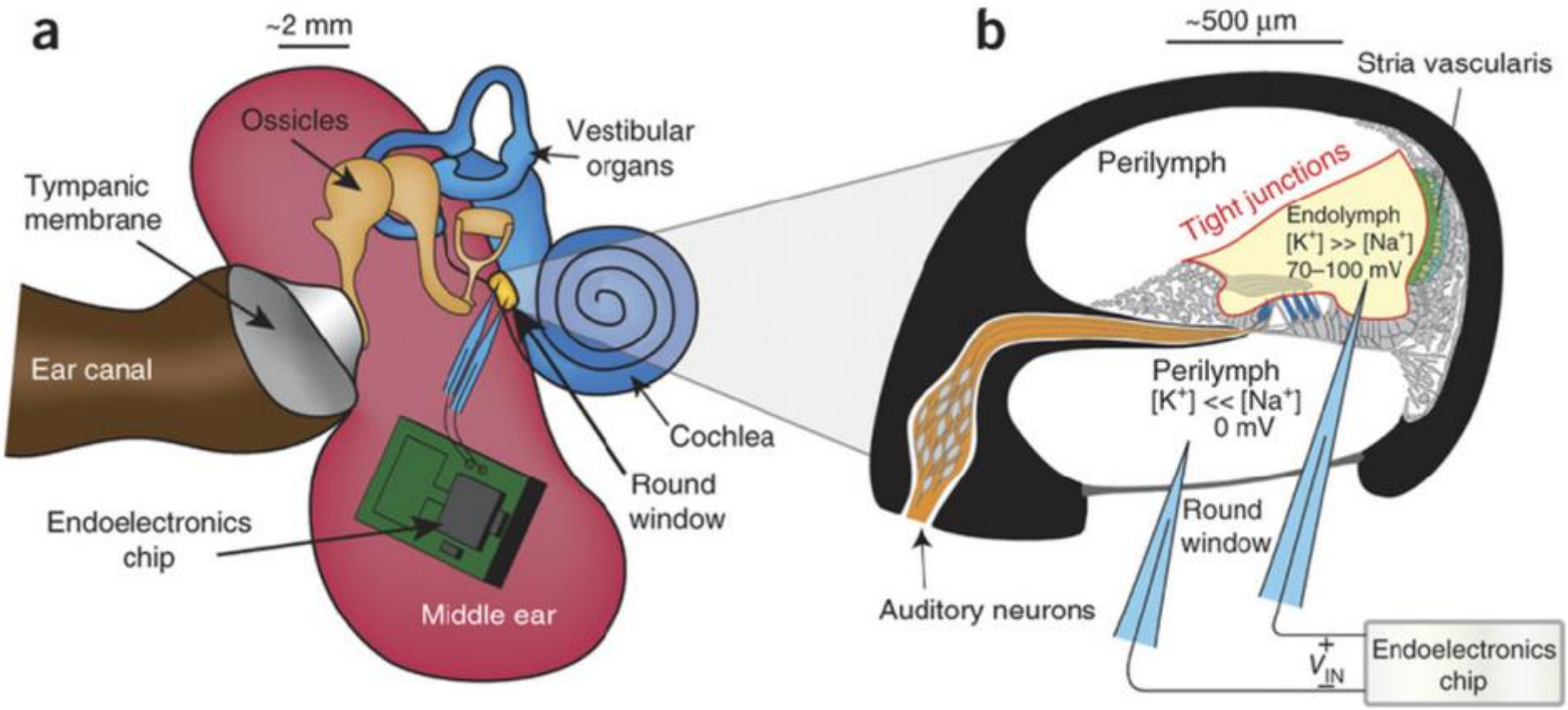
Power extraction from cerebrospinal fluid by an implantable glucose fuel cell: plausible site of implantation within the subarachnoid space and a micrograph of one prototype, showing the metal layers of the anode (centralelectrode) and cathode contact (outer ring) patterned ona silicon wafer

Kateryna Bazaka and Mohan V. Jacob, Implantable Devices: Issues and Challenges , Electronics ,2013



A photovoltaic-drivenenergy-autonomous
CMOS implantable sensor

Kateryna Bazaka and Mohan V. Jacob, Implantable Devices: Issues and Challenges , Electronics ,2013

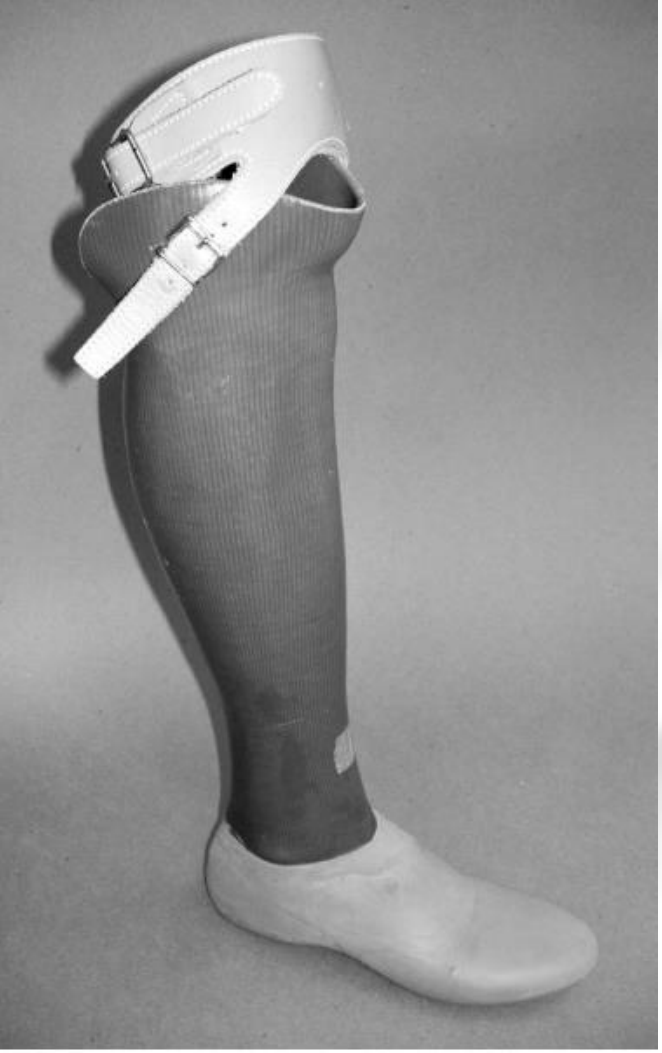


An anatomically sized chip that harvests the energy of the electrochemical potential in the guinea pig cochlea to power a wireless transmitter: (a) plausible site of implantation within the mammalian ear; (b) cross-section of a typical cochlear half-turn, showing the endolymphatic space (yellow) bordered by tight junctions (red), the stria vascularis (green) and hair cells (blue), which are contacted by primary auditory neurons (orange)

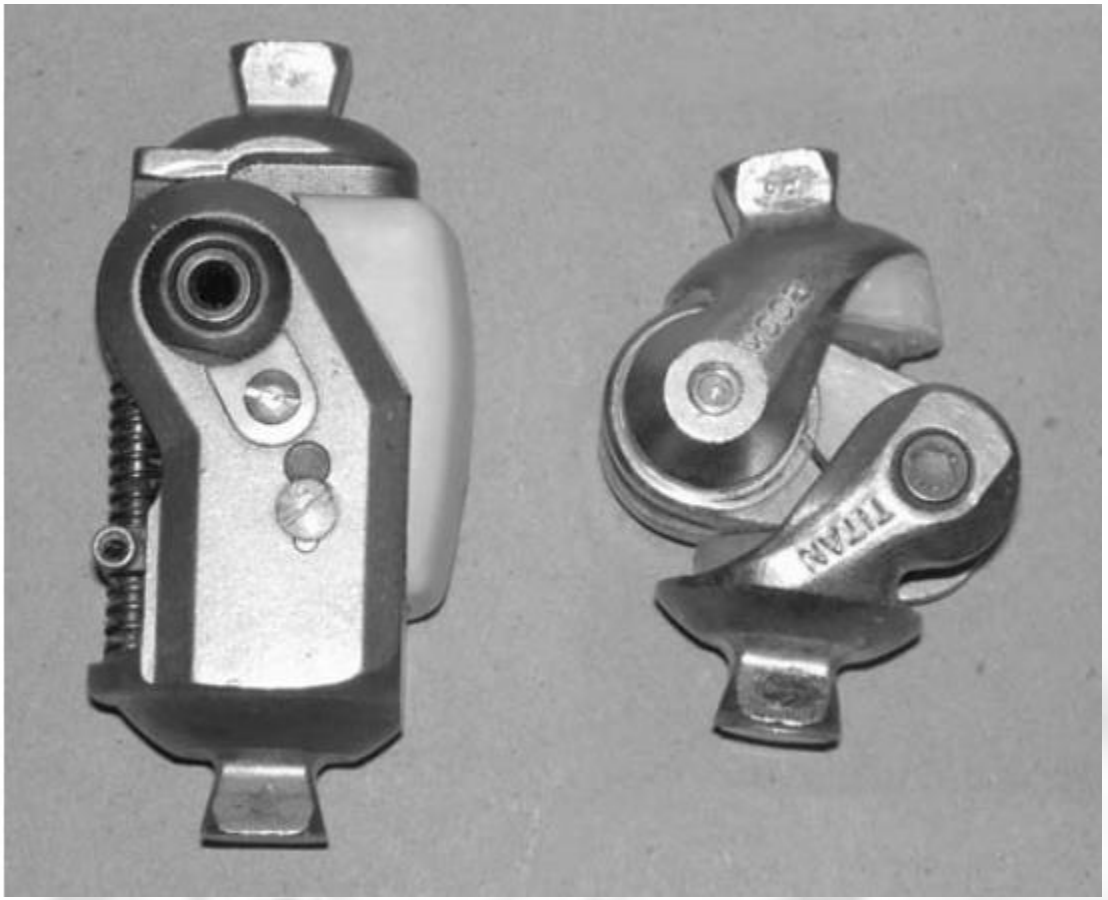
Kateryna Bazaka and Mohan V. Jacob, Implantable Devices: Issues and Challenges , Electronics ,2013

Prosthetic devices

- A prosthetic limb, or ‘‘prosthesis,’’ is an external device that is worn on the body for the purpose of replacing a missing or absent limb or extremity, with the intent of restoring aesthetics or function
- When fitting a prosthesis to a patient, the prosthetist should try to match the device design to the individual’s needs, functional level, and personal rehabilitation goals
- Ideally, the device is simple in design, easy for the patient to learn to use, and should function dependably with little need for repair or replacement

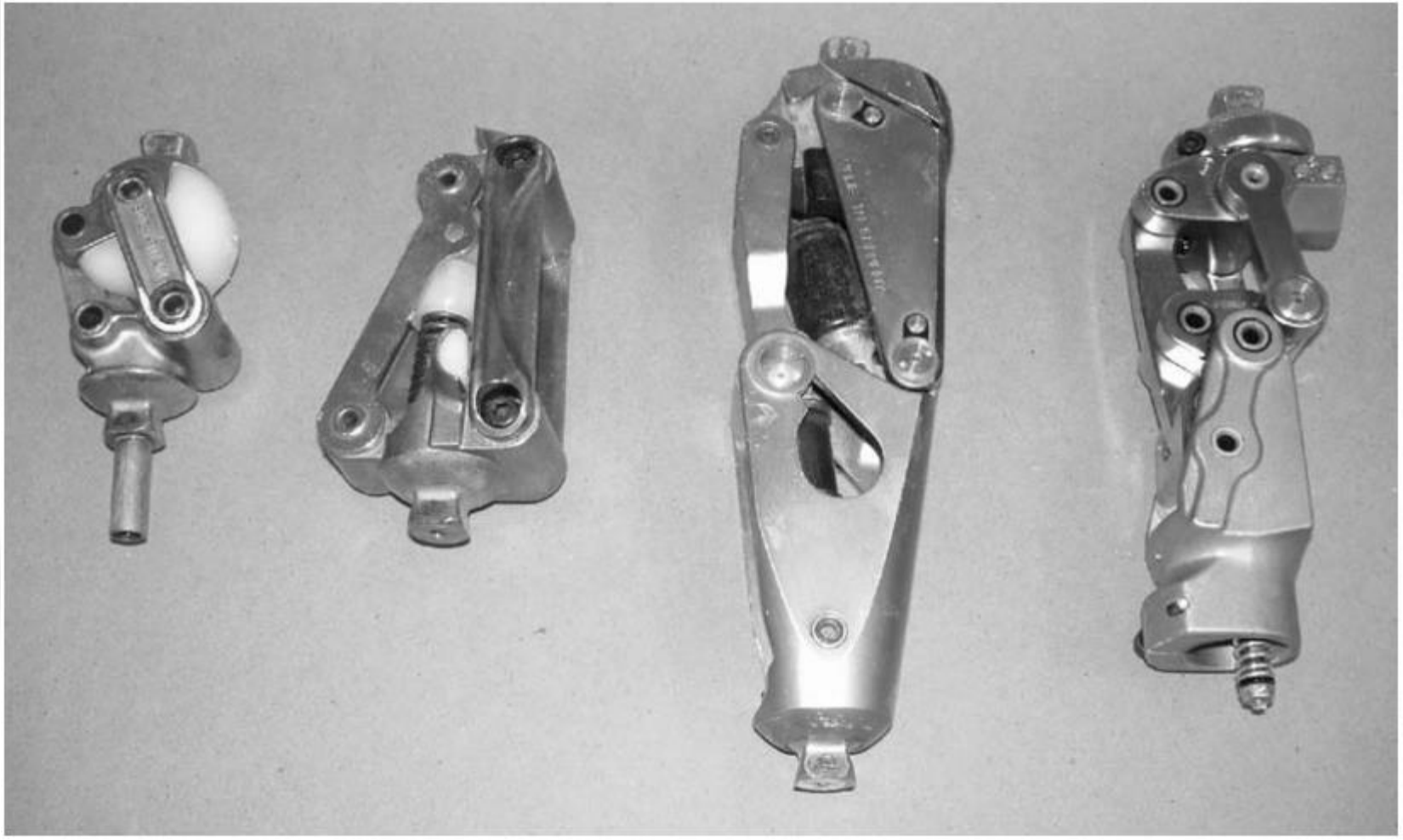


Exoskeletal transtibial prosthesis with supracondylar cuff suspension



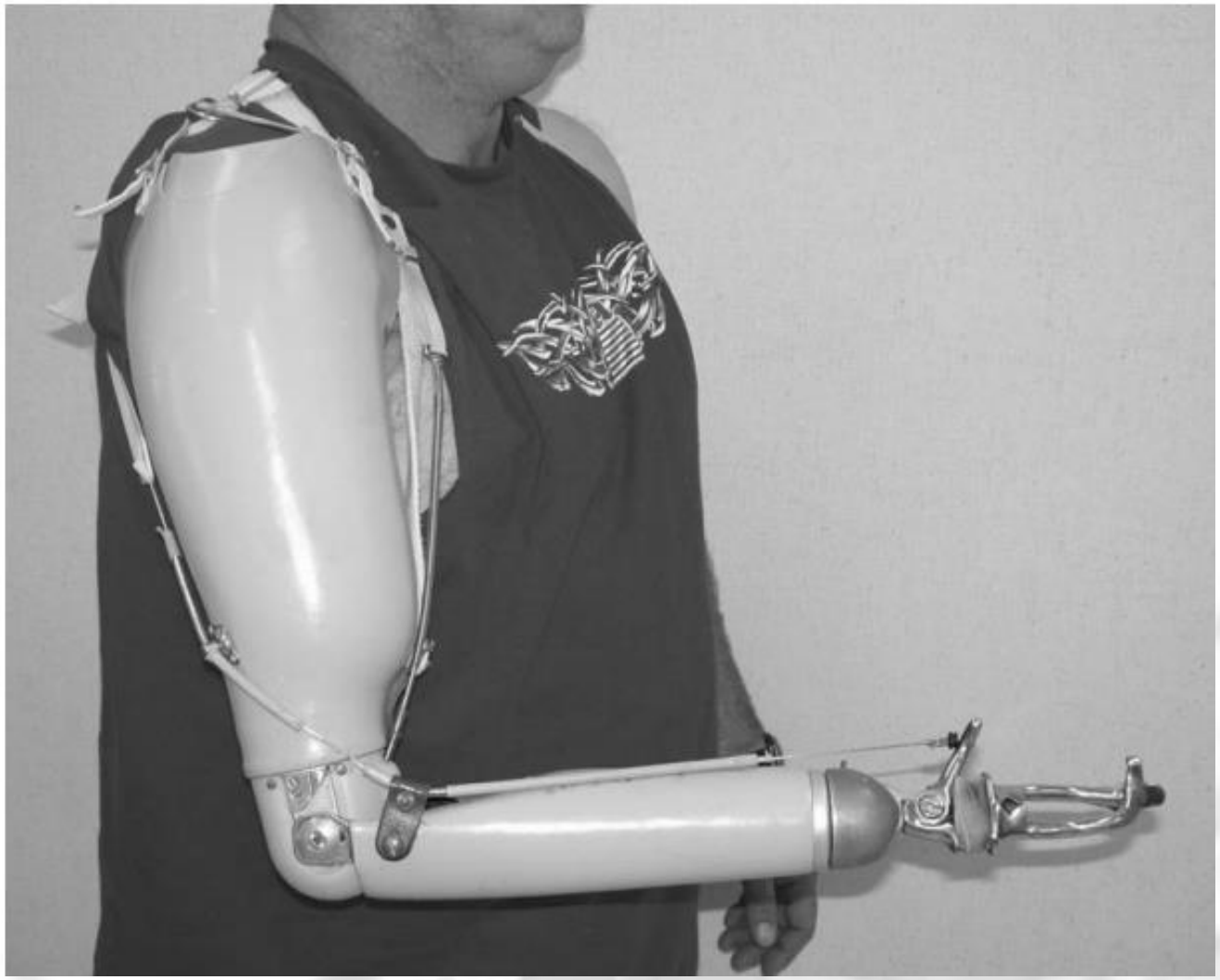
Single-axis knees

Steven Gard, Prosthetic Devices and Methods, Electronics , 2006



Polycentric knees. The two knees on the right are designed to provide stance-phase knee flexion

Steven Gard, Prosthetic Devices and Methods, Electronics , 2006



Transhumeral prosthesis on user. Note the two control cables anterior and posterior to the prosthetic socket, one providing elbow positioning and the other controlling the terminal device

Steven Gard, Prosthetic Devices and Methods, Electronics , 2006

Myoelectric transradial prosthesis. The electrode embedded within the socket detects surface electromyogram (EMG) activity

Steven Gard, Prosthetic Devices and Methods, Electronics , 2006

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